MAY 17 – 22

2019

VSS

ABSTRACTS

19th Annual Meeting

St. Pete Beach, Florida

VSS

VISION SCIENCES SOCIETY

19th Annual Meeting, May 17-22, 2019

TradeWinds Island Resorts, St. Pete Beach, Florida

ABSTRACTS

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SESSIONS OVERVIEW

Abstract Numbering System

Each abstract is assigned a unique 4 or 5 digit number based on when and where it is to be presented. The format of the abstract numbering is DT.RN (where D is the Day, T is the Time, R is the Room and N is the presentation Number).

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2 Saturday	1 Early AM talk session	1 Talk Room 1	1, 2, 3... For talks
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Examples

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MEMBER-INITIATED SYMPOSIA

Schedule Overview

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S1 Reading as a Visual Act: Recognition of Visual Letter Symbols in the Mind and Brain

Friday, May 17, 2019, 12:00 - 2:00 pm, Talk Room 1

Organizer: Teresa Schubert, Harvard University

Presenters: Teresa Schubert, Alex Holcombe, Kalanit Grill-Spector, Karin James

A great deal of our time as adults is spent reading: Deriving meaning from visual symbols. Our brains, which may have evolved to recognize a lion, now recognize the written word "LION". Without recognizing the letters that comprise a word, we cannot access its meaning or its pronunciation: Letter recognition forms the basis of our ability to read. In this symposium, we will highlight work by a growing number of researchers attempting to bridge the gap in research between vision and language by investigating letter recognition processes, from both a behavioral and brain perspective.

How do we recognize letters as visual objects?

Speaker: Teresa Schubert, Harvard University

Additional Authors: David Rothlein, VA Boston Healthcare System; Brenda Rapp, Johns Hopkins University

How do we recognize b and B as instances of the same letter? The cognitive mechanisms of letter recognition permit abstraction across highly different visual exemplars of the same letter (b and B), while also differentiating between highly similar exemplars of different letters (c and e). In this talk, I will present a hierarchical framework for letter recognition which involves progressively smaller reliance on sensory stimulus details to achieve abstract letter representation. In addition to abstraction across visual features, letter recognition in this framework also involves different levels of abstraction in spatial reference frames. This theory was developed based on data from individuals with acquired letter identification deficits (subsequent to brain lesion) and further supported by behavioral and neural research with unimpaired adult readers. I will relate this letter recognition theory to the seminal Marr & Nishihara (1978) framework for object recognition, arguing that letter recognition and visual object recognition require a number of comparable computations, leading to broadly similar recognition systems. Finally, I will compare and contrast neural evidence of cross-modal (visual and auditory letter name) representations for letters and objects. Overall, this talk will provide a theoretical and empirical framework within which to consider letter recognition as a form of object recognition.

Implicit reading direction and limited-capacity letter identification

Speaker: Alex Holcombe, University of Sydney

Additional Author: Kim Ransley, University of Sydney

Reading this sentence was quite an accomplishment. You overcame a poor ability, possibly even a complete inability, to simultaneously identify multiple objects - according to the influential "EZ reader" model of reading, humans can identify only one word at a time. In the field of visual attention, it is known that if one must identify multiple simultaneously-presented stimuli, spatial biases may be present but are often small. Reading a sentence, by contrast, involves a highly stereotyped attentional routine with rapid but serial, or nearly serial, identification of stimuli from left to right. Unexpectedly, my lab has found evidence that this reading routine is elicited when just two widely-spaced letters are briefly presented and observers are asked to identify both letters. We find a large left-side performance advantage that is absent or reversed when the two letters are rotated to face to the left instead of to the right. Additional findings from RSVP (rapid serial visual presentation) lead us to suggest that both letters are selected by attention simultaneously, with the bottleneck at which one letter is prioritized sitting at a late stage of processing - identification or working memory consolidation. Thus, a rather minimal cue of letter orientation elicits a strong reading direction-based prioritization routine, which will allow better understanding of both the bottleneck in visual identification and how reading overcomes it.

How learning to read affects the function and structure of ventral temporal cortex

Speaker: Kalanit Grill-Spector, Stanford University

Additional Authors: Marisa Nordt, Stanford University; Vaidehi Natu, Stanford University; Jesse Gomez, Stanford University and UC Berkeley; Brianna Jeska, Stanford University; Michael Barnett, Stanford University

Becoming a proficient reader requires substantial learning over many years. However, it is unknown how learning to read affects development of distributed visual representations across human ventral temporal cortex (VTC). Using fMRI and a data-driven approach, we examined if and how distributed VTC responses to characters (pseudowords and numbers) develop after age 5. Results reveal anatomical- and hemisphere-specific development. With development, distributed responses to words and characters became more distinctive and informative in lateral but not medial VTC, in the left, but not right, hemisphere. While development of voxels with both positive and negative preference to characters affected distributed information, only activity across voxels with positive preference to characters correlated with reading ability. We also tested what developmental changes occur to the gray and white matter, by obtaining in the same participants quantitative MRI and diffusion MRI data. T1 relaxation time from qMRI and mean diffusivity (MD) from dMRI provide independent measurements of

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microstructural properties. In character-selective regions in lateral VTC, but not in place-selective regions in medial VTC, we found that T1 and MD decreased from age 5 to adulthood, as well as in their adjacent white matter. T1 and MD decreases are consistent with tissue growth and were correlated with the apparent thinning of lateral VTC. These findings suggest the intriguing possibility that regions that show a protracted functional development also have a protracted structural development. Our data have important ramifications for understanding how learning to read affects brain development, and for elucidating neural mechanisms of reading disabilities.

Visual experiences during letter production contribute to the development of the neural systems supporting letter perception

Speaker: Karin James, Indiana University

Additional Author: Sophia Vinci-Booher, Indiana University

Letter production is a perceptual-motor activity that creates visual experiences with the practiced letters. Past research has focused on the importance of the motor production component of writing by hand, with less emphasis placed on the potential importance of the visual percepts that are created. We sought to better understand how different visual percepts that result from letter production are processed at different levels of literacy experience. During fMRI, three groups of participants, younger children, older children, and adults, ranging in age from 4.5 to 22 years old, were presented with dynamic and static re-presentations of their own handwritten letters, static presentations of an age-matched control's handwritten letters, and typeface letters. In younger children, we found that only the ventral-temporal cortex was recruited, and only for handwritten forms. The response in the older children also included only the ventral-temporal cortex but was associated with both handwritten and typed letter forms. The response in the adults was more distributed than in the children and responded to all types of letter forms. Thus, the youngest children processed exemplars, but not letter categories in the VTC, while older children and adults generalized their processing to many letter forms. Our results demonstrate the differences in the neural systems that support letter perception at different levels of experience and suggest that the perception of handwritten forms is an important component of how letter production contributes to developmental changes in brain processing

S2 Rhythms of the Brain, Rhythms of Perception

Friday, May 17, 2019, 12:00 - 2:00 pm, Talk Room 2

Organizers: Laura Dugué, Paris Descartes University; Suliann Ben Hamed, Université Claude Bernard Lyon I

Presenters: Suliann Ben Hamed, Niko Busch, Laura Dugué, Ian Fiebelkorn

The phenomenological, continuous, unitary stream of our perceptual experience appears to be an illusion. Accumulating evidence suggests that what we perceive of the world and how we perceive it rises and falls rhythmically at precise temporal frequencies. Brain oscillations -rhythmic neural signals- naturally appear as key neural substrates for these perceptual rhythms. How these brain oscillations condition local neuronal processes, long-range network interactions, and perceptual performance is a central question to visual neuroscience. In this symposium, we will present an overarching review of this question, combining evidence from monkey neural and human EEG recordings, TMS interference studies, and behavioral analyses.

The prefrontal attentional spotlight in time and space

Speaker: Suliann Ben Hamed, Université Claude Bernard Lyon I

Recent accumulating evidence challenges the traditional view of attention as a continuously active spotlight over which we have direct voluntary control, suggesting instead a rhythmic operation. I will present monkey electrophysiological data reconciling these two views. I will apply machine learning methods to reconstruct, at high spatial and temporal resolution, the spatial attentional spotlight from monkey prefrontal neuronal activity. I will first describe behavioral and neuronal evidence for distinct spatial filtering mechanisms, the attentional spotlight serving to filter in task relevant information while at the same time filtering out task irrelevant information. I will then provide evidence for rhythmic spatial attention exploration by this prefrontal attentional spotlight in the alpha (7-12Hz) frequency range. I will discuss this rhythmic exploration of space both from the perspective of sensory encoding and behavioral trial outcome, when processing either task relevant or task irrelevant information. While these oscillations are task-independent, I will describe how their spatial unfoldment flexibly adjusts to the ongoing behavioral demands. I will conclude by bridging the gap between this alpha rhythmic exploration by the attentional spotlight and previous reports on a contribution of long-range theta oscillations in attentional exploration and I will propose a novel integrated account of a dynamic attentional spotlight.

Neural oscillations, excitability and perceptual decisions

Speaker: Niko Busch, WWU Münster

Numerous studies have demonstrated that the power of ongoing alpha oscillations in the EEG is inversely related to neural excitability, as reflected in spike-firing rate, multi-unit activity, or the hemodynamic fMRI signal. Furthermore, alpha oscillations also affect behavioral performance in perceptual tasks. However, it is surprisingly unclear which latent perceptual or cognitive mechanisms mediate this effect. For example, an open question is whether neuronal excitability fluctuations induced by alpha oscillations affect an observer's acuity or perceptual bias. I will present a series of experiments that aim to clarify the link between oscillatory power and perceptual performance. In short, these experiments indicate that performance during moments of weak pre-stimulus power, indicating greater excitability, is best described by a more liberal detection criterion rather than a change in detection sensitivity or discrimination accuracy. I will argue that this effect is due to an amplification of both signal and noise, and that this amplification occurs already during the first stages of visual processing.

The rhythms of visual attention

Speaker: Laura Dugué, Paris Descartes University

Despite the impression that our visual perception is seamless and continuous across time, evidence suggests that our visual experience relies on a series of discrete moments, similar to the snapshots of a video clip. My research focuses on these perceptual and attentional rhythms. Information would be processed in discrete samples; our ability to discriminate and attend to visual stimuli fluctuating between favorable and less favorable moments. I will present a series of experiments, using multimodal functional neuroimaging combined with psychophysical measurements in healthy humans that assess the mechanisms underlying psychophysical performance during and between two perceptual samples, and how these rhythmic mental representations are implemented at the neural level. I will argue that two sampling rhythms coexist, i.e. the alpha rhythm (8–12 Hz) to allow for sensory, perceptual sampling, and the theta rhythm (3–8 Hz) rather supporting rhythmic, attentional exploration of the visual environment.

Rhythmic sampling of the visual environment provides critical flexibility

Speaker: Ian Fiebelkorn, Princeton University

Environmental sampling of spatial locations is a fundamentally rhythmic process. That is, both attention-related boosts in sensory processing and the likelihood of exploratory movements (e.g., saccades in primates and whisking in rodents) are linked to theta rhythms (3–8 Hz). I will present electrophysiological data, from humans and monkeys, demonstrating that intrinsic theta rhythms in the fronto-parietal network organize neural activity into two alternating attentional states. The first state is associated with both (i) the suppression of covert and overt attentional shifts and (ii) enhanced visual processing at a behaviorally relevant location. The second state is associated with attenuated visual processing at the same location (i.e., the location that received a boost in sensory processing during the first attentional state). In this way, theta-rhythmic sampling provides critical flexibility, preventing us from becoming overly focused on any single location. Every approximately 250 ms, there is a window of opportunity when it is easier to disengage from the presently attended location and shift to another location. Based on these recent findings, we propose a rhythmic theory of environmental sampling. The fronto-parietal network is positioned at the nexus of sensory and motor functions, directing both attentional and motor aspects of environmental sampling. Theta rhythms might help to resolve potential functional conflicts in this network, by temporally isolating sensory (i.e., sampling) and motor (i.e., shifting) functions. This proposed role for theta rhythms in the fronto-parietal network could be a more general mechanism for providing functional flexibility in large-scale networks.

S3 What Can Be Inferred About Neural Population Codes from Psychophysical and Neuroimaging Data?

Friday, May 17, 2019, 2:30 - 4:30 pm, Talk Room 1

Organizer: Fabian Soto, Florida International University

Presenters: Justin L. Gardner, Rosie Cowell, Kara Emery, Jason Hays, Fabian A. Soto

Vision scientists have long assumed that it is possible to make inferences about neural codes from indirect measures, such as those provided by psychophysics (e.g., thresholds, adaptation effects) and neuroimaging. While this approach has been very useful to understand the nature of visual representation in a variety of areas, it is not always clear under what circumstances and assumptions such inferences are valid. This symposium has the goal of highlighting recent developments in computational modeling that allow us to give clearer answer to such questions.

Inverted encoding models reconstruct the model response, not the stimulus

Speaker: Justin L. Gardner, Stanford University

Additional Author: Taosheng Liu, Michigan State University

Life used to be simpler for sensory neuroscientists. Some measurement of neural activity, be it single-unit activity or increase in BOLD response, was measured against systematic variation of a stimulus and the resulting tuning functions presented and interpreted. But as the field discovered signal in the pattern of responses across voxels in a BOLD measurement or dynamic structure hidden within the activity of a population of neurons, computational techniques to extract features not easily discernible from raw measurement increasingly began to intervene between measurement and data presentation and interpretation. I will discuss one particular technique, the inverted encoding model, and how it extracts model responses rather than stimulus representations and what challenges that makes for interpretation of results.

Bayesian modeling of fMRI data to infer modulation of neural tuning functions in visual cortex

Speaker: Rosie Cowell, University of Massachusetts Amherst

Additional Authors: Patrick S. Sadil, University of Massachusetts Amherst; David E. Huber, University of Massachusetts Amherst

Many visual neurons exhibit tuning functions for stimulus features such as orientation. Methods for analyzing fMRI data reveal analogous feature-tuning in the BOLD signal (e.g., Inverted Encoding Models; Brouwer and Heeger, 2009). Because these voxel-level tuning functions (VTFs) are superficially analogous to the neural tuning functions (NTFs) observed with electrophysiology, it is tempting to interpret VTFs as mirroring the underlying NTFs. However, each voxel contains many subpopulations of neurons with different preferred orientations, and the distribution of neurons across the subpopulations is unknown. Because of this, there are multiple alternative accounts by which changes in the subpopulation-NTFs could produce a given change in the VTF. We developed a hierarchical Bayesian model to determine, for a given change in the VTF, which account of the change in underlying NTFs best explains the data. The model fits many voxels simultaneously, inferring both the shape of the NTF in different conditions and the distribution of neurons across subpopulations in each voxel. We tested this model in visual cortex by applying it to changes induced by increasing visual contrast -- a manipulation known from electrophysiology to produce multiplicative gain in NTFs. Although increasing contrast caused an additive shift in the VTFs, the Bayesian model correctly identified multiplicative gain as the change in the underlying NTFs. This technique is potentially applicable to any fMRI study of modulations in cortical responses that are tuned to a well-established dimension of variation (e.g., orientation, speed of motion, isoluminant hue).

Inferring neural coding strategies from adaptation aftereffects

Speaker: Kara Emery, University of Nevada Reno

Adaptation aftereffects have been widely used to infer mechanisms of visual coding. In the context of face processing, aftereffects have been interpreted in terms of two alternative models: 1) norm-based codes, in which the facial dimension is represented by the relative activity in a pair of broadly-tuned mechanisms with opposing sensitivities; or 2) exemplar codes, in which the dimension is sampled by multiple channels narrowly-tuned to different levels of the stimulus. Evidence for or against these alternatives has been based on the different patterns of aftereffects they predict (e.g. whether there is adaptation to the norm, and how adaptation increases with stimulus strength). However, these predictions are often based on implicit assumptions about both the encoding and decoding stages of the models. We evaluated these latent assumptions to better understand how the alternative models depend on factors such as the number, selectivity, and decoding strategy of the channels, to clarify the consequential differences between these coding schemes and the adaptation effects that are most diagnostic for discriminating between them. We show that the distinction between norm and exemplar codes depends more on how the information is decoded than encoded, and that some aftereffect patterns commonly proposed to distinguish the models fail to in principle. We also compare how these models depend on assumptions about the stimulus (e.g. broadband vs. punctate) and the impact of noise. These analyses point to the fundamental distinctions between different coding strategies and the patterns of visual aftereffects that are best for revealing them.

What can be inferred about changes in neural population codes from psychophysical threshold studies?

Speaker: Jason Hays, Florida International University

Additional Author: Fabian A. Soto, Florida International University

The standard population encoding/decoding model is now routinely used to study visual representation through psychophysics and neuroimaging. Such studies are indispensable to understand human visual neuroscience, where more invasive techniques are usually not available, but researchers should be careful not to interpret curves obtained from such indirect measures as directly comparable to analogous data from neurophysiology. Here we explore through simulation exactly what kind of inference can be made about changes in neural population codes from observed changes in psychophysical thresholds. We focus on the encoding of orientation by a dense array of narrow-band neural channels, and assume statistically optimal decoding. We explore several mechanisms of encoding change, which could be produced by factors such as attention and learning, and which have been highlighted in the previous literature: (non) specific gain, (non)specific bandwidth-narrowing, inward/outward tuning shifts, and specific suppression with(out) nonspecific gain. We compared the pattern of psychophysical thresholds produced by the model with and without the influence of such mechanisms, in several experimental designs. Each type of model produced a distinctive behavioral pattern, but only if changes in encoding are strong enough and two or more experiments with different designs are performed (i.e., no single experiment can discriminate among all mechanisms). Our results suggest that identifying encoding changes from psychophysics is possible under the right conditions and assumptions and suggest that psychophysical threshold studies are a powerful alternative to neuroimaging in the study of visual neural representation in humans.

What can be inferred about invariance of visual representations from fMRI decoding studies?

Speaker: Fabian A. Soto, Florida International University

Additional Author: Sanjay Narasiwodeyar, Florida International University

Many research questions in vision science involve determining whether stimulus properties are represented and processed independently in the brain. Unfortunately, most previous research has only vaguely defined what is meant by "independence," which hinders its precise quantification and testing. Here we develop a new framework that links general recognition theory from psychophysics and encoding models from computational neuroscience. We focus on separability, a special form of independence that is equivalent to the concept of "invariance" often used by vision scientists, but we show that other types of independence can be formally defined within the theory. We show how this new framework allows us to precisely define separability of neural representations and to theoretically link such definition to psychophysical and neuroimaging tests of independence and invariance. The framework formally specifies the relation between these different levels of perceptual and brain representation, providing the tools for a truly integrative research approach. In addition, two commonly used operational tests of independence are re-interpreted within this new theoretical framework, providing insights on their correct use and interpretation. Finally, we discuss the results of an fMRI study used to validate and compare several tests of representational invariance, and confirm that the relations among them proposed by the theory are correct.

S4 Visual Search: From Youth to Old Age, from the Lab to the World

Friday, May 17, 2019, 2:30 - 4:30 pm, Talk Room 2

Organizer: Beatriz Gil-Gómez de Liaño, Brigham & Women's Hospital-Harvard Medical School and Cambridge University

Presenters: Beatriz Gil-Gómez de Liaño, Iris Wiegand, Martin Eimer, Melissa L-H Võ, Lara García-Delgado, Todd Horowitz

This symposium aims to show how visual search works in children, adults and older age, in realistic settings and environments. We will review what we know about visual search in real and virtual scenes, and its applications to solving global human challenges. Insights of brain processes underlying visual search during life will also be shown. The final objective is to better understand visual search as a whole in the lifespan, and in the real world; and to demonstrate how science can be transferred to society improving human lives, involving children, as well as younger and older adults.

Visual Search in children: What we know so far, and new challenges in the real world

Speaker: Beatriz Gil-Gómez de Liaño, Brigham & Women's Hospital-Harvard Medical School and Cambridge University

While we have a very substantial body of research on visual search in adults, there is a much smaller literature in children, despite the importance of search in cognitive development. Visual Search is a vital task in everyday life of children: looking for friends in the park, choosing the appropriate word within a word-list in a quiz at school, looking for the numbers given in a math problem... For feature search (e.g. "pop-out" of red among green), it is well-established that infants and children generally perform similarly to adults, showing that exogenous attention is stable across the lifespan. However, for conjunction search tasks there is evidence of age-related performance differences through all stages of life showing the typical inverted U shape function from childhood to older age. In this talk I will review some recent work and present new data showing that different mechanisms of selective attention operate at different ages within childhood, not only at a quantitative level but also qualitatively. Target salience, reward history, child-friendly stimuli and video-game-like tasks may be also important factors modulating attention in visual search in childhood, showing that children's attentional processes can be more effective than has been believed to date. We will also show new results from a visual search foraging task, highlighting it as a potentially useful task in a more complete study of cognitive and attentional development in the real world. This work leads to better understanding of typical cognitive development and gives us insights into developmental attentional deficits.

Visual Search in the older age: Understanding cognitive decline

Speaker: Iris Wiegand, Max Planck UCL Center for Computational Psychiatry and Ageing Research

Did I miss that sign post? - Where did I leave my glasses? Older adults increasingly report experiencing such cognitive failures. Consistent with this experience, age-related decline has been demonstrated in standard visual search experiments. These standard laboratory tasks typically use simple stimulus material and brief trial structures that are well-designed to isolate some specific cognitive process component. Real-world tasks, however, while built of these smaller components, are complex and extend over longer periods of time. In this talk, I will compare findings on age differences in simple visual search experiments to our recent findings from extended hybrid (visual and memory) search and foraging tasks. The extended search tasks resemble complex real-world tasks more closely and enable us to look at age differences in attention, memory, and strategic process components within one single task. Surprisingly, after generalized age-related slowing of reaction times (RT) was controlled for, the extended search tasks did not reveal any age-specific deficits in attention and memory functions. However, we did find age-related decline in search efficiency, which were explained by differences between age groups in foraging strategies. I will discuss how these new results challenge current theories on cognitive aging and what impact they could have on the neuropsychological assessment of age-related cognitive changes.

Component processes of Visual Search: Insights from neuroscience

Speaker: Martin Eimer, Birkbeck, University of London

I will discuss cognitive and neural mechanisms that contribute to VS, how these mechanisms are organized in real time, and how they change across the lifespan. These component processes include the ability to activate representations of search targets (attentional templates), the guidance of attention towards target objects, as well as the subsequent attentional selection of these objects and their encoding into working memory. The efficiency of VS performance changes considerably across the life span. I will discuss findings from search experiment with children, adults, and the elderly, in order to understand which component processes of VS show the most pronounced changes with age. I will focus on the time course of target template activation processes, differences between space-based and feature-based attentional guidance, and the speed with which attention is allocated to search targets.

Visual Search goes real: The challenges of going from the lab to (virtual) reality

Speaker: Melissa L-H Võ, Goethe University Frankfurt

Searching for your keys can be easy if you know where you put them. But when your daughter loves playing with keys and has the bad habit of just randomly placing them in the fridge or in a pot, your routine search might become a nuisance. What makes search in the real world usually so easy and sometimes so utterly hard? There has been a trend to study visual perception in increasingly more naturalistic settings due to the legit concern that evidence gathered from simple, artificial laboratory experiments does not translate to the real world. For instance, how can one even attempt to measure set size effects in real world search? Does memory play a larger role when having to move your body towards the search target? Do target features even matter when we have scene context to guide our way? In this talk, I will review some of my labs' latest efforts to study visual search in increasingly realistic environments, the great possibilities of virtual environments, and the new challenges that arise when moving away from highly controlled laboratory settings for the sake of getting real.

Crowdsourcing Visual Search in the real world: Applications to Collaborative Medical Image Diagnosis

Speaker: Lara García-Delgado, Biomedical Image Technologies, Department of Electronic Engineering at Universidad Politécnica de Madrid, and member of Spotlab, Spain

Additional Authors: Miguel Luengo-Oroz, Daniel Cuadrado, & María Postigo. Universidad Politécnica de Madrid & founders of Spotlab

We will present the MalariaSpot.org project that develops collective tele-diagnosis systems through visual search video games to empower citizens of all ages to collaborate in solving global health challenges. It is based on a crowd-computing platform, which analyses medical images taken by a 3D printed microscope embedded in a smartphone connected to the internet, using image processing and human crowdsourcing through online visual search and foraging video games. It runs on the collective power of society in an engaging way, using visual and big data sciences to contribute to global health. So far more than 150.000 citizens around the world have learnt and contributed to diagnosis of malaria and tuberculosis. The multidisciplinary nature of this project, at the crossroads of medicine, vision science, video games, artificial intelligence and education, involves a diverse range of stakeholders that requires tailoring the message to each discipline and cultural context. From education activities to mainstream media or policy engagement, this digital collaboration concept behind the project has already impacted several dimensions of society.

Discussant

Speaker: Todd Horowitz, Program Director at the National Cancer Institute

Discussant will summarize the five talks and will open a general discussion with the audience about visual search appliances in the real life in the life span.

S5 What Deafness Tells Us About the Nature of Vision

Friday, May 17, 2019, 5:00 - 7:00 pm, Talk Room 1

Organizer: Rain Bosworth, University of California, San Diego

Presenters: Matthew Dye, Olivier Pascalis, Rain Bosworth, Fang Jiang, Geo Kartheiser

It is widely believed that loss of one sense leads to enhancement of the remaining senses – for example, deaf see better and blind hear better. The reality, uncovered by 30 years of research, is more complex, and this complexity provides a fuller picture of the brain's adaptability in the face of atypical sensory experiences. In this symposium, neuroscientists and vision scientists will discuss how sensory, linguistic, and social experiences during early development have lasting effects on perceptual abilities and visuospatial cognition. Presenters offer new findings that provide surprising insights into the neural and behavioral organization of the human visual system.

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Spatial and Temporal Vision in the Absence of Audition

Speaker: Matthew Dye, Rochester Institute of Technology/National Technical Institute for the Deaf (RIT/NTID)

Changes in the visual system due to deafness provide information about how multisensory processes feedback to scaffold the development of unisensory systems. One common perspective in the literature is that visual inputs are highly spatial, whereas auditory inputs, in contrasts, are highly temporal. A simple multisensory account for sensory reorganization therefore predicts spatial enhancements and temporal deficits within the visual system of deaf individuals. Here I will summarize our past and ongoing research which suggests that evidence for this multisensory scaffolding hypothesis is confounded due to language deprivation in many samples. This is because most deaf people are born to nonsigning parents, and deaf children do not have full access to the spoken language around them. By studying visual processing in deaf individuals who are exposed early to perceivable visual language, such as American Sign Language, we (i) gain a better understanding of the interplay between auditory and visual systems during development, and (ii) accumulate evidence for the importance of early social interaction for the development of higher order visual abilities. Our data suggest that changes in vision over space are ecologically driven and subject to cognitive control, and that early linguistic interaction is important for the development of sustained attention over time.

What is the Impact of Deafness on Face Perception and Peripheral Visual Field Sensitivity?

Speaker: Olivier Pascalis, Laboratoire de Psychologie et NeuroCognition, CNRS, Grenoble, France

It is well established that early profound deafness leads to enhancements in visual processes. Different findings are reported for peripheral versus central vision. Visual improvements have been mainly reported for the peripheral visual field, which is believed to be a result of deaf people's need to compensate for inaccessible auditory cues in the periphery, but for central visual processing, mixed results (including no changes, poorer, and superior performance) have been found for deaf people. We consider two important intriguing (and often overlooked) issues that pertain to deaf vision: One, deaf people, and many hearing people too, use sign language which requires steady fixation on the face. Signers pay rigorous attention to the face because faces provide critical intonational and linguistic information during communication. Two, this also means that most of the manual language information falls in the perceiver's lower visual field, as the signer's hands almost always fall in front of the torso region. I will present a series of studies in which we tried to separate the impacts of deafness and sign language experience on face processing and on peripheral field sensitivity. In order to address the role of sign language, in the absence of deafness, we report results from hearing signers. Our results suggest that sign language experience, not associated with deafness, may be also a modulating factor of visual cognition.

Psychophysical Assessment of Contrast, Motion, Form, Face, and Shape Perception in Deaf and Hearing People

Speaker: Rain Bosworth, University of California, San Diego

Visual processing might be altered in deaf people for two reasons. One, they lack auditory input, compelling them to rely more on their intact visual modality. Two, many deaf people have extensive experience using a visual signed language (American Sign Language, ASL), which may alter certain aspects of visual perception that are important for processing of ASL. While some deaf people have ASL exposure since birth, by virtue of having deaf parents, many others are born to hearing parents, with no signing knowledge, and have delayed visual language exposure. In this study, we asked if deafness and/or sign language experience impact visual perception in 40 Deaf signers and 40 Hearing nonsigners, for psychophysical tests of motion, form, shape, and face discrimination, while controlling for contrast detection, age, visuospatial IQ, and gender makeup. The Deaf signers were separated into two groups, Deaf native signers who were exposed to ASL between ages 0 to 2 years and Deaf late-exposed signers who were exposed to ASL after the age of 3 years. Results indicated that enhanced face processing was found in Deaf native signers who have early visual language exposure, but not in Deaf late-exposed signers. Moreover, Deaf late-exposed signers actually have impoverished motion processing, compared to Deaf native signers and Hearing nonsigners. Together, these provide evidence that language exposure to sign or language deprivation in the first 2 years of life does have a lasting impact on visual perception in adults.

Measuring Visual Motion Processing in Early Deaf Individuals with Frequency Tagging

Speaker: Fang Jiang, University of Nevada, Reno

Early deaf individuals show enhanced performance at some visual tasks, including the processing of visual motion. Deaf individuals' auditory and association cortices have been shown to respond to visual motion, however, it is unclear how these responses relate to their enhanced motion processing ability. Here I will present data from two recent studies, where we examined deaf and hearing participants' fMRI and EEG responses frequency-tagged to the presentation of directional motion. Our results suggest the intriguing possibility that deaf participants' increased direction-selective motion responses in the right STS region of could potentially support their behavioral advantage reported in previous studies.

Neuroplasticity of Spatial Working Memory in Signed Language Processing

Speaker: Geo Kartheiser, NTID Center on Cognition and Language, Rochester Institute of Technology

Signed language is a natural language perceived through the eyes and produced in space with levels of linguistic organization that are found in spoken languages such as phonology, morphology, and syntax. The visuospatial processing demands that arise from using signed languages have been shown in studies to impact signers' spatial cognition—something that is generally considered malleable across the lifespan. However, signed languages and its underlying brain sites, just like spoken languages, have been shown to be sensitive to age of language exposure (AoE)—time point in life where the human was exposed to a language. Here, we ask whether AoE to a signed language impacts neural activity related to spatial working memory (SWM). Using a spatial n-back task while participants were recorded with functional Near Infrared Spectroscopy (fNIRS) brain recording, we tested three groups of hearing, adult signers based on their age of exposure and proficiency in American Sign Language (ASL). As expected, we found that all three groups showed equal behavioral performance across all n-back conditions. However, only Native signers showed significantly greater brain activity in left dorsolateral prefrontal cortex and bilateral ventrolateral prefrontal cortex for specific n-back conditions when compared with Proficient and New signers. Taken together, these results show that early exposure to a signed language impacts the way the brain processes spatial information—a finding that raises the possibility that early exposure to a signed language may be used as a novel tool to improve spatial cognition in the general population.

S6 Prefrontal Cortex in Visual Perception and Recognition

Friday, May 17, 2019, 5:00 - 7:00 pm, Talk Room 2

Organizer: Biyu Jade He, NYU Langone Medical Center

Presenters: Diego Mendoza-Halliday, Vincent B. McGinty, Theofanis I Panagiotaropoulos, Hakwan Lau, Moshe Bar

The role of prefrontal cortex (PFC) in vision remains mysterious. While it is well established that PFC neuronal activity reflects visual features, it is commonly thought that such feature encoding in PFC is only for the service of behaviorally relevant functions. However, recent emerging evidence challenges this notion, and instead suggests that the PFC may be integral for visual perception and recognition. This symposium will address these issues from complementary angles, deriving insights from the perspectives of neuronal tuning in nonhuman primates, neuroimaging and lesion studies in humans, recent development in artificial intelligence, and to draw implications for psychiatric disorders.

Partially-segregated population activity patterns represent perceived and memorized visual features in the lateral prefrontal cortex

Speaker: Diego Mendoza-Halliday, McGovern Institute for Brain Research at MIT

Additional Authors: Julio Martinez-Trujillo, Robarts Research Institute, Western University, Canada

Numerous studies have shown that the lateral prefrontal cortex (LPFC) plays a major role in both visual perception and working memory. While neurons in LPFC have been shown to encode perceived and memorized visual stimulus attributes, it remains unclear whether these two functions are carried out by the same or different neurons and population activity patterns. To systematically address this, we recorded the activity of LPFC neurons in macaque monkeys performing two similar motion direction match-to-sample tasks: a perceptual task, in which the sample moving stimulus remained perceptually available during the entire trial, and a memory task, in which the sample disappeared and was memorized during a delay. We found neurons with a wide variety of combinations of coding strength for perceived and memorized directions: some neurons preferentially or exclusively encoded perceived or memorized directions, whereas others encoded directions invariant to the representational nature. Using population decoding analysis, we show that this form of mixed selectivity allows the population codes representing perceived and memorized directions to be both sufficiently distinct to determine whether a given direction was perceived or memorized, and sufficiently overlapping to generalize across tasks. We further show that such population codes represent visual feature space in a parametric manner, show more temporal dynamics for memorized than perceived features, and are more closely linked to behavioral performance in the memory than the perceptual task. Our results indicate that a functionally diverse population of LPFC neurons provides a substrate for discriminating between perceptual and mnemonic representations of visual features.

Mixed selectivity for visual features and economic value in the primate orbitofrontal cortex

Speaker: Vincent B. McGinty, Rutgers University - Newark, Center for Molecular and Behavioral Neuroscience Rutgers University - Newark, Center for Molecular and Behavioral Neuroscience

Primates use their acute sense of vision not only to identify objects, but also to assess their value, that is, their potential for benefit or harm. How the brain transforms visual information into value information is still poorly understood, but recent findings suggest a key role for the orbitofrontal cortex (OFC). The OFC includes several cytoarchitectonic areas within the ventral frontal lobe, and has a long-recognized role in representing object value and organizing value-driven behavior. One of the OFC's most striking anatomical features is the massive, direct input it receives from the inferotemporal cortex, a ventral temporal region implicated in object identification. A natural hypothesis, therefore, is that in addition to well-documented value coding properties, OFC neurons may also represent visual features in a manner similar to neurons in the ventral visual stream. To test this hypothesis, we recorded OFC neurons in macaque monkeys performing behavioral tasks in which the value of visible objects was manipulated independently from their visual features. Preliminary findings include a subset of OFC cells that were modulated by object value, but only in response to objects that shared a particular visual feature (e.g. the color red). This form of 'mixed' selectivity suggests that the OFC may be an intermediate computational stage between visual identification and value retrieval. Moreover, recent work showing similar mixed value-feature selectivity in inferotemporal cortex neurons suggests that neural mechanisms of object valuation may be distributed over a continuum of cortical regions, rather than compartmentalized in a strict hierarchy.

Mapping visual consciousness in the macaque prefrontal cortex

Speaker: Theofanis I Panagiotaropoulos, Neurospin, France

In multistable visual perception, the content of consciousness alternates spontaneously between mutually exclusive or mixed interpretations of competing representations. Identifying neural signals predictive of such intrinsically driven perceptual transitions is fundamental in resolving the mechanism and identifying the brain areas giving rise to visual consciousness. In a previous study, using a no-report paradigm of externally induced perceptual suppression, we have shown that functionally segregated neural populations in the macaque prefrontal cortex explicitly reflect the content of consciousness and encode task phase. Here I will present results from a no-report paradigm of binocular motion rivalry based on the optokinetic nystagmus (OKN) reflex read-out of spontaneous perceptual transitions coupled with multielectrode recordings of local field potentials and single neuron discharges in the macaque prefrontal cortex. An increase in the rate of oscillatory bursts in the delta-theta (1-9 Hz), and a decrease in the beta (20-40 Hz) bands, were predictive of spontaneous transitions in the content of visual consciousness that was also reliably reflected in single neuron discharges. Mapping these perceptually modulated neurons revealed stripes of competing populations, also observed in the absence of OKN. These results suggest that the balance of stochastic prefrontal fluctuations is critical in refreshing conscious perception, and prefrontal neural populations reflect the content of consciousness. Crucially, consciousness in the prefrontal cortex could be observed for faces and complex objects but also for low-level stimulus properties

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like direction of motion therefore suggesting a reconsideration of the view that prefrontal cortex is not critical for consciousness.

Persistent confusion on the role of the prefrontal cortex in conscious visual perception

Speaker: Hakwan Lau, UCLA

Is the prefrontal cortex (PFC) critical for conscious perception? Here we address three common misconceptions: (1) PFC lesions do not affect subjective perception; (2) PFC activity does not reflect specific perceptual content; and (3) PFC involvement in studies of perceptual awareness is solely driven by the need to make reports required by the experimental tasks rather than subjective experience per se. These claims are often made in high-profile statements in the literature, but they are in fact grossly incompatible with empirical findings. The available evidence highlights PFC's essential role in enabling the subjective experience in perception, contra the objective capacity to perform visual tasks; conflating the two can also be a source of confusion. Finally we will also discuss the role of PFC in perception in the light of current machine learning models. If the PFC is treated as somewhat akin to a randomly connected recurrent neural network, rather than early layers of a convolution network, the lack of prominent lesion effects may be easily understood.

What's real? Prefrontal facilitations and distortions

Speaker: Moshe Bar, Bar-Ilan University, Israel

Additional Author: Shira Baror, Bar-Ilan University, Israel

By now, we know that visual perception involves much more than bottom-up processing. Specifically, we have shown that object recognition is facilitated, sometimes even afforded, by top-down projections from the lateral and inferior prefrontal cortex. Next we have found that the medial prefrontal cortex, in synchrony with the para-hippocampal cortex and the retrosplenial cortex form the 'contextual associations network,' a network that is sensitive to associative information in the environment and which utilizes contextual information to generate predictions about objects. By using various behavioral and imaging methods, we found that contextual processing facilitates object recognition very early in perception. Here, we go further to discuss the overlap of the contextual associations network with the default mode network and its implications to enhancing conscious experience, within and beyond the visual realm. We corroborate this framework with findings that imply that top-down predictions are not limited to visual information but are extracted from social or affective contexts as well. We present recent studies that suggest that although associative processes take place by default, they are nonetheless context dependent and may be inhibited according to goals. We will further discuss clinical implications, with recent findings that demonstrate how activity in the contextual associations network is altered in visual tasks performed by patients experiencing major depressive disorder. To conclude, contextual processing, sustained by the co-activation of frontal and memory-relate brain regions, is suggested to constitute a critical mechanism in perception, memory and thought in the healthy brain.

SATURDAY MORNING TALKS

Eye Movements: Perception

Saturday, May 18, 8:15 - 9:45 am, Talk Room 1

Moderator: Doris Braun

21.11, 8:15 am **The Effect of Extended Target Concealment on Motion Extrapolation** Carlene A Horner[1](carlene.horner@tufts.edu), Julia E Schroeder[2], Stephen R Mitroff[3], Matthew S Cain[1,4]; [1]Center for Applied Brain and Cognitive Sciences, Tufts University, [2]Amazon, [3]Department of Psychology, The George Washington University, [4]U.S. Army Natick Soldier Research, Development, and Engineering Center

Slow smooth-pursuit eye movements help maintain the image of an object on the fovea during visible object motion for increased visual acuity. When a visually tracked object disappears, the visual system no longer receives sensory information regarding the current position or velocity of the target and becomes dependent upon previous knowledge related to the target velocity that is held in a short-term velocity memory store. Previous research indicates that the velocity and occlusion duration of a target influence the accuracy in extrapolating an object's motion. The present study measured both explicit location predictions and eye positions to investigate how the smooth pursuit system supports motion prediction. Participants observed a target moving along a circular path at one of three speeds and eventually disappearing. After a delay of one of three durations, participants indicated whether the target would have passed a probe line. Slowly moving targets were significantly more difficult to follow than faster targets, with decreased response accuracy and increased eye position error and eye velocity. Responses were less accurate in the long occlusion duration compared to the short occlusion duration. However, eye position was more accurate in the long occlusion duration, suggesting that the ability of the smooth pursuit system to accurately track an occluded object increases as occlusion duration increases. This divergent finding suggests that response accuracy, while the most common dependent variable in target concealment studies, does not provide a complete understanding of the smooth pursuit system. Accessing the short-term velocity memory store is not instantaneous and requires time to integrate that knowledge with the oculomotor system. While initial decay is evident, top-down information continues to provide the feedback needed throughout extended occlusion durations to correct for errors in eye position.

21.12, 8:30 am **Eye decide: eye movement initiation relates to decision accuracy in a go/no-go interception task** Jolande Fooken[1,2](jolande.fooken@rwth-aachen.de), Miriam Spering[1,2,3]; [1]Department of Ophthalmology & Visual Sciences, University of British Columbia, Vancouver, Canada, [2]Graduate Program in Neuroscience, University of British Columbia, Vancouver, Canada, [3]Center for Brain Health, University of British Columbia, Vancouver, Canada

Natural tasks, such as catching a fly, require a continuous readout of sensory information to decide whether, when, and where to act. These goal-directed actions are preceded by perceptual decisions relying on brain areas also involved in the planning and execution of eye movements. Recent studies showed that eye movements during or shortly after decision formation are modulated by decision outcome. For example, saccades are initiated earlier and faster in the decision-congruent direction in motion discrimination tasks. However, whether eye movements contribute to decision formation is not yet known. We tested observers in EyeStrike—a rapid manual interception task—allowing us to evaluate eye movements during go/no-go decisions. Observers (n=45) viewed a briefly presented (100-300 ms) moving target that followed a linear-diagonal trajectory either passing ("go" response required) or missing ("no-go" required) a strike box. Observers indicated their choice by intercepting the target inside the strike box (go) or by withholding a hand movement (no-go). The target elicited a combination of smooth pursuit and saccadic eye movements. The first saccade was reliably initiated ~240 ms after target onset. Hand movements were initiated shortly after the initial saccade onset (~180 ms), indicating that decision formation occurred prior to the initial saccade. Importantly, more accurate early pursuit was related to higher decision accuracy, reflected in a negative correlation between eye velocity error (between target onset and initial saccade) and decision accuracy. These results suggest that pursuit eye movements continuously update decision processes until the initiation of the first saccade.

Acknowledgement: Natural Sciences and Engineering Research Council Discovery Grant and Accelerator Supplement to MS

21.13, 8:45 am **Preparing to act: Modulations of visual perception across the foveola associated with microsaccade preparation.** Natalya D Shelchkova[1](nshelch@gmail.com), Martina Poletti[1]; [1]Department of Neuroscience, University of Rochester

Most research on eye movements focuses on their influences on visual perception outside the foveola, the small one-degree retinal region enabling high-resolution vision. Here, instead, we investigated how microsaccade preparation differently modulates vision within the foveola. We used a combination of techniques allowing for high-resolution recordings of eye position and accurate gaze localization. Observers (n=5) fixated on a marker surrounded by eight boxes arranged in a circle (20' radius). Stimuli were presented foveally and measured only a few arcminutes. During fixation a central saccade cue appeared pointing toward one of the boxes. Observers were instructed to shift their gaze on the box indicated by the saccade cue. They naturally used microsaccades (average amplitude 20') to re-center the gaze on the nearby box. Immediately before the execution of a microsaccade, nine probes (7'x2' bars) were briefly flashed, one in each box and one at the center of gaze. Trials were selected so that, during probe presentation, the center of gaze was equidistant from all peripheral probes. Later on, after the gaze shifted, a response cue appeared. Subjects reported the orientation of the bar previously presented at the location indicated by this cue. Performance was assessed as a function of the distance (ranging from 0' to 41') between the microsaccade target location and the response cue location. Performance was also tested in trials in which microsaccades did not occur. Our findings show that fine pattern discrimination was selectively enhanced at the microsaccade target location and it abruptly decreased to almost chance level at all the other locations, including adjacent locations (7' away), and at the center of gaze ($F(4,16)=18.7$; $p< 0.0001$, Tukey HSD post-hoc tests). Such perceptual modulation of foveal vision was the result of microsaccade preparation; when a microsaccade was not executed, performance at all peripheral locations substantially deteriorated ($p = 0.002$).

Acknowledgement: NSF- BCS-1534932

21.14, 9:00 am **Resource limitations in transsaccadic integration** Lisa M Kroell[1,2](lisa.m.kroell@gmail.com), David Aagten-Murphy[3], Paul M Bays[3]; [1]Humboldt-University of Berlin, Berlin School of Mind and Brain, [2]Ludwig-Maximilians-University Munich, Graduate School of Systemic Neurosciences, [3]University of Cambridge

Saccadic eye movements cause large-scale transformations of the image falling on the retina. Rather than starting visual processing anew after each saccade, it has been proposed that new information is integrated with an existing representation of visual input preceding the saccade. Crucially, the relative contribution of each source of information is weighted according to its precision. We reasoned that, if pre-saccadic input is maintained in a resource-limited store such as visual working memory, its precision will depend on the number of items in the pre-saccadic scene, and their priority for attention. We asked observers to report the color of a disk visible both before and after a saccade by clicking on a color wheel. The color changed imperceptibly during the saccade, and we examined where the mean reported color fell on the continuum between pre- and post-saccadic values. We observed a monotonic increase in bias towards the post-saccadic color value as the number of items in the pre-saccadic display increased from 1 to 4, consistent with an increased weighting of the post-saccadic input as precision of the pre-saccadic representation declined. In a second experiment, we investigated if transsaccadic memory resources are preferentially allocated to attentionally prioritized items. An arrow-cue indicated one of four items in the pre-saccadic display that was more likely to be chosen for report after the saccade. As predicted, a valid cue increased response precision and biased responses towards the pre-saccadic color. While adaptive variations in bias indicate that pre- and post-saccadic representations are weighted based on their reliabilities, response variabilities were higher than predicted

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by an ideal observer model of cue integration. This may be explained by a lingering effect of pre-saccadic memory load on post-saccadic precision. We conclude that transsaccadic integration relies on a limited memory resource that is flexibly distributed between pre-saccadic stimuli.

21.15, 9:15 am **Object identity determines transsaccadic integration** Michael H Herzog[1](Michael.Herzog@epfl.ch), Leila Drissi Daoudi[1], Haluk Ögmen[2], Guido Marco Cicchini[3]; [1]Laboratory of Psychophyics, EPFL, Switzerland, [2]Department of Electrical and Computer Engineering, University of Denver, USA, [3]Institute of Neuroscience, National Research Council, Pisa, Italy

Very little information is transferred across saccades. It is commonly thought that detailed vision starts mainly anew with each saccade. Here, we show that transsaccadic integration occurs even for very fine grained and unconscious information when object identity prevails across saccades through non-retinotopic reference-frames. We presented a single line followed by subsequent lines, one each of its sides creating the impression of two expanding motion streams. When one line is offset in one of the streams (Vernier offset), all lines in this, and only this stream, appear to be offset. When a second line in this stream is offset into the opposite direction, the two offsets cancel each other- even when the offsets are presented 400ms apart from each other. Integration is mandatory and unconscious, i.e., observers cannot tell which lines and how many lines are offset. Surprisingly, mandatory integration occurs also when observers make a saccade during the stream motion- even when one offset is presented before and the other one after the saccade. Importantly, the before-and-after-the-saccades parts of the streams are presented at very different locations on the retina. When these two parts of the streams are presented at the same retinal locations but observers make no saccade, two parts of two streams with two independent offsets are perceived. There is no integration of the motion streams and offsets. Hence, the human brain first establishes a motion reference-frame that unites the two parts of the motion streams to preserve object identity and then it integrates the offsets across space, time, and retinal locations according to prevailing object identities. Our results cannot easily be explained by classic remapping because integration depends on the trajectory of the streams, which, at the time of the saccade is not granted.

Acknowledgement: SNF n 320030_176153 / 1 “Basics of visual processing: from elements to figure”

21.16, 9:30 am **Face familiarity revealed by oculomotor inhibition on the fringe of awareness** Yoram S Bonneh[1](yoram.bonneh@gmail.com), Gal Rosenzweig[2]; [1]School of Optometry and Vision Science, Faculty of life Sciences, Bar-Ilan University, Ramat-Gan, Israel

Background: Involuntary eye movements during fixation of gaze are typically transiently inhibited following stimulus onset. This oculomotor inhibition (OMI), which includes microsaccades and spontaneous eye blinks, is known to be modulated by stimulus saliency and anticipation, with shorter inhibition for more salient stimuli and longer inhibition for oddballs or surprise. It is currently unknown whether the OMI is sensitive to familiarity, and whether the familiar stands out as salient or as surprising. Methods: We measured the OMI while observers (n=19) passively viewed a slideshow of one universally familiar and 7 unfamiliar facial images presented very briefly (10 ms) at 1Hz in random order. Initial experiments indicated that the OMI was often insensitive to familiarity when the facial images were highly visible. We therefore limited the visibility using backward masking (70ms SOA, two successive nature images), so that the faces were barely visible or at the fringe of awareness. We assessed statistical significance using a non-parametric permutation test. Results: The inhibition of both microsaccades and eye-blinks was significantly prolonged for the familiar face, as compared to the average of the non-familiar (~60ms, p=0.0005 for microsaccades; p=0.002 for blinks). We also found a small but significant effect of earlier (around ~100ms) microsaccade inhibition onset with familiarity (p=0.01, 30ms difference). Conclusions: These findings demonstrate, for the first time, the sensitivity of the OMI to familiarity, with familiar faces prolonging the OMI similar to oddball stimuli. Because this can be measured on the fringe of awareness and in passive viewing, the OMI can be used as a novel physiological measure for studying hidden memories with potential implications for health, legal, and security purposes.

Acknowledgement: None.

Spatial Vision: Crowding, eccentricity, natural image statistics, texture

Saturday, May 18, 8:15 - 9:45 am, Talk Room 2

Moderator: David Whitney

21.21, 8:15 am **The gradient of parafoveal crowding** Daniel R Coates[1](drcoates@uh.edu), Dennis M Levi[2], Ramkumar Sabesan[3]; [1]College of Optometry, University of Houston, [2]School of Optometry, University of California, Berkeley, [3]Department of Ophthalmology, University of Washington

The spatial extent of interference from nearby stimuli (“crowding”) has been well-mapped in the visual periphery, where its magnitude is strong. The exact dimensions of the crowding zone in the fovea and parafovea have been more elusive, however, since identification targets at threshold sizes in central vision are strongly affected by blur and eye movements. To combat these technical limitations we used adaptive optics (AO) to present optimally-corrected stimuli to the eye, permitting precise retinal targeting and the use of stimuli smaller and brighter than possible with conventional displays. In an AO scanning-laser ophthalmoscope (AOSLO), we measured crowding zones for Tumbling-E targets flanked by four Tumbling-Es in the fovea and at 1o eccentricity. The 1.5o raster resulted in a pixel size of ~0.18’. In separate experimental runs, QUEST controlled the size of letters flanked at nominal edge-to-edge spacings of 1, 2, or 4 times the letters size, as well as unflanked items. Letter sizes resulting in asymptotic (unflanked) performance of ~90% correct were used to compute crowding zones. The corresponding letters had a bar-width of ~0.7’ and ~1.27’ at the fovea and 1o, respectively. To determine the critical spacing for crowding, we fitted an exponential function to the performance versus flanker spacing curves. Using a strict criterion of >95% of the asymptotic performance level, we estimated critical spacings of 1.3’ and 5.1’ edge-to-edge, for the fovea and 1o,respectively. The corresponding E2 values (eccentricity where foveal thresholds double) were 1.3o for resolution and 0.34o for the critical spacing, in good agreement with previous work showing the anatomical versus neural loci of these tasks. While there remains some debate about the exact relationship between foveal and peripheral crowding, these results bridge these two regimes, revealing the smooth gradient when limiting factors can be effectively controlled.

Acknowledgement: NIH R01EY020976, NIH P30EY001730, Unrestricted grant from the Research to Prevent Blindness, Research to Prevent Blindness Career Development Award, Burroughs Welcome Fund Careers at the Scientific Interfaces, Murdock Charitable Trust

21.22, 8:30 am **Lost lines in warped space: Evidence for spatial compression in crowded displays** Fazilet Zeynep Yildirim[1](fazilet.yildirim@psy.unibe.ch), Daniel R. Coates[1,2], Bilge Sayim[1,3]; [1]Institute of Psychology, University of Bern, Bern, Switzerland, [2]College of Optometry, University of Houston, Houston, TX, USA, [3]SCALab - Sciences Cognitives et Sciences Affectives, CNRS, UMR 9193, University of Lille, Lille, France

Crowding is the deleterious influence of neighboring stimuli on peripheral target perception. Typically, crowding deteriorates discrimination but not detection. However, recent studies revealed that elements are often omitted in crowded displays, resembling failures to detect. It has been suggested that omissions in repeating patterns consisting of as few as three items (triplets) are due to a mechanism called “redundancy masking”. Here, we show how redundancy masking goes hand in hand with systematic compressions of perceived space. Observers were presented with 3-7 identical, equally spaced lines at 10º eccentricity. We varied the spacing between the lines (5 levels). Using a dual task, observers first indicated the number of perceived lines. Second, observers judged the separation between adjacent lines in Experiment 1, and the horizontal extent of the entire line array from the innermost to the outermost line in Experiment 2. In both experiments, the number of perceived lines was reduced in the majority of trials, showing strong redundancy masking. Next, we compared the separation estimates of the line triplets for correct trials with those in ‘masked’ trials where only 2 lines were reported. In Experiment 1, separation estimates were larger in masked (M=1.52+/-0.16) than in correct (M=1.01+/-0.16) trials. By contrast, in Experiment 2, separation estimates were smaller in masked (M=0.83+/-0.18) than in correct (M=1.25+/-0.19) trials. Importantly, the reported separation of the two lines was approximately the same in the masked trials of both

experiments, indicating that the entire array underwent spatial compression. Probe experiments to identify the perceived centroid of the arrays ruled out alternative hypotheses. We suggest that the systematic compression of visual space in redundancy masking is a major contributor to crowding in displays with repeating elements.

Acknowledgement: The Swiss National Science Foundation (PP00P1_163723 to Bilge Sayim).

21.23, 8:45 am **Inhomogeneous Visual Acuity Correlated With Idiosyncratic Mislocalization** Zixuan Wang[1](zixuan@berkeley.edu)**,** Yuki Murai[1,2]**,** David Whitney[1,3,4]; [1]Department of Psychology, University of California, Berkeley, [2]Japan Society for the Promotion of Science, [3]Vision Science Program, University of California, Berkeley, [4]Helen Wills Neuroscience Institute, University of California, Berkeley

Accurately perceiving the positions of objects is a critical visual function. Recent research demonstrated that observers consistently mislocalize brief objects throughout the visual field in an idiosyncratic manner: observes mislocalize objects in different ways in different parts of the visual field (Kosovicheva & Whitney, 2017). One possibility is that these fingerprints of distorted space perception are related to differences in the resolution of position coding throughout the visual field. If so, there may be systematic differences in acuity throughout the visual field that correlate with the mislocalizations. Here, we tested this. In a first experiment, we constructed localization bias maps throughout the visual field for individual observers. Observers were asked to localize a brief noise patch target with a mouse cursor. The possible target locations covered much of the visual field. Mislocalization (constant) errors were recorded and found to be significant and idiosyncratic, such that each observer mislocalized targets consistently in a unique way throughout the visual field. Because of the mislocalizations, there were some regions of the visual field that were effectively compressed (sinks) and other regions that were expanded (sources).In a second experiment, we tested whether these individualized perceptual distortion maps correlated with differences in visual resolution. We tested Vernier acuity thresholds at 6 locations in each observer's visual field, specifically 4 in the compressed and expanded regions identified in the first Experiment and 2 in neutral regions. Interestingly, we found significantly higher acuity in perceptually compressed regions than in the expanded regions. The results reveal a primitive inhomogeneity in the spatial resolution of position coding, which may then bias assigned object position. This inhomogeneity indicates that our visual system evidently has a compensatory mechanism to correct the individualized biases, to establish an accurate and stable position representation that is ultimately consistent between observers.

21.24, 9:00 am **Using fMRI to link crowding to hV4** Augustin Burchell[1](augustin.burchell@gmail.com)**,** Noah C Benson[2]**,** Jing Y Zhou[2]**,** Jonathan A Winawer[2]**,** Denis G Pelli[2]; [1]Cognitive Science, Swarthmore College, [2]Psychology Department and Center for Neural Science, New York University

Crowding, the unwanted perceptual merging of adjacent stimuli, is well studied and easily measured, but its physiological basis is contentious. We explore its link to physiology by combining fMRI retinotopy of cortical area hV4 and psychophysical measurements of crowding in the same observers. Crowding distance (i.e. critical spacing) was measured radially and tangentially at eight equally spaced sites at 5° eccentricity, and ±2.5° and ±10° on the horizontal midline. fMRI mapped the retinotopy of area hV4 in each hemisphere of the 5 observers. From the map we read out cortical magnification, radially and tangentially, at the 12 sites tested psychophysically. We also estimated the area of hV4 in mm2. Combining fMRI with psychophysics, last year we reported conservation of a roughly 1.8 mm crowding distance on the surface of hV4 (the product of cortical magnification in mm/deg and crowding distance in deg) across eccentricity and orientation, in data averaged across observers (Zhou et al. 2018 VSS). Crowding distances were less well preserved in the V1-V3 maps. Conservation of the hV4 crowding distance across individual observers would mean a fixed product of visual crowding distance and cortical magnification, which implies a negative correlation between log crowding distance and log magnification. Separate linear mixed-effects models of log crowding area and log cortical magnification each account for about 98% of the variance. Log areal hV4 cortical magnification shows a trend toward a negative correlation with log areal crowding across 10 hemispheres (r=-0.53, p=0.11); log hV4 surface area and log areal crowding show a similar negative correlation (r=-0.55, p=0.1). The trend toward larger crowding distances in observers with less surface area in hV4 is consistent with the possibility that crowding distances, though highly variable when measured in the visual field, are approximately conserved on the surface of the hV4 map.

Acknowledgement: 1R01EY027964

21.25, 9:15 am **A canonical computational model of cortical area V2** Timothy D Oleskiw[1](oleskiw@nyu.edu)**,** Eero P Simoncelli[1]; [1]New York University

As visual information propagates along the ventral pathway, individual neurons respond selectively to stimulus features of increasing complexity. Neurons in primary visual cortex (V1) respond to oriented gratings, while many neurons of the second visual area (V2) respond to more complex patterns, such as the pseudo-periodic structure of visual texture (Freeman et al., 2013; Yu et al., 2015). Although V1 neurons are well explained by simple receptive field models localized in space, orientation, and scale, it is unknown how a neuron in V2, receiving input from a subset of V1 afferents, achieves selectivity for complex visual features common to natural scenes. Recently we have leveraged the statistics of natural images to learn a low-dimensional computational model of visual texture selectivity (Oleskiw & Simoncelli, SfN 2018). Our model, trained to detect naturalistic statistics across stimuli matched in local orientation energy, learns computational units resembling localized differences (i.e., derivatives) spanning the 4-dimensional space of V1 selectivity, namely horizontal and vertical position, orientation, and scale. In the present work, we use this observation to construct a population of V2-like units that captures statistics of natural images. Images are first encoded in the rectified responses of a population of V1-like units localized in position, orientation, and scale. We then explicitly compute derivatives of local spectral energy via linear combinations over the 4D space of V1 activity. A low-dimensional population of simple (rectified linear) and complex (squared) V2-like units is shown to accurately distinguish natural textures from spectrally matched noise, outperforming even the optimal Fisher linear discriminant trained over the full set of V1 afferents (91% vs. 86% accuracy, using only 0.2% of available dimensions). We conclude by demonstrating how this canonical and physiologically-plausible model of V2 computation selectively captures complex features of natural images from the local spectral energy conveyed by V1.

Acknowledgement: Howard Hughes Medical Institute

21.26, 9:30 am **Extracting image statistics by human and machine observers** Chien-Chung Chen[1,2](c3chen@ntu.edu.tw)**,** Hsiao Yuan Lin[1]**,** Charlie Chubb[3]; [1]Department of Psychology, National Taiwan University, [2]Neurobiology and Cognitive Science Center, National Taiwan University, [3]Department of Cognitive Sciences, University of California, Irvine

Machine learning has found many applications in research for higher visual functions. However, few studies have applied machine learning algorithms to understand early visual functions. We applied a deep convolution neural network (dCNN) to analyze human responses to basic image statistics. The stimuli were band-passed random dot textures whose pixel luminance distribution was modulated away from uniform by a linear combination of Legendre polynomials with orders i and j, where i = 2 or 3, and j was from 1 to 8 but not i. There were 30 modulation depths from 0 (uniform distribution) to 1 (some luminance level had zero probability) for each polynomial pair. The Gaussian spatial frequency bands had peaks that ranged from 2 to 32 cyc/deg and a half-octave space constant. Each of six observers classified 7500–22500 textures by contrast, skewness, glossiness, naturalness or aesthetic preference. The psychophysical results served as ground truth for a VGG16 dCNN pretrained for Imagenet. The decisive layer was identified by removing the convolution layers one by one and observing the point when validation accuracy of the network, with retrained output layer, dropped below 80%. The decisive layer for contrast discrimination contained filters with a profile that consisted of repeated geometric patterns, suggesting a general texture processing mechanism. The decisive layer was the same for all of glossiness, naturalness, and aesthetic preference and comprised filters whose profiles looked like parts of objects. The spatial frequency tuning function, assessed by the validation accuracy with one spatial frequency band left out from the training set was low-pass for all properties except contrast, which showed an inverted-W shape peaked at 4 and 16 cyc/deg. Our results suggest possible properties of the visual mechanisms used to sense texture qualities, and our analysis also shows that dCNN can be a useful tool for early vision research.

Acknowledgement: MOST(Taiwan) 105-2420-H-002 -006 -MY3

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3D Perception

Saturday, May 18, 10:45 am - 12:30 pm, Talk Room 1

Moderator: Jody Culham

22.11, 10:45 am **Does the world look flat? Sustained representation of perspectival shape** Jorge Morales[1](jorge.morales@jhu.edu), Chaz Firestone[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

Arguably the most foundational principle in perception research is that our visual experience of the world goes beyond the retinal image; we perceive the distal environment itself rather than the proximal stimulation it causes. Shape, in particular, may be the paradigm case of such "unconscious inference": When a circular coin is rotated in depth, for example, we experience it as the circular object it truly is, rather than as the perspectival ellipse it projects on the retina. But what is the fate of such perspectival shapes? Once our visual system infers that an elliptical projection arose from a distally circular object, do our minds continue to represent the "ellipticality" of the rotated coin? If so, objectively circular objects should, when rotated, impair search for objectively elliptical objects. Here, four experiments demonstrate that this is so, suggesting that perspectival shape representations persist far longer than is traditionally assumed. Subjects saw a simple two-item search array containing cue-rich images of differently shaped 3D "coins"; their task on each trial was simply to locate a distally elliptical coin. Surprisingly, objectively circular coins slowed search for elliptical objects when the circular coins were rotated in depth, even when subjects clearly reported seeing them as circular. This pattern arose for images containing both static (Exp.1) and motion-based (Exp.2) depth cues, and it held not only for speeded judgments but also in a delayed-judgment condition in which subjects viewed the coins for a sustained period before responding (Exp.3). Finally, a completely different paradigm (Exp.4) showed that viewing a rotated circular object boosted subsequent identification of an elliptical line-drawing, suggesting that rotated objects also prime their perspectival shapes. We conclude that objects in the world have a surprisingly persistent dual character in the mind: Their objective shape "out there", and their perspectival shape "from here".

Acknowledgement: JHU Science of Learning Institute

22.12, 11:00 am **Perceived distance to augmented reality images is influenced by ground-contact** Grant Pointon[1](grant.pointon@psych.utah.edu), Carlos Salas[2], Haley Adams[2], Sarah Creem-Regehr[1], Jeanine Stefanucci[1], Bobby Bodenheimer[2], William B Thompson[1]; [1]University of Utah, [2]Vanderbilt University

Recent advancements in augmented reality (AR) have led to the development of several applications in domains such as architecture, engineering, and medical training.Typically, these applications present users with 3D virtual images in real environments that would not easily be portrayed otherwise (e.g., floor plans, arteries, etc.).The way users perceive the scale (i.e., size, distance, etc.) of such displays is important for decision making and learning outcomes.The current study aimed to asses users' perception of distance to AR images, which has previously been shown to be underestimated in other virtual technologies.We focused our investigation on the influence of ground contact, which is an important cue for distance perception that many AR images lack because they are presented above the ground surface.Furthermore, binocular cues should be particularly important for users to overcome the lack of ground contact in many AR images. To test both the influence of ground contact and the importance of binocular cues, we conducted a study where participants were asked to blind walk to AR cubes presented at 3m, 4.5m, and 6m.Participants completed this task with cubes rendered on the ground surface or 0.2m above the ground surface. Additionally, we had each participant perform this task under monocular and binocular viewing conditions.We found that participants blind walked farther to AR cubes presented above the ground surface and that this effect was exaggerated under monocular viewing conditions.However, we found that participants blind walked shorter to AR cubes presented on the ground which was not expected.We also found underestimation of cube distance, regardless of where the cubes were presented or the viewing condition.Our results suggest that distance in AR environments is generally underestimated and that a lack of ground contact influences users' perception of distance to AR images.

Acknowledgement: Office of Naval Research grant N00014 - 18 - 1 - 2964

22.13, 11:15 am **Real-time blur with chromatic aberration drives accommodation and depth perception** Steven A Cholewiak[1](steven.cholewiak@berkeley.edu), Peter Shirley[2], Morgan McGuire[2], Martin S Banks[1]; [1]Optometry & Vision Science, University of California, Berkeley, [2]NVIDIA

In computer-generated imagery and vision science, defocus blur is often rendered to simulate objects closer or farther than the focal plane. But depth-dependent optical effects, like longitudinal chromatic aberration (LCA), are not implemented in a physically correct manner. Recent evidence has shown that incorporating LCA into rendered images produces a powerful cue for driving accommodation and depth perception. But implementing correct LCA effects is computationally expensive. Applied implementations of defocus blur with LCA are possible, but require approximations in order to run in real-time. We investigated whether real-time implementation of blur with LCA using approximate blur kernels and simplified treatment of occlusions can still drive accommodation and improve perceived depth compared to conventional methods that do not incorporate LCA. We measured accommodative responses with an autorefractor while participants viewed stimuli at various real and simulated distances. For real changes, a focus-tunable lens altered the optical distance of the stimulus, producing a blurred retinal image with the observer's natural aberrations. For simulated changes, optical distance was constant and rendered image content changed. These stimuli were generated using 1) conventional defocus blur with all color channels treated the same; 2) defocus blur and LCA with each channel treated correctly; or 3) approximate defocus and LCA using truncated 2D Gaussian blur kernels within a real-time game engine. Simulated changes in defocus with LCA (both physically accurate and real-time) drove accommodation as well as real changes. In another experiment, participants viewed images with two planes, one partially occluding the other, and made relative depth judgments. Incorporating physically correct rendered LCA or real-time approximations improved depth ordering relative to conventional techniques that do not incorporate LCA. Chromatic information is important for accommodation and depth perception and can be implemented in real-time applications.

Acknowledgement: NSF Research Grant BCS-1734677, Corporate University Research, Intel Labs

22.14, 11:30 am **Which aspects of size and distance for real objects are coded through the hierarchy of visual areas?** Margarita V Maltseva[1,2](mmaltsev@uwo.ca), Derek J Quinlan[1,2], Kevin M Stubbs[1,2], Talia Konkle[3,4], Jody C Culham[1,2]; [1]Department of Psychology, Western University, [2]Brain and Mind Institute, Western University, [3]Department of Psychology, Harvard University, [4]Center for Brain Science, Harvard University

The visual system must transform two-dimensional retinal information into estimates of real-world distance and physical size based on pictorial and binocular cues. Although numerous human neuroimaging studies have investigated how various brain regions represent retinal size, distance, familiar size, physical size, these studies have often used visually impoverished stimuli, typically images, with conflicting cues, and studied factors in isolation. We investigated how brain activation levels (and patterns) in ventral- and dorsal-stream regions depend upon multiple factors (retinal size, physical size, familiar size, distance) that co-occur in the real world. We presented real objects at real distances during functional magnetic resonance imaging (fMRI). We manufactured MR-compatible Rubik's cubes and dice at their typical sizes (5.7 cm and 1.6 cm, respectively) and each other's typical sizes. We oriented them obliquely at two distances (25 cm, within reach, vs 91 cm, out of reach), such that two combinations subtended the same retinal angle (4.7o for small, near and large, far) while other combinations yielded smaller (1.3o; small, far) or larger (15.9o; large, near) retinal angles. Univariate contrasts revealed that the dorsal-stream regions -- left superior parietal occipital cortex (SPOC) and bilateral anterior intraparietal sulci (aIPS) – showed higher activation for objects in near (vs. far) space, even when retinal angles were matched, and for physically large (vs. small) objects in near space. Higher-order perceptual visual areas – lateral occipital cortex (LOC) and the parahippocampal place area (PPA) – distinguished between the two objects, showing higher activation for the Rubik's cube (vs. die). Activation in bilateral V1 and PPA increased with retinal size. Taken together, our results suggest that distance and physical size are processed in the dorsal stream, where those features are critical for actions such as reaching and grasping; whereas, object features are more important in the ventral stream, where they are relevant for perception.

Acknowledgement: NSERC, BrainsCAN

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22.15, 11:45 am **The size of objects in visual space compared to pictorial space** Adam O Bebko[1](adambebko@gmail.com), Nikolaus F Troje[2]; [1]Department of Psychology, York University, Toronto, Canada, [2]Department of Biology, York University, Toronto, Canada

The visual space in front of our eyes and the pictorial space that we see in a photo or painting of the same scene behave differently in many ways. Here, we used virtual reality (VR) to investigate size perception of objects in visual space and their projections in the picture plane. We hypothesize that perceived changes in the size of objects that subtend identical visual angles in pictorial and visual space are due to the dual nature of pictures: The flatness and location of the picture "cross-talks" (Sedgwick, 2003) with the perception of the depicted three-dimensional space. If the picture is at distance dpic and the depicted object at dobj, size-distance relations influence perceived relative sizes. The picture is expected to be scaled by a factor c*(dobj / dpic - 1) + 1 to match the object, where c is a constant between 0 and 1. In a VR environment, eight participants toggled back and forth between a view of an object seen through a window in an adjacent room, and a picture that replaced the window. Participants adjusted the picture scale to match the size of the object through 60 trials varying dobj and dpic. A multilevel regression indicated that the above model does not hold. Rather, we found a striking asymmetry between the roles of object and picture. If dobj was greater than dpic (object behind picture) then c was 0.005 ($t(7) = 7.80$, $p < 0.001$). In contrast, if dobj was less than dpic (object in front of picture), c was 0.33 ($t(7) = 3$, $p < 0.001$). We discuss this result in the context of a number of different theories that address the particular nature by which the flatness of the picture plane influences the perception of pictorial space.

Acknowledgement: NSERC

22.16, 12:00 pm **The Intrinsic Constraint Model: A non-Euclidean approach to 3D shape perception from multiple image signals** Jovan T Kemp[1](jtk194@gmail.com), Evan Cesanek[1], Fulvio Domini[1]; [1]Cognitive, Linguistic, and Psychological Sciences, Brown University

How does the visual system derive estimates of 3D shape properties? Typically, models assume that sources of depth information such as texture gradients and binocular disparities are processed independently to produce a set of unbiased estimates sharing a common spatial metric. Under this assumption, the independent estimates can be optimally combined into a unified, accurate depth representation via Maximum Likelihood Estimation (MLE). However, this approach tacitly assumes that the visual system has learnt a veridical mapping between the individual image signals and the 3D properties they encode. An alternate approach, termed the Intrinsic Constraint (IC) model, does not require this assumption and instead considers raw image signals as vector components of a multidimensional signal. Critically, as long as the raw signals are proportional to physical depth, the vector magnitude will be as well. Assuming a fixed, but generally non-veridical scaling of the image signals (a normalization step), the IC model directly maps for any mixture of signals: (1) a vector magnitude to a perceived depth and (2) a fixed change in vector magnitude to a Just-Noticeable Difference (JND). We tested these predictions in two related studies. In the first, we asked participants to adjust a 2D probe to indicate the perceived depth of stimuli with simulated depths defined by disparity only, texture only, or disparity and texture together. In the second, participants adjusted the depths of cue-conflict stimuli with five fixed conflict ratios (texture depth relative to disparity depth: 0, 0.41, 1, 2.41, ∞) until all appeared equally deep. In both studies, JNDs were then measured for personalized sets of stimuli that evoked the same perceived depth. The results were incompatible with the assumption of accurate depth perception central to the MLE approach, while the IC model fared well in predicting the data of each task without free parameters.

22.17, 12:15 pm **Influence of 2D Shape on Contour Depth Perception** Krista A Ehinger[1](kehinger@yorku.ca), Yiming Qian[1], Laurie M Wilcox[1], James H Elder[1]; [1]Centre for Vision Research, York University

Objective. The bounding contour of an object serves as an important constraint in recovering 3D shape. In the image, the bounding contour is planar, but it projects from a 3D space curve lying on the object - the rim (Koenderink, 1984) - that may be oblique to the observer and non-planar. Determining the 3D shape of this space curve from a 2D projection is ill-posed, but statistical regularities of objects (smoothness, symmetry, and parallelism) and projection (the generic view assumption) may provide cues. Here we assess this hypothesis using a novel psychophysical approach. Methods. From random perspective projections of 3D laser-scanned objects (Mehrani & Elder, 2017) we generated a set of 3D rims subtending an average of 8.3 dva and displayed them stereoscopically using a Wheatstone stereoscope. To assess the effect of the shape of the 2D bounding contour on perceived depth, two modified configurations of the rim were generated. In the shifted configuration, the 2D shape matched the original bounding contour, but the depth values were rotated along the contour by one quarter of the contour length. In the circle configuration, the 2D shape was a circle with the same depth values as the original rim. Observers were shown a contour in of the three stimulus configurations for two seconds, followed by the same contour but in one of the other two configurations, and asked to adjust the depth gain of this second stimulus to match the depth range perceived in the first stimulus. Results. Results indicate that observers perceive greater depth in the shifted configuration than the other two configurations. These findings show that the 2D shape of a contour can influence the perceived variation in depth, suggesting a sensitivity to statistical regularities linking the 3D rim and its image projection.

Acknowledgement: Vision: Science to Applications (VISTA) award to K.A.E. and NSERC Discovery grants to J.H.E. and L.M.W.

Attention: Animacy, attentional blink

Saturday, May 18, 10:45 am - 12:30 pm, Talk Room 2

Moderator: Yaffa Yeshurun

22.21, 10:45 am **Are familiar rhythms a top-down – bottom-up hybrid cue of visual temporal attention?** Asaf Elbaz[1](asafelbaz@gmail.com), Yaffa Yeshurun[1]; [1]Psychology Department, University of Haifa

Visual attention can be allocated in space (spatial attention) or in time (temporal attention). Like spatial attention, temporal attention can either be allocated in accordance with one's goals (i.e., top-down, endogenous) or triggered by external events (i.e., bottom-up, exogenous). However, some cues of visual spatial attention do not fit this dichotomy perfectly. For instance, a central arrow leads to attention allocation to the location it indicates even when it is not predictive, suggesting that it involves involuntary exogenous processes. Yet, the indicated location can only be extracted based on learned associations, suggesting that top-down processes are also involved. This study examined, for the first time, whether a similar 'hybrid' cue can be found for visual temporal attention. The target was the letter T in an upright or inverted orientation, and the task required reporting the target's orientation. Target onset was preceded by auditory rhythms. We rely on previous demonstrations that isochronous rhythms (i.e., with a fixed inter-onset-interval –IOI) that do not predict target onset improve performance for targets appearing in-sync with the rhythm, suggesting exogenous entrainment of temporal attention to these in-sync points in time. Critically, we also employed asynchronous familiar rhythms as temporal analog of arrows. On the one hand, with asynchronous familiar rhythms expectations regarding the time in which the next event will occur can only be based on past exposure, necessitating the involvement of top-down information. On the other hand, the rhythms we employed did not predict target onset, and therefore did not encourage voluntary attention allocation. We found that asynchronous familiar rhythms, which included pitch variations, could entrain attention even though they were not informative. Thus, this study provides a novel demonstration of hybrid (top-down-exogenous) cueing of visual temporal attention.

Acknowledgement: Israel Science Foundation Grant 1081/13 to YY

22.22, 11:00 am **Ensemble perception of faces within the focus of attention is biased towards unattended and task-irrelevant faces** Viola S Störmer[1](vstoermer@ucsd.edu); [1]Department of Psychology, University of California San Diego

While much research has shown that attention enhances perceptual processing, it is unclear how unattended and irrelevant information influences perceptual representations of attended objects. Here we asked how ensemble processing of a set of attended faces is affected by other, irrelevant face ensembles presented at unattended locations. Participants monitored a stream of images that contained faces and noise patches on one side of the display (e.g., right visual field) and reported the average emotion of the faces at the end of each trial. In Experiment 1 (N=20) we used a set of faces that continuously varied in emotional units from happy to sad (Haberman & Whitney, 2007), and presented a set of four faces in each stream. Another stream of images was presented on the unattended, task-irrelevant side (e.g., left visual field) and participants were instructed to ignore it. Critically, the average emotion of these irrelevant faces was systematically varied such that it would either match the average emotion of the attended faces, or be on average happier or sadder than the attended set. We found that the perceived ensemble was biased towards the average emotion of the irrelevant face set, such that if happier faces were presented in the unat-

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tended stream, participants were biased to perceive the attended faces as happier, and vice versa (p=0.007). Similar biases towards the irrelevant face set were observed in Experiment 2 (N=25; p=0.005), in which we used a circular face space with 360 faces that varied in emotional units from happy to sad to angry. Together, these data indicate that percepts of objects within the spatial focus of attention are not isolated from the rest of the visual scene, but are instead influenced by irrelevant inputs, at least those that match the current attentional template.

22.23, 11:15 am **High-level interference and low-level priming in the Attentional Blink** Daniel Lindh[1,2](dnllndh@gmail.com), Ilja Sligte[2], Kimron Shapiro[1], Ian Charest[1]; [1]School of Psychology, University of Birmingham, UK, [2]Department of Psychology, University of Amsterdam, Netherlands

The Attentional Blink (AB) phenomenon has been at the epicentrum of attention research for over two decades. However, the neural mechanisms underlying the phenomenon have still eluded understanding. How is it possible that subjects can easily report two targets (T1 and T2) embedded in a visual stream of distractors? Yet, when they are separated in time by 200-500 ms, T2 is often unavailable for conscious report. Most prevalent theories posit that T1 occupies attentional resources necessary for T2's conscious access. Here, we provide evidence that the AB can be understood in terms of target-target activity-pattern similarity. To define similarity, 18 subjects completed two fMRI sessions performing a working memory (WM) task, and four sessions of EEG performing an AB task. In fMRI, similarity was defined as the voxel-pattern similarity, while in EEG, similarity was based on the T1 scalp-patterns. We show that in higher-tier visual areas, target-target similarity is detrimental for T2 performance. ROI-based analyses revealed robust negative correlations between similarity and T2 performance, most prominently in the Lateral Occipital Cortex (LOC) and Ventral Stream (VS). In contrast, similarity in V1 increased the probability of conscious access to T2. In EEG, similarity in the time window of 140-300ms negatively correlated with performance, consistent with our LOC and VS results. The negative correlations were present both when T2 was presented 200ms (Lag-2) and 700ms (Lag-7) after T1, demonstrating that the WM maintenance of T1 interfered with T2 encoding. Meanwhile, similarity in V1 only improved performance during Lag-2, implying a short-lasting priming effect. Our findings indicate that conscious access in AB depends on two contending target-interaction processes that are temporally and spatially separated. These insights into how, when and where T1 affects the probability of conscious access to T2 highlight important neural correlates for visual conscious processing.

22.24, 11:30 am **Visual search proceeds concurrently during the attentional blink and response selection bottleneck** JongMin Lee[1](dydysy123@gmail.com), Suk Won Han[1]; [1]Department of Psychology, Chungnam National University

Does visual search freeze up during the central stage of information processing, at which the processes of working memory encoding and response selection take place? To address this issue, in the first experiment, we had participants identify and maintain a target (T1) embedded in a rapid serial visual presentation (RSVP) of digit distractors. The centrally presented RSVP was followed by a visual search task. Importantly, contrary to previous studies, a conjunction search task of searching for a green 'T' among green 'O' and red 'T' was used. We manipulated the SOA between the T1 and T2 (200-ms vs. 1200-ms) and set-size of visual search stimuli (3 vs. 6). The results showed that the T2 RT was significantly greater at the short SOA than at the long SOA, $p < .001$ and the T2 RT was significantly greater for the set-size 6 trials than for the set-size 3 trials across the SOAs, $p < .001$. Importantly, at the short SOA, the magnitude of set-size effect was significantly smaller than at the long SOA (23-ms vs. 47-ms), $p < .005$, revealing that increased processing duration of T2 was absorbed into slack time evoked by the concurrent process of working memory encoding. We suggest that this underadditive interaction between the SOA and set-size is because visual search proceeds concurrently during the attentional blink. In the second experiment, the first task was replaced to a four-alternative, speeded response task, followed by the same visual search task as in Experiment 1. The results of Experiment 2 also revealed a similar pattern of significant interaction between the SOA and set-size, $p < .001$, suggesting that visual search can also proceed during response selection stage. Taken together, we conclude that the perceptual processing of conjunction search stimuli took place during the central stage of information processing.

22.25, 11:45 am **Do Non-Target Emotional Stimuli Modulate the Attentional Blink?** Lindsay A Santacroce[1](lsantacroce@uh.edu), Nathan Petro[2], Christopher Walker[1], Benjamin J Tamber-Rosenau[1]; [1]Department of Psychology, University of Houston, [2]Department of Psychology, University of Nebraska Lincoln

In the attentional blink (AB), the second of two targets separated by a short lag in a rapid serial visual presentation (RSVP) stream is difficult to report. Researchers have reported two kinds of emotional interactions with the AB: First, the AB is modulated when one of the targets itself has emotional valence. Second, AB modulation is obtained when just one target among neutral distractors is in close proximity to a to-be-ignored emotional stimulus (critical distractor item; CDI). However, previous studies have yet to examine whether the addition of a valenced CDI can modulate the "classic" two-target AB. Here, participants were presented with RSVP streams of neutral words that included two targets as well as a pleasant, neutral, or unpleasant CDI immediately following the first target, i.e., with a variable lag to the second target. In Experiment 1, valenced word CDIs did not modulate the AB. Experiment 2 aimed to increase the salience of the CDIs by replacing them with similarly-sized images, but still showed no effect of valence on the AB. Experiment 3 aimed to further increase the CDIs' salience by enlarging the size of the images to full-screen. Here, CDI valence had an effect on the AB, where participants performed better when the CDIs were neutral, compared to both pleasant and unpleasant. Bayesian analyses support a Valence×Lag interaction in Experiment 3, but show substantial support for equivalence of pleasant, neutral, and unpleasant CDIs in Experiments 1 and 2. The results suggest that emotional stimuli must be attended (as targets or as highly salient items) in order for their valence to have an effect on the AB. Future experiments will test if the modality shift in Experiments 2 and 3 (word RSVP with image CDIs) makes attending to salient images less likely by using images for all RSVP items.

22.26, 12:00 pm **The Cognitive Architecture of Intentionality Perception: Animacy, Attention and Memory** Ning Tang[1](ningtang@g.ucla.edu), Haokui Xu[1], Chris Baker[2], Josh Tenenbaum[3], Tao Gao[1,4]; [1]Department of Statistics, UCLA, [2]iSee AI, [3]Department of Brain and Cognitive Sciences, MIT, [4]Department of Communication, UCLA

Human vision supports social perception by efficiently detecting agents and extracting rich information about their actions, goals, and intentions. Here we explore the cognitive architecture of perceiving intention by constructing Bayesian models that integrate domain-specific hypotheses of social agency with domain-general cognitive constraints on sensory, memory, and attentional processing. Our model posits that the perception of intention combines a bottom-up, feature-based, parallel search for goal-directed movements with a top-down selection process for intent inference. The interaction of these architecturally distinct processes makes the perception of intentionality fast, flexible, and yet cognitively efficient. In the context of chasing, in which a predator (the "wolf") pursues a prey (the "sheep"), our model addresses the computational challenge of identifying target agents among varying numbers of distractor objects, despite a quadratic increase in the number of possible interactions as more objects appear in a scene. By comparing modeling results with human psychophysics in several studies, we show that the effectiveness and efficiency of human perception of intention can be explained by a Bayesian ideal observer model with realistic cognitive constraints. These results provide an understanding of perceived animacy and intention at the algorithmic level—how it is achieved by cognitive mechanisms such as attention and working memory, and how it can be integrated with higher-level reasoning about social agency.

22.27, 12:15 pm **Intrinsic curiosity may give rise to animate attention** Julian De Freitas[1](defreitas@g.harvard.edu), Kun Ho Kim[2], Nick Haber[2], Colin Conwell[1], George A Alvarez[1], Daniel L.K. Yamins[2]; [1]Harvard University, [2]Stanford University

Humans naturally pay attention to other animate agents in their environment, a prosocial behavior that has been documented as early as a few weeks. What internal mechanisms give rise to this behavior? A standard hypothesis is that the human brain has a built-in module that specifically detects animacy from visual input. We hypothesize that animate attention naturally arises from a more general process of curiosity driven learning. We ran experiments to measure important features of animate attention. Observers (N = 12, A gerange = 43 years) wore a mobile eye tracker while watching a display consisting of four self-propelled, spherical robots travelling along a mat. Using kinematics alone, the robots were made to appear animate, random, periodic, or static. Average fixations proportions were animate 55%, random 24%, periodic 14%, and static 7%, with 10 of 12 observers fixating most on animate. We also administered an autism assessment scale and

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found that observers scoring high on this scale attended to animate robots significantly less ($r = -0.65$, $p = 0.02$), suggesting that our attentional-fraction metric is an indicator of variance in social behavior. We then built a neural network agent embodying concepts of intrinsic curiosity, and embedded it within a virtual environment emulating the real world robot display. The agent was tasked to predict the virtual robot trajectories and was constrained to focus on one robot at a time. Results show that the neural network agent produces an aggregate attentional fixation pattern identical to that of human adults. Crucially, the network achieves this without the requirement for any specific built-in modules favoring animacy. Instead, the pattern arises from the agent's discovery of the inherent relative "interestingness" of animacy as compared to random, periodic, and static motion. More broadly, our results suggest that key characteristics of social behavior may emerge naturally from intrinsically-motivated learning agents.

Multisensory Processing: Auditory 1

Saturday, May 18, 8:30 am - 12:30 pm, Banyan Breezeway

23.301 **Bayesian causal inference modeling of attentional effects on the temporal binding window of multisensory integration** Leslie D Kwakye[1](lkwakye@oberlin.edu), Victoria Fisher[1], Margaret Jackson[1], Oona Jung-Beeman[1]; [1]Neuroscience Department, Oberlin College

In order to understand the world around us, we combine information across the different senses. This multisensory integration is highly dependent on the temporal relationship between unisensory events and our brain's ability to discern small timing differences between stimuli (crossmodal temporal acuity). Our previous research found that increasing both visual and auditory perceptual load led to sharp declines in participants' crossmodal temporal acuity. Previous research in other labs has demonstrated that the brain integrates multisensory information in a Bayes' optimal way and that the integration of temporally disparate audiovisual stimuli can be modeled using Bayesian causal inference modeling. The present study investigates the influence of visual and auditory perceptual load on the integration of simple stimuli using Bayesian modeling. Participants completed a simultaneity judgment (SJ) task during which they determined whether temporally offset flash-beep stimuli occurred (a)synchronously. In addition, participants completed the SJ task alone (distractor free; DF), in the presence of task-irrelevant visual or auditory distractors (no load; NL), and while completing a concurrent visual or auditory distractor task (high load; HL). Data was modeled using the causal inference model derived in Magnotti et al. 2013, which is based on Bayesian statistics. Our preliminary data show an increase in the temporal binding window for both visual and auditory NL and HL as compared to DF conditions, indicating that the presence of extraneous stimuli enlarge the temporal binding window. Sensory noise increased in the visual and auditory HL conditions as compared to the DF and NL. Similarly, the prior likelihood to assume synchronicity (prior) decreased only when participants attended to the distractors (HL). These preliminary findings indicate that attention alters both low-level (sensory noise) and high-level (priors) processing of simple multisensory stimuli and that our previously observed effects of attention multisensory temporal processing are generalizable

23.302 **Temporal binding across senses facilitates change detection within senses** Thomas P.F. Schaffhauser[1](thomas.schaffhauser@ens.fr), Yves Boubenec[1], Pascal Mamassian[1]; [1]Laboratoire des Systèmes Perceptifs, École Normale Supérieure - PSL Univeristy, Paris

In a multisensory task, the extent to which unisensory signals are combined depends not only on the saliency of each cue but also on the likelihood that these signals are caused by a common sensory event. This causal inference problem can be solved if these signals share a common feature. We therefore investigated whether the performance in an audio-visual redundant signal paradigm would be influenced by a temporal binding feature. In this paradigm, participants were simultaneously presented a random dot motion and a tone cloud. The random dot motion consisted of 150 white dots displayed on a dark background in a 5.0dva circular aperture, and randomly repositioned every 83ms. The tone cloud corresponded to a train of 5 simultaneous short pure tones (83ms) uniformly drawn from a range of 3 octaves (330 to 2640Hz) with a resolution of 12 semitones per octave. Participants were asked to detect rising or descending patterns appearing in the auditory or visual modalities (unisensory changes) or redundant changes in both modalities (bimodal changes). Critically, dots contrast and tone level were modulated by a temporal envelope that was irrelevant to the detection task. These envelopes could be identical or different between the two modalities, therefore allowing us to modulate the extent to which the unisensory cues reflected a common multisensory object. Compared to unisensory changes, bimodal changes elicited faster responses and violated the theoretical Miller's bound. Interestingly, response times for unisensory changes were more precise when the two modalities had the same temporal envelope, compared to different temporal envelopes. This suggests that, when auditory and visual modalities are temporally bound, a multisensory object is formed, and all features of this object are enhanced. Extracting the temporal coherence of the modalities might therefore help solving the correspondence problem and binding information across the senses.

23.303 **Time Dependence of Predictive and Postdictive Auditory-Visual Processing: The Temporally Extended Audiovisual Rabbit Illusion** Armand R. Tanguay, Jr.[1,2](atanguay@usc.edu), Noelle R. B. Stiles[2,3], Ishani Ganguly[2], Shinsuke Shimojo[2]; [1]University of Southern California, Departments of Electrical Engineering, Chemical Engineering and Materials Science, Biomedical Engineering, Ophthalmology, and Physics and Astronomy, and Neuroscience Graduate Program, [2]California Institute of Technology, Division of Biology and Biological Engineering, [3]University of Southern California, Department of Ophthalmology

Background: Postdiction occurs when a later stimulus influences the perception of an earlier stimulus. The Audiovisual Rabbit illusions (Stiles, 2018) demonstrate that postdictive processing bridges multiple senses. When a beep-flash, beep, beep-flash sequence was presented with the second flash displaced laterally, participants perceived three flashes (one illusory), with the illusory flash postdictively shifted toward the final flash. In this experiment, we extended the time between the second beep and the final beep-flash pair by either 100, 300, 500, 700, or 900 ms to determine the time dependence of postdiction (Experiment 1).Furthermore, we determined the predictive influence on flash location by extending the time between the first beep-flash pair and the second beep/third beep-flash pair by either 100, 300, 500, 700, or 900 ms (Experiment 2). Methods: The Audiovisual Rabbit illusion was tested with two flashes (17 ms each) presented at a 10º eccentricity (below fixation) with apparent left-to-right or right-to-left horizontal motion, randomly ordered.The first and second flashes were paired with 7 ms beeps, with an additional beep but no flash in between. Participants reported the number of flashes perceived and their locations. Results: Participants (N = 6) reported a decreasing shift of the illusory flash toward the first beep-flash pair (Experiment 1, Postdiction), and a decreasing shift of the illusory flash toward the final beep-flash pair (Experiment 2, Prediction) as the time delay increased.Both postdictive and predictive shifts were significant, and for some participants extended over the entire range of time delays tested. Postdiction significantly shifted the illusory flash toward the final flash for time delays up to at least 500 ms. Discussion: These experiments provide a comparison of the predictive and postdictive time dependencies and relative influences within the Audiovisual Rabbit Illusion, and therefore constrain the neural models that describe predictive and postdictive crossmodal behavior.

Acknowledgement: We are grateful for support from the National Institutes of Health, the Philanthropic Educational Organization Scholar Award Program, the Arnold O. Beckman Postdoctoral Scholars Fellowship Program, the National Science Foundation, and the Core Research for Evolutional Science and Technology Program of the Japan Science and Technology Agency.

23.304 **Vision in the extreme-periphery (2): Concurrent auditory stimuli degrade visual detection** Takashi Suegami[1,2](suegami@caltech.edu), Christopher C Berger[2], Daw-An Wu[2], Mark Changizi[3], Shinsuke Shimojo[2]; [1]Yamaha Motor Corporation U.S.A., [2]California Institute of Technology, [3]2 AI Lab

Although peripheral vision (20˚-40˚ eccentricity) has been characterized as categorically different from foveal vision in both spatial and temporal resolution, research on extreme-peripheral vision (> 40˚) has been neglected. Previous work investigating the cross-modal influence on visual perception suggests that concurrent auditory stimuli can facilitate visual detection in the fovea and periphery (e.g., Frassinetti et al., 2002). However, visual perception in the extreme periphery is highly ambiguous, and therefore likely to be the most susceptible to cross-modal modulation. Thus, we hypothesized that the brain compensates for visual ambiguity in the extreme periphery by utilizing inferences made from unambiguous cross-modal signals to either facilitate or inhibit visual perception (i.e., a 'compensation hypothesis'). To test this hypothesis, we conducted a psychophysics experiment that examined the effect of auditory stimuli on visual detection in the extreme-periphery. A white-dot (2˚ diameter) presented in either the left or right extreme-periphery (50ms) served as the target for the visual detection task (central fixation). The target location was set to each participant's detection threshold (50% accuracy; M = 96.4˚). Participants performed the visual detection task while one of four different types of auditory stimuli (white noise, brown noise, beep, or, no-sound control) was presented (50ms) concurrently from a speaker co-located with the target. The target location and type of auditory stimulus was fixed in each session (total = 8), and the order was counter-balanced across participants. Contrary to the facilitation-based compensation hypothesis, the results (n = 16) showed that visual detection (i.e., d') was best when no sound was presented, and significantly decreased when a beep-sound was presented (p = .034); a result likely driven by an increased false-alarm rate in the beep-sound condition (p = .053). These results suggest that simultaneous cross-modal stimuli may suppress, rather than facilitate, ambiguous visual input in the extreme-periphery.

Acknowledgement: Yamaha Motor Corporation U.S.A.

23.305 **Human sensory dominance is modulated by stimulus temporal uncertainty rather than by spatial uncertainty** Pi-Chun Huang[1](pichun_huang@mail.ncku.edu.tw), Yi-Chuan Chen[2]; [1]Department of Psychology, National Cheng Kung University, [2]Department of Medicine, Mackay Medical College

When it comes to detecting or identifying sensory signals, vision is typically the dominant modality over audition. One classic example is the Colavita visual dominant effect: The presentation of a beep sometimes goes undetected when it is paired with a flash, even though each stimulus is well detected when presented alone. Visual dominance effect is suggested to be attributed to the fact that the majority of the cerebral cortex is recruited for visual processing; nevertheless, attending to audition can help balance such a natural bias. Here we investigated whether visual dominance effect can be modulated by stimulus uncertainty in the temporal and spatial domain, respectively. In Experiment 1, a visual target (a 1-degree disc), an auditory target (a 1000-Hz pure tone burst), or a bimodal target (the combination of the above two) was presented with equal probability. Participants had to press a key when detecting the visual target, another key when detecting the auditory target, and both keys when detecting the bimodal target. The classic visual dominance effect was replicated so that the participants made visual-only responses more often than auditory-only responses on the bimodal trials. In Experiment 2, we enlarged the temporal uncertainty of targets by increasing the inter-stimulus interval (ISI) in 25% of the trials (mean ISI: 200 vs. 1700 ms). To increase spatial uncertainty in Experiment 3, the flash was presented either in the center or 4 degrees above or below the center in 25% of the trials. The visual dominance effect was eliminated when increasing temporal uncertainty, whereas it remained significant when increasing spatial uncertainty. We therefore demonstrate a novel factor that temporal uncertainty reduced the dominance of vision over audition, suggesting that people's sensory dominance is context dependent. Our result also implies a modality-appropriate view that visual dominance most likely occurs in a spatial-related task.

Acknowledgement: PCH is supported by Ministry of Science and Technology in Taiwan (MOST 104-2628-H-006 -001 -MY3).YCC is supported by Ministry of Science and Technology in Taiwan (MOST 107-2410-H-715 -001 -MY2).

23.306 **Time-resolved discrimination of audiovisual expressions of emotion in children with and without autism** Kirsty Ainsworth[1](kirsty.ainsworth@mcgill.ca), Federica Falagiarda[2], Olivier Collignon[2,3], Armando Bertone[1]; [1]Perceptual Neuroscience Laboratory for Autism and Development (PNLab), McGill University, Montréal, QC, Canada, [2]Institute of Research in Psychology (IPSY) & Institute of Neuroscience (IoNS), University of Louvain, Louvain, Belgium, [3]Centre for Mind/Brain Studies, University of Trento, Trento, Italy

Atypical sensory perception is now recognized as one of the key characteristics of autism (APA, 2013), with research suggesting that disrupted multisensory integration (MSI) may underlie the sensory behaviours seen in this population (Feldman et al., 2018). Further, the integration of social information (such as faces and facial expressions of emotion) has been shown to be particularly anomalous for individuals with autism (Charbonneau et al., 2013). A novel gating paradigm was used to assess the discrimination of emotion expressions (anger, fear, happiness and sadness) communicated by voices, faces or multisensory stimuli presented through 10 incremental gates of ~33ms (Falagiarda and Collignon, 2018). 32 children with autism (Mage 12.13 (3.45)) and 56 typical controls (Mage 11.91 (3.41)) responded to the stimuli via a 4-alternative forced choice paradigm. Thresholds were extracted from logistic psychometric curves. An ANOVA revealed a significant effect of modality (F = 79.34, p < 0.001) indicating that bimodal stimuli were easiest to detect, next visual, last auditory (all ps < 0.001; Bonferroni corrected). An overall effect of emotion was also observed (F = 5.27, p = 0.01) with fear being detected the fastest. The model also revealed a main effect of group (F = 5.92, p = 0.02) showing higher thresholds in children with autism. Our study is the first to define time-resolved discrimination of audiovisual expressions of emotion in children with and without autism. Results demonstrate that in children, faces elicit earlier detection of emotion compared to voices, while bimodal stimulation is superior to unimodal. Further, results indicate that children with autism need additional, accumulated sensory information for reliable emotion detection which is generalizable across senses and across emotions. The relationship between emotion discrimination performance and sensory-related behaviors at different periods of development will also be explored.

23.307 **Modality switch effects and the impact of predictability of the sensory environment.** Maria Bianca Amadeo[1,2](mariabianca.amadeo@iit.it), Michael C. Crosse [3,4], Monica Gori[1], Claudio Campus[1], John J. Foxe [3,4,5], Sophie Molholm [3,4]; [1]Unit for Visually Impaired People, Italian Institute of Technology, ITALY, [2]Department of Informatics, Bioengineering, Robotics and Systems Engineering, Università degli Studi di Genova, ITALY, [3]The Sheryl and Daniel R. Tishman Cognitive Neurophysiology Laboratory, Department of Pediatrics, Albert Einstein College of Medicine, Montefiore Medical Center, NY, [4]The Dominick P. Purpura Department of Neuroscience, Rose F. Kennedy Intellectual and Developmental Disabilities Research Center, Albert Einstein College of Medicine, Bronx, NY, [5]Department of Neuroscience, The Ernest J. Del Monte Institute for Neuroscience, University of Rochester School of Medicine and Dentistry

The modality switch effect (MSE) refers to the increase in reaction time that occurs when switching between different sensory modalities (Spence, Nicholls, & Driver, 2001). Our perceptual system is thought to continually make predictions about upcoming sensory information and this may contribute to our reluctance to switchmodality when the probability of a repeated stimulus is high. The MSE has traditionally been tested in the context of bimodal detection tasks. Here, we tested MSEs in a more complex, trimodal environment where the probability of a repeated stimulus is lower. We hypothesized two possible outcomes: 1) increasing the complexity by adding a third sensory modality could lead to greater MSEs or 2) MSEs could decrease due to the increased uncertainty that leads us to make fewer predictions. In 12 healthy adults, we measured RTs to bisensory (audio and/or visual) and trisensory (audio, visual and/or tactile) signals presented on the left index finger in random order. MSEs for the bisensory and the trisensory condition were calculated as the area between the cumulative distribution functions of the RT distributions for repeat (same modality) and switch (different modalities) trials. Comparing switch costs between the bisensory and the trisensory context, we found lower MSEs in the trisensory context for audio and visual stimuli, whereas the opposite pattern was seen for the audio-visual stimuli. Overall, results show that participants can more easily switch between modalities when the complexity of the sensory environment increases and a stimulus repetition becomes less likely. These findings suggest that expectancy-driven effects affect our sensory processing but the uncertainty of a complex environment likely forces us to make fewer predictions. We become less "sticky" to the previous sensory modality and engage in a more sensory-driven bottom-up mode of processing.

23.308 **Auditory information facilitates sensory evidence accumulation during visual object recognition** Jamal R Williams[1](jrw002@ucsd.edu), Viola S Störmer[1]; [1]Department of Psychology, University of California, San Diego

Research has shown that early visual processing is enhanced when preceded by spatially co-localized sounds (Störmer et al 2009). While this work has shown that visual perception for low-level stimuli (Gabor patches) is cross-modally influenced by equally low-level auditory stimuli (noise bursts), it is not known whether such cross-modal influences exist at higher processing stages. Here, we asked whether and how complex, real-world sounds facilitate visual processing of real-world objects. We designed a novel cross-modal paradigm that tracks the amount of sensory evidence needed to accurately detect real-world objects. We then compared object recognition performance when these visual objects were preceded by congruent or incongruent auditory information. Each trial started with the presentation of a 2-s sound (e.g., a train) which was immediately followed by the presentation of a continuous visual stimulus. This stimulus started out as an incoherent, grayscale noise patch that slowly and continuously decreased its noise level to eventually form a clearly visible object. On half of the trials the object was congruent (e.g., a train), and on the remaining trials it was incongruent (e.g., an elephant) with the sound. Participants were instructed to press a key as soon as they recognized the object, which also immediately ceased the stimulus presentation. Subsequently participants indicated which object they saw from two, within-category, highly similar objects positioned on either side of fixation. Participants (n=26) showed shorter reaction times

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when initially recognizing the object on congruent trials relative to incongruent trials (p=0.005). Overall, our results show that visual object recognition can be facilitated when preceded by congruent vs. incongruent auditory information. Broadly, this indicates that naturalistic sounds enhance the perceptual processing of visual objects.

23.309 **Visual-auditory crossmodal priming affects visual texture recognition** Kohta Wakamatsu[1](wakamatsu16@vpac.cs.tut.ac.jp), Michael J. Proulx[2], Shigeki Nakauchi[1]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, [2]Department of Psychology, University of Bath

We associate certain sounds with psychological concepts such as size and sharpness. This phenomenon is called sound symbolism. Some sound-symbolic words have universality regardless of different linguistic backgrounds, as shown in the Bouba-Kiki Effect (Ramachandran & Hubbard, 2001). Prior research has found crossmodal correspondences between sound and texture in Japanese (Hamano, 1998; Watanabe et al., 2011). However, these studies were based on subjective impressions. Here we investigated whether the texture-sound symbolic effect can be seen in objective indices such as response time, using a crossmodal priming paradigm. Moreover, we compared two groups who have a different first language (Japanese and English) to investigate whether the effect is universal between different languages. Participants were instructed to classify an image on a display as glossy vs. matte, hard vs. soft, or rough vs. smooth in three different blocks for each texture. They were also instructed to do the task as fast and accurate as possible, and to ignore the sound. We used images from our database which have been evaluated independently to have certain textures (glossiness, hardness, and roughness) and synthesized the sound of words that were used to express its texture impression in Japanese. Images and sounds were randomly paired and presented. Thus, each pair of the image and sound is one of the following: congruent (e.g., glossy image and glossy sound), incongruent (e.g., glossy image and matte sound), or neutral (e.g., glossy image and beep sound). The participant's response time in incongruent conditions was slowed compared to congruent conditions because of the crossmodal priming effect in both Japanese and English speakers. The effect agrees with the previous report (Wakamatsu et al., VSS 2017) in terms of a weaker effect on both non-Japanese speakers, and on glossiness. This result provides evidence for the universality of texture-sound symbolism between different linguistic backgrounds.

Acknowledgement: This work was supported by JSPS KAKENHI Grant Number JP15H05922 to SN, and a Bath International Research Funding Scheme award to MJP.

Faces: Disorders

Saturday, May 18, 8:30 am - 12:30 pm, Banyan Breezeway

23.310 **Development of facial expression recognition following extended blindness: The importance of motion** Sharon Gilad-Gutnick[1](sharongu@mit.edu), Grace Kurian[2], Priti Gupta[3], Kashish Tiwari[3], Pragya Shah[3], Sruti Raja[1], Shlomit Ben-Ami[1], Tapan Gandhi[4], Suma Ganesh[3], Pawan Sinha[1]; [1]Department of Brain and Cognitive Sciences Massachusetts Institute of Technology, [2]Faculty of Medicine, University of Geneva, GE, Switzerland, [3]Dr. Shroff's Charity Eye Hospital, [4]Department of Electrical Engineering, Indian Institute of Technology Delhi

Despite her still poor visual acuity and minimal visual experience, a 2-3 month old baby will reliably respond to facial expressions, smiling back at her caretaker or older sibling.But what if that same baby had been deprived of her early visual experience?We describe the development of facial expression recognition in a unique population: children who had been treated for bilateral congenital blindness several years after birth (ages 6-22 at treatment).We find that within the first few months after treatment, these children fail to demonstrate substantial improvements in a basic expression recognition task, but thereafter begin to show significant progress.Specifically, when we probe the children's ability to recognize expressions based on dynamic versus static information, we find that their performance on the dynamic task improves much quicker and surpasses their ability to recognize expressions from static images.Recognition of static facial expressions, on the other hand, continues to fall significantly short of control levels, even years after treatment.Our findings support the important role of motion for early visual learning and binding of visual features.Furthermore, our findings suggest that dynamic information continues to be important for learning and progressively improving the recognition of facial expressions even well after treatment, suggesting a prolonged and robust reliance on motion information late in the visual developmental trajectory.

Acknowledgement: NEI (NIH) grant R01 EY020517

23.311 **Effects of simulated visual impairment on orientation, shape, and emotion perception** Andrea Li[1](Andrea.Li@qc.cuny.edu), Byron Johnson[1], Carolyn Ortiz-Wood[1], Monika Devi[1], Chayala Friedman[1], Silvia Calderon[1], Khalid Barnes[1], Chananya Stern[1], Michael Martinez[1], Brianna Bisogno[1], Hafsah Khan[1], Nicole Cavallo[1]; [1]Psychology, Queens College CUNY

Visual impairment is reduced vision resulting from conditions that cannot be corrected by usual means like corrective lenses, and its prevalence is increasing as the lifespan of the population increases. We explore the effects of digitally simulated visual impairment on orientation, shape, and emotion perception in individuals with normal vision. Relative effects of blur and contrast reduction were examined by equating impairment levels via visual acuity; we determined levels of each impairment type needed to reduce visual acuity to 20/40 or 20/60 levels. These impairment levels were then applied to 1.5 and 4.5 cpd Gabor stimuli to measure effects on tilt thresholds, 3- and 4-lobed radial frequency (RF) patterns to measure effects on shape discrimination thresholds, and eyes extracted from emotional face stimuli to measure effects on emotion categorization. Both levels of contrast reduction increased tilt thresholds at both frequencies. 20/40 blur had no effect on tilt thresholds while 20/60 blur increased tilt thresholds only at 4.5 cpd. Similar results were obtained in the shape paradigm in which amplitude thresholds required to distinguish 3- and 4-lobed RF patterns were measured; contrast reduction and only 20/60 blur increased shape thresholds. Surprisingly, similar results were also obtained for an emotion categorization task. Subjects were asked to categorize the emotion expressed by eye images as happy, sad, angry, fearful, or surprised. Reduced contrast and 20/60 blur impaired performance. The only stimulus across all our experiments to be affected by 20/40 blur was the categorization of the happy expression. In conclusion, contrast reduction that is mild enough to earn a driver's license (20/40) can affect orientation, shape, and emotion perception. For the stimuli used, blur affects the perception of spatial forms and emotion via eyes only at moderate 20/60 levels, except for the categorization of happy which is also affected at mild levels.

Acknowledgement: Support for this project was provided by three PSC-CUNY Awards (68197-00 46, 69702-00 47, 61251-00 49 to A. Li), jointly funded by The Professional Staff Congress and The City University of New York

23.312 **Behavioural profiles and neural correlates of higher-level vision after posterior cerebral artery stroke** Grace E Rice[1](grace.rice@mrc-cbu.cam.ac.uk), Sheila J Kerry[2], Ro Julia Robotham[3], Alex P Leff[2], Matthew A Lambon Ralph[1], Randi Starrfelt[3]; [1]MRC Cognition and Brain Sciences Unit, University of Cambridge, UK, [2]Institute of Cognitive Neuroscience, University College London, UK, [3]Department of Psychology, University of Copenhagen, Denmark

The presence and degree of category-selective responses in the human brain remains a central research question in visual neuroscience. Evidence for category-selectivity in higher-level vision primarily stems from neuroimaging studies of healthy participants. Converging evidence also exists in patients after brain injury, however they often focus either on in-depth analysis of single case-studies or behavioural testing of one category, for example faces or words. Here we adopt a novel approach to studying higher-level vision after brain injury by exploring the largest sample of posterior cerebral artery stroke patients currently available (n = 64; 33 left hemisphere, 23 right hemisphere, 8 bilateral). Patients were tested using an in-depth behavioural battery encompassing both low-level visual tests (e.g., visual field, visual acuity, contrast sensitivity) and higher-level visual tests of word, object, and face processing. A data-driven approach (principal component analysis) was used to establish a pattern of co-occurrence within higher-level vision. The data revealed two principal components underlying patients' performance. The first component included tests with a verbal (written word) input. The second component included tests with a non-verbal (picture) input, including face and object processing. This behavioural model was mapped onto the patients' lesion profiles using voxel-based lesion symptom mapping. The two components had unique lesion correlates: The verbal input component with damage in the left inferior occipital and posterior temporal lobe, and the non-verbal input component with damage in the right occipital and medial temporal lobe. This approach to studying higher-level vision after brain injury using a data-driven approach suggests that patient's behavioural performance did not reflect strict category-selective responses.

23.313 **Face processing in patients with Parkinson's disease and dementia: examined with morphing face discrimination, dynamic emotion recognition, and expression imitation tasks**
Wen Reng Mary Ho[1](maryho1130@gmail.com), Sarina Hui-Lin Chien[1,2], Chon-Haw Tsai[3], Hsien-Yuan Lane[1]; [1]Graduate Institute of Biomedical Sciences, China Medical University, Taichung, Taiwan, [2]Graduate Institute of Neural & Cognitive Sciences, China Medical University, Taichung, Taiwan, [3]Department of Neurology, China Medical University Hospital, Taichung, Taiwan

Introduction: Parkinson's disease (PD) is a degenerative brain disease. As it progresses, the patients often develop dementia (PD-D) which affect their mental functions. Previous studies revealed PD patients with impaired facial identity recognition and emotion perception; however, few studies explored face discrimination and dynamic facial emotion perception in PD-D patients. Therefore, with three tasks, we examined the PD-D patients' face discrimination threshold, their capability to recognize the six-basic emotions in dynamic display, and their ability to imitate facial expressions. Method: We tested 25 PD-D patients (mean age: 74.72±6.05) and 21 healthy controls (mean age: 68.76±6.54) with three tasks: (1) Same/different morphing-face discrimination, where it involves comparing a target face and a comparison morphing face at 0% (same) or 20%, 40%, 60%, and 80% (different) sequentially; (2) Dynamic facial emotion task, in which participants were to identify the six basic emotions (anger, disgust, fear, happy, sad, and surprise); and (3) Expression imitation task, where they were asked to imitate the six basic expressions and coded by i-motion software. Results: (1) PD-D patients exhibited a similar discrimination threshold but have a shallower response function, indicating a high uncertainty in discriminating faces than healthy controls. (2) The patients performed worse in recognizing anger, disgust, sad, and surprise, and had a longer response time as compared to the controls. (3) The patients had a significantly lower probability when imitating "Happiness" and "Surprise"; additionally, their "Engagement" in facial muscle activation was also lower. Conclusion: Our findings suggested that PD-D patients suffer greater internal noises when discriminating faces. They are impaired in recognizing negative emotions but can imitate some emotions with less intensity. Although PD-D patients performed significantly worse in all three tasks, they retain face processing capacity at some level. Thus, the face perception neural network in PD-D patients seems partially intact.

Acknowledgement: MOST 105-2420-H-039-001-MY3, to Dr. Chien and MOST 107-2632-B-039-001-to Dr. Chien, Dr. Lane, and Dr. Tsai

23.314 **Impairment in facial expression perception but normal biological motion perception in a patient with a lesion to right posterior STS**
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Humans often perceive body and facial expression cues simultaneously, but it is unclear whether these perceptual processes rely on joint or separate neural mechanisms. Support for joint mechanisms comes from recent studies showing that brain regions in the pSTS processing facial dynamics adjoin or somewhat overlap those processing human biological motion. On the other hand, support for disjoint mechanisms comes from LG, a developmental visual agnosic individual with normal biological motion perception but impaired perception of dynamic face expressions. To gain further insights about these mechanisms, here we investigated Faith, a 55-year-old woman with acquired prosopagnosia. Faith reports problems deciphering facial expressions but not body language. We tested her ability to perceive facial expressions from dynamic subtle or intense cues, and her biological motion perceptual thresholds from point light displays. In line with Faith's subjective reports, we first found that her biological motion perceptual thresholds and her reaction times were in the normal range compared to age and gender-matched neurotypical controls (n=17) or to other control groups (n=13, n=18, n=18). Second, we found that her perception of subtle dynamic facial expressions was significantly impaired. We also delineated Faith's lesion (extending into her right temporal and ventral cortex), and compared it to the expected locations of pSTS regions sensitive to facial expressions and to biological motion. While brain lesions do not often follow regional borders, Faith's dissociation provides further evidence that the perception of dynamic body cues and the perception of dynamic facial cues depend on different processing routes.

Acknowledgement: This research was supported by the Israel Science Foundation (grant No. 4115841) to SGD, by the NSF Graduate Research Fellowship to SBH, and by the NSF grant 1634098 to BD.

23.315 **Evidence for separate processing of facial identity and expression information in an acquired prosopagnosic**
Marie-Luise Kieseler[1](kieseler.gr@dartmouth.edu), Sarah B Herald[1], Guo Jiahui[1], Bradley C Duchaine[1]; [1]Dartmouth College

In the two most well-known models of face processing (Bruce & Young, 1986; Haxby et al., 2000), facial identity and facial expression are processed separately, and the Haxby model further proposes that identity computations are performed in a ventral pathway that includes FFA while expression is represented in a dorsal pathway that includes pSTS-FA. However, in an influential review, Calder and Young (2005) proposed identity and expression processing within the visual system depend on the same processes, and no brain-damaged patients have shown unequivocal visual dissociations between identity and expression recognition. Here, we present findings from a 53-year-old right-handed woman we'll refer to as Alma-Jean who, following encephalitis that lesioned her right temporal lobe, experiences severe difficulties with facial identity recognition but no loss of expression recognition. A dynamic localizer revealed intact face-selective areas in Alma-Jean's left hemisphere. In the right hemisphere, OFA and pSTS-FA were spared but FFA and aSTS-FA were absent and within the lesioned area. Across seven tests of facial identity, Alma-Jean showed clear impairments. In contrast, she scored normally (z scores ranging from -1.0 to 0.5) on five tests of expression recognition. Alma-Jean's normal expression scores appear to depend on typical processes, because like controls, she showed much better performance with upright faces than inverted faces. To confirm that her identity recognition deficits are due to visual problems rather than higher-level deficits, we showed that she performs normally on voice identity tests. In summary, Alma-Jean's results provide the first evidence from a thoroughly tested brain-damaged case for a visual dissociation between facial identity and facial expression, and Alma-Jean's results are consistent with the Haxby model's ventral/dorsal distinction for identity and expression processing.

Acknowledgement: NFS Grant Award Number: 1634098, Project Title:Testing and building models of face perception via acquired prosopagnosia

23.316 **Congenital Prosopagnosics Show Reduced Configural Effects in an Odd-Man-Out Detection Task**
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One potential explanation for the deficit in holistic processing exhibited by congenital prosopagnosics (CPs) is that CPs have smaller receptive fields (r.f.s) in face selective regions (Witthoft et al., 2016). Large, overlapping receptive fields allow small differences in similar faces to affect the activation of cells whose r.f.s are distributed throughout the face. Xu et al. (2014) demonstrated that the face configural effect, described as the benefit in accuracy in identifying a studied individual's eyes, nose, or mouth in the context of the individual's face as compared to when presented in isolation, could be attributed to large r.f.s. While effective in measuring the configural effect in control subjects, their memory-based paradigm was ill-suited to measure the configural effect in individuals who struggle with learning faces. The present study used an odd-man-out paradigm in which 216 subjects had to detect which one of a diagonal array of three faces was different. Each image included a pair of eyes, a nose, and a mouth, either arranged from top to bottom or in the reverse order and either viewed in the context of a head or in isolation (Fig. 1). Subjects who failed to demonstrate normal proficiency on standard tests of face recognition (USCFPT, CFMT, PI20) (Fig. 2) showed significantly reduced benefits on their detection RTs from the presence of a head and the natural ordering of the face parts (Fig. 2) indicating their failure to benefit from a configural representation

Acknowledgement: Harold W. Dornsife Research Fund

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23.317 **Differences in representational geometries of prosopagnosics and neurotypical controls**

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In the human visual system, broad categories of visual stimuli form a representational space remarkably consistent across people. Previous research studied the relationship between these neutrally and behaviorally derived representational spaces – "representational similarity matrices" (RSMs) – and suggested methods for analyzing these similarity structures. The current study explores similarity of RSMs between two developmental prosopagnosics and a group of neurotypical controls. Participants (Ncontrols = 78, Mage = 22.41, SDage = 3.65, range = 18-35; Nprosopagnosic = 2, ages: 52, 51) completed two types of visual search task. In the between-category trials, they searched for an object from a particular category presented amongst objects from a different category (e.g. search for a body surrounded by chairs as distractors). In within-category trials, they searched for a particular exemplar of one category amongst other exemplars of the same category (e.g. search for face A surrounded by distractors of face B). Representational similarity matrices were then constructed based on pairwise similarities inferred from reaction times on each task (such that shorter RTs implied that categories are more similar as they are less confusable). Prosopagnosics' accuracy did not differ from the control group on any task. Crucial differences emerged in comparing the organization of RSMs. For one prosopagnosic, the within-category RSM was significantly different from that of an average control participant, but only for faces. The other prosopagnosic participant showed an RSM similar to the average control participant on all tasks. This finding suggests that the face recognition impairment in some prosopagnosics might stem from a differently organized feature space for faces, but not for other categories of visual stimuli. We discuss potential clusters of prosopagnosic population characterized by different strategies (e.g., compensatory mechanisms more closely aligned to holistic face processing) or neural activation patterns and explore further ideas for representational similarity analysis research.

Acknowledgement: This research was jointly funded by the Herchel Smith Harvard Undergraduate Science Research Program and the National Science Foundation Career Fund.

23.318 **Facial gender discrimination in developmental prosopagnosia**

Katie L.H. Gray[1](k.l.h.gray@reading.ac.uk), Jade E. Marsh[1], Richard Cook[2]; [1]School of Psychology and Clinical Language Science, University of Reading, [2]Department of Psychological Sciences, Birkbeck, University of London

Developmental prosopagnosia (DP) is a neurodevelopmental condition associated with difficulties recognising familiar faces and distinguishing unfamiliar faces. However, the extent to which DP is associated with deficits in processing other facial attributes, such as emotion and gender, is still debated. Recent evidence suggests that when sensitive tasks are used (e.g. where participants are not at ceiling performance), DPs have difficulties recognising emotional expressions relative to controls. The extent to which DPs also have difficulty extracting facial gender is unclear, as findings to date have been mixed. We tested 12 DPs on two sensitive gender categorisation tasks and compared results to that of age- and gender-matched controls. In the first task, trials presented faces drawn from a morph continua that blended an average male face with an average female face. Observers were required to make a binary 'male'/'female' judgement on each trial; psychometric functions were modelled using cumulative Gaussians. Results showed that judgement precision, inferred from the slope of each function, was significantly lower in the DP than the control group. In the second task, trials presented stimuli that blended female or male facial identities with a gender-neutral average face. Observers categorised each stimulus as either 'female' or 'male', and we measured their sensitivity (d´). Task difficulty was manipulated by varying the strength of each facial identity, relative to the weighting of the gender-neutral average face (20-80%, 30-70%, 40-60%, or 50-50%). As expected, categorisation accuracy varied as a function of the strength of the gender signal. However, DPs were significantly less sensitive at all morph-levels than controls. The results from these two studies confirm that, in many cases, visual processing difficulties seen in DP extend beyond the extraction of facial identity. Evidence of gender processing deficits accords with an apperceptive characterisation of DP.

23.319 **The prevalence and nature of face perception impairments in developmental prosopagnosia**

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Researchers have suggested that perceptual impairments are a fundamental aspect of developmental prosopagnosia (DP). However, on any particular test, studies have shown that DP group-level face perception performance is within the normal range with considerable between-DP heterogeneity.This heterogeneity may be due to different types of perceptual deficits or rather different strategies that DPs employ. Comparing DP and control performance across a variety of perceptual tests could help us better understand the prevalence of perceptual deficits in DPs. Using a battery of five face matching/discrimination tasks, we sought to compare the prevalence of perceptual dysfunction ($z < -.98$)/perceptual deficits ($z < -1.96$) in a group of 20+ DPs and matched/simulated controls. Participants were asked to match/discriminate real faces (Computerized Benton Facial Recognition Test and two 2AFC face matching tasks with lighting and viewpoint changes) and face morphs (Cambridge Face Perception Test, USC Face Perception Test). We found that 50% of DPs demonstrated a perceptual deficit ($z < -1.96$) on at least one test and 22% on two tests, whereas 8% and 2% of the control group demonstrated deficits on one and two tests, respectively. For perceptual dysfunction ($z < -.98$), we found that 95% of DPs showed dysfunction on at least one test and 67% on two tests, whereas 40% and 21% of the control group exhibited dysfunction on one and two tests, respectively. Interestingly, we found that DPs demonstrated significantly more intra-individual variability across perceptual tasks than controls, even for the DPs without perceptual deficits. Further, there was a consistently lower correlation between perceptual tasks in DPs (range: .0-.4) than controls (range: .4-.6), suggesting greater inter-individual variability in DPs. In sum, these results suggest that approximately 50% of DPs have impaired face perception and perceptual intra- as well as inter-individual variability may be a defining characteristic of DP.

Acknowledgement: National Eye Institute

23.320 **The temporal limits of the face inversion effect in developmental prosopagnosia**

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The face inversion effect (FIE) is considered a key marker of holistic face processing; participants are slower and less accurate when judging the identity of inverted compared to upright faces. While this effect is robust in neurotypical adults, the FIE in developmental prosopagnosia (DP) – a neurodevelopmental condition associated with difficulties recognising familiar and distinguishing unfamiliar faces – has not been consistently replicated. In DP, the absence of a disproportionate impairment when perceiving inverted faces has been attributed to an impairment of holistic processing. However, this effect could likewise be attributed to the difficulty of matching tasks previously used; if the accuracy of upright identity judgements are close to chance in DP, inversion will cause a smaller drop in performance relative to controls. Here, we compared the FIE in 12 DPs and 12 age- and gender-matched controls using sensitive time-accuracy function analysis. On each trial, participants viewed a single face presented for one of ten durations (1, 2, 3, 4, 6, 8, 10, 14, 18, 24 frames), and participants were asked to make a binary gender ('male'/'female') judgement. The point at which each observers' performance reached asymptote (i.e. where performance stopped improving as a function of increased stimulus presentation time) was modelled. As expected, we found a significant effect of orientation on asymptote level, with performance for upright faces reaching a higher asymptote level than inverted faces. Importantly, this FIE was found in both the control and the DP group, despite the DP group achieving significantly lower asymptotes than the controls overall. These results suggest that, when a sensitive task is used, it is possible to observe the FIE in DP. The results also challenge the view that face processing impairments seen in DP can be explained by deficits in holistic processing.

23.321 **Developmental prosopagnosics have impaired recollection but intact aspects of familiarity during recognition of newly-learned faces** Anna D Stumps[1,2](anna.stumps@gmail.com), Elyana Saad[1,2], EunMyoung Lee[1,2], Joseph Arizpe[1,2], Joseph DeGutis[1,2]; [1]Boston Attention and Learning Laboratory, VA Boston Healthcare System, [2]Department of Psychiatry, Harvard Medical School

Despite developmental prosopagnosia (DP) being a deficit in face recognition memory, researchers have yet to characterize impairments in specific memory mechanisms. DPs have demonstrated deficits in explicitly recognizing faces, but at times have shown preserved implicit recognition such as increased electrodermal activity or the presence of an N250 ERP component when presented with famous faces. We sought to build on these findings and test the integrity of two facets of face recognition memory: recollection (retrieving specific details associated with the face) and familiarity (general feeling you've seen the face before).In particular, we had 13 DPs/13 matched controls perform an old-new face recognition memory paradigm where they studied 60 novel faces presented for two-seconds each over two rounds. After the study phase, subjects were immediately presented with 120 faces (60 old/60 new) and asked to indicate on a scale of 1-6 their level of confidence in classifying each face as "old" or "new" (confident old, somewhat sure old, guessing old, guessing new, somewhat sure new, confident new). By employing the dual-process signal detection model from Koen et al. 2014's receiver operating characteristics toolbox, we were able to determine the contribution of familiarity and recollection to recognition memory performance. In this model, recognition memory is theorized to initially rely on recollection in which qualitative information is retrieved about the studied items, but if recollection fails, recognition memory relies on a "feeling" of familiarity. We found that the recollection parameter was significantly smaller in DPs (0.14+/-0.11) than controls (0.45+/-0.21, p< 0.001) whereas DPs' familiarity parameter (0.62+/-0.34) was similar to controls (0.54+/-0.61, p=0.678). These results show that at least some aspects of face recognition familiarity are intact in DPs and we are currently performing a follow-up experiment to determine if the source of this familiarity signal is similar to controls.

Acknowledgement: National Eye Institute

23.322 **Prosopagnosia without object agnosia? A systematic study of a large sample of developmental cases** Tirta Susilo[1](tirta.susilo@vuw.ac.nz), Hazel K Godfrey[1]; [1]School of Psychology, Victoria University of Wellington

Can prosopagnosia exist without object agnosia? A recent review concludes that most developmental prosopagnosics (DPs) have trouble with object recognition (Geskin & Behrmann, 2018), but a closer look at the surveyed cases highlights the need for new studies with large samples, rigorous measures, and robust statistics (various responses to Geskin & Behrmann, 2018). Here we report a systematic study of face and object recognition with 93 DPs and 100 age/sex-matched controls. DPs were selected based on impaired scores on Cambridge Face Memory Test (CFMT), a famous face test, and self-report prosopagnosia index (PI-20), plus a normal score on Leuven-Perceptual Organization Screening Test (L-POST) and a lack of history of brain damage. Controls are MTurk participants who scored in the normal range of CFMT. DPs and controls completed object recognition measures for five categories (bodies, bicycles, cars, hairs, houses), each tested using the rigorous and well-validated format of Cambridge Memory Test. DPs and controls also completed a second CFMT to avoid double-dipping CFMT scores used for participant screening. As a group, DPs are most impaired with faces and to a lesser extent with cars, but they show normal recognition of the remaining categories. However, single-case analyses reveal that individual DPs who show impaired face recognition but normal object recognition under the stringent statistics of "classical dissociation" are in the minority: 5-10% DPs are normal with all five object categories, 10-15% with four or more, and 15-20% with three or more. These estimates suggest that prosopagnosia can exist without object agnosia, but firm dissociations between face and object recognition across multiple categories are only present in some DPs.

Acknowledgement: Royal Society of New Zealand Marsden Fund 16-VUW-175

23.323 **Is Grapheme Colour Synesthesia linked to Prosopagnosia?** Thea K Ulimoen[1], Thomas Alrik Sørensen[1]; [1]Aalborg University

Grapheme colour synaesthesia is a heterogeneous phenomenon in a small subset of otherwise neurotypical individuals for whom experience of a grapheme automatically and involuntarily elicits an experience of colour. One theory describing why people develop synaesthesia states that it occurs in response to challenging learning tasks (Watson et al 2014). That is, the main purpose of synaesthesia is to act as an aid to perceptual and conceptual understanding of complex categorical learning challenges. Considering the wide range of complex categorical information we need to process and organise, both sensory and cognitively, it may be the case that atypical categorisation techniques adopted by synesthetes are not limited to the inducer stimulus, but apply to a wider range of categorised items. Based on this theoretical proposal, in conjunction with anecdotal reports from synesthetes detailing problems with face recognition, we explored the possibility that difficulties in face recognition may be a characteristic of grapheme-colour synesthesia. Synesthetes were recruited together with age-and-gender matched controls. All observers completed a battery consisting of the Cambridge Face Memory Test (Duchaine & Nakayama, 2006) a test of face recognition, the Vanderbilt Holistic Face Processing Test (Richler, Floyd & Gauthier, 2014) a test of holistic face processing, as well as the Faces and Emotion Questionnaire (Freeman, Palermo, & Brock, 2015). The results seem to indicate that observers with grapheme colour synaesthesia do in fact have an abnormal processing of face information, which gains further support from previous findings where Sørensen (2013) used the Cambridge Face Perception Test (Duchaine, Germine, & Nakayama, 2007) to explore a similar question.

23.324 **The neural basis underlying impaired recognition of angry expression in ADHD children measured by near-infrared spectroscopy** Megumi Kobayashi[1], Masako Nagashima[2], Tatsuya Tokuda[3], Takahiro Ikeda[2], Yukifumi Monden[2,4], So Kanazawa[5], Masami K Yamaguchi[6], Ryoichi Sakuta[7], Takanori Yamagata[2], Ippeita Dan[3]; [1]Institute for Developmental Research, Aichi Human Service Center, [2]Department of Pediatrics, Jichi Medical University, [3]Applied Cognitive Neuroscience Laboratory, Chuo University, [4]Department of Pediatrics, International University of Health and Welfare, [5]Department of Psychology, Japan Women's University, [6]Department of Psychology, Chuo University, [7]Child Development and Psychosomatic Medicine Center, Dokkyo Medical University Saitama Medical Center

Children with ADHD have impairment in recognition of angry expression, although they recognizes happy expressions accurately (e.g., Pelc et al., 2006). Also, atypical pattern of brain activity to facial expressions have been reported in ADHD. ADHD children showed brain activation for happy expression but not for angry expression, whereas typical developing children showed brain activity for both expressions (Ichikawa et al., 2014). However, little is known about neural basis of impaired recognition of facial expressions in ADHD. Therefore, we further explored processing of facial expressions in ADHD children using near-infrared spectroscopy. We compared hemodynamic responses in ADHD children when observing happy and angry expressions before and after methylphenidate (MPH) administration. MPH increases synaptic transmission by inhibiting reuptake of dopamine, and consequently improves not only cerebral processing but also cognitive performance (e.g., Monden et al., 2012). Considering that MPH administration improved recognition of angry expression (Williams et al., 2008), we predicted that activation in brain areas involved in recognition of angry expressions increased after MPH administration. As a result, we found that compared to baseline, right inferior temporal cortex (IT) showed increased brain activity to angry expression after MPH administration but not before MPH administration, whereas showed brain activation to happy expression regardless of MPH administration. The left IT showed no significant activation to angry expression before and after MPH administration. However, we found significant difference in brain activity to angry expression between before and after MPH administration. In sum, we revealed increased hemodynamic responses in right IT to angry expression after MPH administration, suggesting that this region is involved in impaired recognition of angry expressions in ADHD children. Additionally, our finding that left IT showed significant difference in hemodynamic responses to angry expressions between before and after MPH administration implies that an alternative processing of angry expression may be driven.

Acknowledgement: This work was supported in part by JST-RISTEX to ID, and Grant-in-Aid for Scientific Research on Innovative Areas No. 17H06343

23.325 **Red background facilitates low spatial frequency fearful face processing in groups with high autistic tendency** Eveline Mu[1](emu@swin.edu.au), Laila Hugrass[2], David P Crewther[1]; [1]Centre for Human Psychopharmacology, Swinburne University of Technology, [2]School of Psychology and Public Health, La Trobe University

Wiesel and Hubel (1966) showed that diffuse red light suppresses firing rates of Type IV magnocellular (MC) cells, prompting human behavioural studies to use spatial frequency filtering and red backgrounds to intuit MC

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contributions to face processing, reporting a reduction in MC efficiency with red backgrounds. However, no human electrophysiological study, to date, has investigated whether red backgrounds influence the rapid effects of fearful expressions on visual evoked potentials (VEPs). Here we measured performance accuracy and early event-related potentials (P100 and N170) in response to low- and high- spatial frequency fearful and neutral faces, which were presented on red and green backgrounds of the same luminance. Examining the effects of red surrounds on Type IV MC cells may also provide insight into the commonly reported MC abnormality in groups with higher autistic traits. Thus, responses were compared for groups of neurotypical adults with low (n=21, AQ mean = 8.6±2.7) and high (n=22, AQ mean = 29±7.4) scores on the Autistic Spectrum Quotient (AQ). Unexpectedly (Awasthi et al., 2016), there were no substantial effects of background colour on emotion identification accuracy for either AQ group (p=0.35). This finding may be explained by the long presentation duration (500ms) allowing for conscious percept and MC recovery. Our VEP data showed that fearful expressions produced greater P100 amplitude when presented on a green background (p=0.04), but not when presented on a red background (p=0.70). Interestingly, however, red surrounds increased the P100 amplitude for low spatial frequency fearful stimuli for the high AQ group (p=0.04). Our findings suggest that suppressing the Type IV MC cells facilitates rapid VEP responses to fearful emotion for groups with MC abnormalities such as high AQ, yet it has the opposite effort for those with low AQ.

23.326 **Slow segmentation of faces in Autism Spectrum Disorder** Carlijn van den Boomen[1,2](c.vandenboomen@uu.nl), Johannes J Fahrenfort[3], Tineke M Snijders[4,5], Chantal Kemner[1,2,6]; [1]Experimental Psychology, Helmholtz Institute, 3584 CS Utrecht, The Netherlands, [2]Developmental Psychology, Utrecht University, The Netherlands, [3]Department of Experimental and Applied Psychology, Vrije Universiteit Amsterdam, The Netherlands, [4]Max Planck Institute for Psycholinguistics, The Netherlands, [5]Donders Institute for Brain, Cognition, and Behaviour Donders Centre for Cognitive Neuroimaging, Radboud University, The Netherlands, [6]Dept. of Child and Adolescent Psychiatry, Rudolf Magnus Institute of Neuroscience, University Medical Center, The Netherlands

Atypical visual segmentation, affecting object perception, might contribute to face processing problems in Autism Spectrum Disorder (ASD). The current study investigated impairments in visual segmentation of faces in ASD. Thirty participants (ASD: 16; Control: 14) viewed texture-defined faces, houses, and homogeneous images, while electroencephalographic and behavioral responses were recorded. The ASD group showed slower face-segmentation related brain activity and longer segmentation reaction times than the control group, but no difference in house-segmentation related activity or behavioral performance. Furthermore, individual differences in face-segmentation but not house-segmentation correlated with score on the Autism Quotient. Segmentation is thus selectively impaired for faces in ASD, and relates to the degree of ASD traits. Face segmentation relates to recurrent connectivity from the fusiform face area (FFA) to the visual cortex. These findings thus suggest that atypical connectivity from the FFA might contribute to delayed face processing in ASD.

Acknowledgement: This work was supported by a Netherlands Organization for Scientific Research (NWO) VICI grant (45307004) and the Consortium on Individual Development (CID). CID is funded through the Gravitation program of the Dutch Ministry of Education, Culture, and Science and the NWO (grant number 024.001.003).

23.327 **Fast periodic visual stimulation EEG reveals reduced social bias in autism** Sofie Vettori[1,3](Sofie.vettori@kuleuven.be), Milena Dzhelyova[2,3], Stephanie Van der Donck[1,3], Corentin Jacques[2], Jean Steyaert[1,3], Bruno Rossion[2,4,5], Bart Boets[1,3]; [1]Center for Developmental Psychiatry, Department of Neurosciences, KU Leuven, Belgium, [2]Institute of Research in Psychological Science, Institute of Neuroscience, University of Louvain, Belgium, [3]Leuven Autism Research (LAuRes), KU Leuven, Leuven, Belgium, [4]Université de Lorraine, CNRS, CRAN - UMR 7039, F-54000 Nancy, France, [5]Université de Lorraine, CHRU-Nancy, Service de Neurologie, F-54000, France

Developmental accounts of autism spectrum disorder (ASD) state that infants and children with ASD are less attracted by and less proficient in processing social stimuli, such as faces. While reduced viewing preferences for social stimuli have indeed been demonstrated in ASD, it is unclear how this reduced social bias is manifested at the neural level. Social cues may be neglected in ASD because they are represented less saliently, or they may actively be avoided because they are experienced too intensively. To address this issue, we used EEG recording during fast periodic visual stimulation (FPVS) in combination with eye tracking. We tested 21 boys with ASD (8-12 years old) and 21 typically developing (TD) control boys, matched for age and IQ. In a first experiment, streams of images of faces were presented at 6 Hz alongside images of houses presented at 7.5 Hz or vice versa. Eye-tracking data showed that TD children looked significantly longer to faces than to houses, while this social viewing preference was not present in the ASD group. Likewise, EEG data revealed that the relative neural response to faces versus houses was significantly larger in the TD group as in the ASD group, especially along lateral occipito-temporal areas. The strong correlation (r=0.74) between the social bias (i.e. response to faces minus response to houses) measured by eye-tracking and by EEG suggests a close link between viewing preferences and neural responses. The neural observations were closely replicated in a second experiment where we superimposed the two streams of stimulation, thereby controlling for possible effects of spatial attention and disengagement. Accordingly, in both experiments, the data shows that preference for social visual information, i.e. faces, is lower in children with ASD.

Acknowledgement: Research Foundation Flanders (FWO), Marguerite-Marie Delacroix foundation

23.328 **Trait anxiety is associated with an enhanced perceptual sensitivity for negative facial expressions.** Li-Chuan Hsu[1,2](lichuanhsu2001@gmail.com), Yi-Min Tien[3], Chia-Yao Lin[1,2], Ya-Ting Wu[4]; [1]School of Medicine, China Medical University, Taichung, Taiwan, [2]Graduate Institute of Biomedical Sciences, Taichung, Taiwan, [3]Department of Psychology, Chung Shan Medical University, Taichung, Taiwan, [4]College of Public Health, China Medical University, Taichung, Taiwan

People with high trait anxiety demonstrate deteriorated performance in cognitive tests and an attentional bias toward threating stimulus. In addition, the sensitivity of recognizing fearful faces is higher for individuals with high than those with low trait anxiety. The goal of the present study was to examine whether individuals with high trait anxiety would also displayed a higher sensitivity in perceiving other types of facial expressions. The participants' trait anxiety was assessed using The State-Trait Anxiety Inventory- Trait Scale (N = 100). In Experiment 1, the emotional intensity of four facial expressions (happiness, fear, sadness, anger) was manipulated. The participants had to detect any emotionality of the presented faces. In Experiment 2, by blending two facial expressions with reciprocal proportions using FaceGen Modeller software, three sets of morphing were created: the happy face gradually morphs into one of the negative faces (fear, sadness, or anger), such as a face consisting of 20% happy and 80% fearful expressions. The participants had to discriminate the facial expression as positive or negative. In both experiments, the group with high trait anxiety demonstrated significantly higher sensitivity to facial expressions of sad, angry and fearful faces compared to the group with low trait anxiety. Our results therefore suggest that an individual' s trait anxiety biases his/her perception of a facial expression appearing to be a negative one in a top-down fashion.

Acknowledgement: MOST 106-2629-H-040-001 107-2410-H-039-002

23.329 **The role of attachment style in the holistic perception of expression** Elizabeth C Gregory[1](lizcgregory97@gmail.com), Xiaoyi Liu[1], James W Tanaka[1]; [1]Department of Psychology, University of Victoria, BC

Attachment style theory posits that the quality of early child-caregiver relationships will shape an individual's feelings and behaviors in adult relationships. In face recognition, individuals who are rated as highly anxious in their attachment style are faster and more accurate in their judgments of facial expression than non-anxious individuals. In this study, we investigated the timing of processes that link expression recognition and attachment style. We hypothesized that highly anxious people perceive expressions more holistically than non-anxious people. To test the relationship between the holistic expression recognition and attachment style, we created expression composites by joining the top and bottom halves of happy and angry expressions that formed either congruent (e.g., angry top + angry bottom) or incongruent (e.g., angry top + happy bottom) expressions. Neutral face composites (e.g., angry top + neutral bottom) and isolated halves (e.g., angry top only) were used as baseline comparisons.In this experiment, participants (n = 36) were asked to report the expression in the cued top (or bottom) half of the face as "happy" or "angry".Faces were randomly presented at stimulus onset asynchronies (SOA's) of 17, 50, or 250 ms and then masked. After the expression task, participants completed the Revised Adult Attachment Style

Questionnaire (RAAS). Our main results showed that participants performed significantly better in the congruent condition and significantly worse in the incongruent condition relative to the neutral and isolated conditions. The congruency effect was evident even at the shortest SOA indicating that expressions were perceived holistically after an exposure duration as brief as 17 ms. Reaction time analysis showed that the magnitude of the holistic effect increases with a higher anxious attachment style score. Together these results suggest that: 1) holistic perception of expression occurs rapidly and 2) the expression advantage of anxiously attached individuals might be mediated by holistic mechanisms.

Acknowledgement: Natural Sciences and Engineering Research Council

Perceptual Learning: Models, applications

Saturday, May 18, 8:30 am - 12:30 pm, Banyan Breezeway

23.330 **Transfer of Expertise in Deep Neural Networks** Sumit Binnani[1](sumit.binnani@gmail.com), Tejash Desai[1], Garrison Cottrell[1]; [1]Computer Science and Engineering, University of California, San Diego

Based on expertise and innate ability, subjects may differ greatly in visual performance. Experts and novices, when presented with the same visual stimuli, organize and process them differently. Here we define experts as systems that categorize stimuli at a subordinate level, and novices as systems that categorize the same stimuli at a coarser grain. We model both expert and novice as deep convolutional neural networks. After the model is trained, we highlighted the regions in the images relevant for predicting the target. These attention maps for the target classes were obtained by using the gradients of target flowing into the final convolutional layer to produce a coarse localization map. We later trained a new novice model by adding attention map obtained from the expert to the input image of the new novice model. We report two main results: (1) The attention map used by the expert network has higher entropy, and smaller, local features than the novice networks (suggesting that the expert looks at multiple locations to make a classification decision); and 2) the attention map used by the expert can be used to train the novice, resulting in faster training and better performance. We consider this to be analogous to the expert telling the novice where to look for discriminative regions of the image.

23.331 **Leveling the Field: Comparing the Visual Perception of Stability across Humans and Machines** Colin Conwell[1](conwell@g.harvard.edu), George A Alvarez[1]; [1]Harvard University, Department of Psychology

Is there a physicist in your visual cortex? Popular models of intuitive physics—our implicit understanding of physical contingencies in complex environments—posit the process of physical inference to be a richly structured simulation: a predominately cognitive process. In this study, we probe the possibility that at least certain aspects of our intuitive physics may be handled directly by computations in perceptual systems. Assuming deep neural networks to be a reasonable model of inferotemporal visual cortex, we employ a method of comparative psychophysics designed to gauge the similarity of human and machine judgments in a standard intuitive physics task: predicting the stability of randomly arranged block towers. We show that a convolutional neural network with comparable performance to human observers nonetheless differs in the variables that predict the specific choices it makes, variables we compute directly from the stimuli. Using these 'features' as the basis for an ideal observer analysis, we show that human behavior is best predicted by a feature that corresponds directly to the groundtruth stability of the tower, while the machine's behavior is predicted by a less optimal feature. Training smaller, feedforward networks, we subsequently confirm that this divergence from human behavior is not the failure of any specific computation (e.g. an operation the network simply cannot perform), but of different feature biases. Simultaneously, we demonstrate that humans under time pressure tend to behave more like the neural network, their responses predicted by features that correlate less overall with the groundtruth stability of the tower. Taken together, these results suggest that at least some portion of the information processing involved in intuitive physics may be handled by the more feedforward elements of the visual system, but that further algorithmic, architectural or training modulations might be necessary to better model the perceptual processing of physical information more generally.

23.332 **Evolution of decision weights and eye movements through learning in visual search** Ilmari Kurki[1](ilmari.kurki@helsinki.fi), Miguel P Eckstein[2]; [1]Department of Psychology and Logopedics, Faculty of Medicine, University of Helsinki, [2]Department of Psychological and Brain Sciences, University of California Santa Barbara

An important component of perceptual learning in complex visual environments is the dynamic optimization of eye movements to maximize the acquisition of visual information. Here, we investigate how the temporal evolution of eye movements and perceptual decision weights results in performance improvements. We used a new classification image - based method to estimate and visualize how observers dynamically vary the parts of the search stimulus used for perceptual decisions on each trial and compare it to eye movements across trials. Further, a Bayesian model observer that predicts the next saccade location from a history of previous stimuli and responses was used to analyze constrains in (1) memory and (2) spatial sampling. The stimuli were 16 Gabor patches on a virtual ring (radius 5.8 degrees). The contrast of each patch was randomly varied on each trial. Observers' task was to detect a contrast increment (50% target present trials) in one patch. Stimulus duration was 300 ms, allowing for one or two saccades to the target. Observers knew that the target patch was at the same, randomized, location for a learning block of 300 trials. The landing points of the first saccade on every trial were extracted. Decision weights for each location were estimated by a maximum likelihood method that uses a history of stimulus values and responses. In the initial trials of the learning block observers used explorative search patterns. Then, after typically 50 – 100 trials, observers repetitively fixated to a single location that often but not always contained the target. The results show a close correspondence between estimated decision weights and saccade locations. A model observer with rather long trial memory and foveated vision could best predict subsequent saccade locations. Together this suggests dynamic and common representations mediating eye movement and perceptual decision learning.

23.333 **How do regularities bias attention to visual targets?** Ru Qi Yu[1](ruqiyu@psych.ubc.ca), Jiaying Zhao[1,2]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

The visual environment is highly stable, where one object often predicts the presence of another object (e.g., a fork is often next to a knife). Such regularities can be useful in guiding visual search (e.g., seeing a fork may help the search for a knife). Here we examine how regularities bias attention to visual targets. In a visual search paradigm, participants searched for the target (a rotated T) among L-shaped distractors as quickly and accurately as they could. The target and distractors were presented in distinct colors. Unbeknownst to the participants, one distractor color (e.g., green) always predicted the nearby location of the target in the structured condition. In a separate random condition, participants viewed the same array except the colors were randomly shuffled for every trial, so the distractor color did not predict target location. We found that participants were faster to find the target in the structured condition than in the random condition (Experiment 1), suggesting a beneficial effect of regularities on visual search, consistent with previous studies. However, when we increased the number of predictive distractor colors (i.e., two distractor colors always predicted the nearby location of the target), we found the exact opposite effect: participants were slower to find the target in the structured condition than in the random condition (Experiment 2). This suggests that the two co-occurring colors may be distracting, drawing attention away from the target to the colors themselves, despite the fact the colors predict the nearby target location. The results demonstrate that regularities do not always benefit target search, in some cases can hurt search performance if regularities themselves compete for attention. The study raises a possible mechanism where the predictor draws attention to itself first and then directs attention to the target.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

23.334 **Does exogenous spatial attention facilitate perceptual learning transfer in acuity and hyperacuity tasks?** Ian Donovan[1](ian.donovan@nyu.edu), Angela Shen[1], Antoine Barbot[1], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Background. Perceptual learning improves performance, but usually only at trained retinal locations. Exogenous attention can facilitate transfer of learning across locations in orientation discrimination tasks (Donovan, Szpiro & Carrasco, 2015). Location specificity is especially persistent in acuity tasks, in which performance is constrained by spatial resolution, and it is unknown whether attention can facilitate transfer in these tasks. Method. We trained observers for 3 days in either Landolt (gap location discrimination; Experiment 1) or Vernier (Gabor misalignment discrimination; Experiment 2) acuity tasks at locations in the peripheral visual field. Before and after Training, 75%-correct thresholds in were measured at Trained and Untrained locations. Half of observers were trained with valid exogenous pre-cues (Attention group), and the other half was trained with neutral pre-cues (Neutral group). Results. In the Landolt task (Experiment 1), the Neutral group showed location specificity: significant improvement in gap-size threshold at Trained locations, but not at Untrained locations; the Attention group showed location transfer: comparable improvement in gap-size threshold at both Trained and Untrained locations. In the Vernier task (Experiment 2), both Neutral and Attention groups showed location specificity: misalignment thresholds improved at Trained locations, but not at Untrained locations. Conclusions. Results from Experiment 1 show that exogenous spatial attention can facilitate transfer in an acuity task – Landolt gap discrimination. However, exogenous attention did not transfer learning in Experiment 2. Thus Vernier discrimination, associated with visual hyperacuity, shows more persistent location specificity than other tasks, i.e. Landolt acuity and orientation discrimination, even after training with exogenous attention.

Acknowledgement: NIH NEI RO1 – EY019693

23.335 **Trial-by-trial feedback does not improve performance or metacognition in a large-sample perceptual task** Nadia Haddara[1](nadiahaddara@gatech.edu), Dobromir Rahnev[1]; [1]School of Psychology, Georgia Institute of Technology

While some studies report that trial-by-trial feedback improves performance on perceptual tasks, others have suggested that it has little to no effect. In the present study, we examined the effect of trial-by-trial feedback on both the perceptual decision and confidence in the accuracy of that decision (metacognition) in a large sample of participants (n = 450). Participants were randomly assigned to a trial-by-trial feedback group or no-feedback group and completed two perceptual tasks. In Task 1, participants were required to make a perceptual judgment concerning whether the letter X or O occurred more frequently in a 7 x 7 grid, and the assigned group received feedback on the accuracy of each response. Task 2 included a similar 7 x 7 grid with a red/blue discrimination. Both groups were given no feedback on Task 2 in order to determine whether any putative improvements would generalize to a new task. All perceptual decisions were followed by a 4-point confidence rating. Although a steady improvement in performance over time was observed in both tasks, results demonstrated that trial-by-trial feedback had no effect on either task performance or confidence ratings. Specifically, in Task 1, participants in the feedback and no-feedback groups had similar perceptual sensitivity (d'feedback= 1.86, d'no-feedback = 1.86; p= .97) and metacognitive ability (Mratiofeedback = 0.70, Mrationo-feedback = 0.76; p= .11). The lack of difference between the feedback and no-feedback groups extended to Task 2 as well (d'feedback = 1.76, d'no-feedback = 1.70; p= .28, Mratiofeedback = 0.71, Mrationo-feedback = 0.77; p= .16). Considering that the sample used was much larger than previous reports, these data indicate the possibility that trial-by-trial feedback may not meaningfully impact either perceptual performance or metacognition.

23.336 **Persistent and flexible perceptual training effect in simulated retinal implant vision** Lihui Wang[1,2](lihui.wang28@gmail.com), Fariba Sharifian[1], Jonathan Napp[1], Carola Nath[1], Stefan Pollmann[1,2]; [1]Department of Psychology, Otto-von-Guericke University Magdeburg, German, [2]Center for Behavioral Brain Sciences, Otto-von-Guericke University Magdeburg, Germany

The perception gained by retina implants (RI) is limited, which asks for a learning regime to improve patients' visual perception. Here we investigated if object recognition in RI vision can be improved and maintained through training. To reduce unnecessary testing burden for patients, we conducted simulation experiments mimicking the limited vision of the patients with a subretinal implant. Importantly, we asked if the trained object recognition can be generalized to a new task context, and to new viewpoints of the trained objects. For this purpose, we adopted two training tasks, a labelling task where participants had to choose the correct label out of other distracting labels for the presented object, and a reverse labelling task where participants had to choose the correct object out of other distracting objects to match the presented label. Our results showed that, despite of the task order, recognition performance was improved considerably (~18.4% accuracy) through a short period of training (~one hour), and this improvement can last at least for a week. The improved object recognition, however, can be transferred only from the labelling task to the reverse labelling task but not vice versa. Additionally, the trained object recognition can be transferred to new viewpoints of the trained objects only in the labelling task but not in the reverse labelling task. These transfer effects were consistently observed irrespective of whether the task difficulty was well controlled (Experiment 1) or increased through the training procedure (Experiment 2). Training with the labelling task is therefore recommended for RI patients to achieve persistent and flexible visual perception.

23.337 **Differences in Task-Relevant Perceptual Learning For Older Adults** Ryan V Ringer[1,2](rvringer@ksu.edu), Dominic Canare[1], Jake Ellis[1], Inga Sogaard[1], Rui Ni[1]; [1]Department of Psychology, College of Liberal Arts, Wichita State University, [2]Department of Psychological Sciences, College of Arts and Sciences, Kansas State University

Age-related declines in contrast sensitivity have real-world implications for safety among older adults in situations like driving. Such aging effects could be ameliorated by perceptual learning, which improves perceptual performance through repeated exposure or practice with a perceptual task. In this study, older adults completed three days of perceptual learning training in one of three different tasks: binocular orientation discrimination (Group 1), stereoscopic slant in depth (rotation toward vs. away) for Group 2 and Group 3. A 2D Gabor pattern was used in all three tasks. In Group 1 the same patch was presented to both eyes, while in Group 2, the orientation difference appeared in the right eye. In Group 3, the orientation difference could appear in either eye. CSF thresholds were estimated monocularly at five orientations (45 to 135 degrees) before and after training for all participants. Training always occurred at 45 degrees orientation. If improvements on low-level perceptual tasks are found across all groups in both the trained and untrained eyes and orientations, then perceptual learning would be occurring at at later processing stages. This is because binocular information would not be integrated until later stages of visual processing (e.g., V2, IPS, etc.). If improvement occurs for only the trained eye and orientation, then there would be evidence in favor of an early, low-level mechanism (i.e., at V1) since these neurons are limited to monocular visual input at specific orientations. The results showed unique effects of training on eye and orientation for each group on the CSF bandwidth and peak frequency, while all groups improved sensitivity to binocular orientation discrimination. These results suggest that perceptual learning of different features of a stimulus can occur concurrently at both early and later stages of processing.

Acknowledgement: National Institute of Health (Grant #P20GM113109)

23.338 **Training with simulated lung nodules in X-rays can improve the localization performance of radiology residents**
Malerie G McDowell[1](malerie.g.mcdowell@vanderbilt.edu), William R Winter[2], Edwin F Donnelly[2], Frank Tong[1]; [1]Psychology Department, Vanderbilt University, [2]Department of Radiology, Vanderbilt University Medical Center

It is estimated that a certified radiologist will have read between 10,000 and 20,000 chest radiographs upon completing a four-year training residency and clinical fellowship. Despite extensive exposure to chest radiographs, residents rarely have the opportunity to read cases involving solitary lung nodules because of their low incidence rate of ~0.2%. Inadequate experience with lung nodule cases may contribute to their high rate of missed detection, which ranges from 20-30% in retrospective clinical studies. We sought to investigate whether a regimen of visual-cognitive training at a challenging lung nodule localization task might improve localization performance for these nodules. Due to the potential training relevance of this study, radiology residents were recruited as observers for this experiment. Because of the low incidence rate, lung nodules in our training stimuli were simulated using lab-developed software, which allowed control over their location, contrast, size and spatial profile. Residents (n=6) were asked to localize the occurrence of a nodule in individual chest X-rays over 4 training sessions (150 trials per session). We also obtained pre-training and post-training measures of performance, by presenting 20 cases of simulated nodules and also 20 cases of real nodules to evaluate whether benefits of training would generalize. During training sessions, audio and visual feedback was given to indicate the correct location of the nodule in each trial. This training resulted in increased localization performance wherein accuracy in detecting simulated nodules was significantly increased (52.5% pre-test, 86.7% post-test, p = 0.004), and a non-significant trend was observed for real nodules (62.5% pre-test, 71.7% post-test, t(5) = 1.53, p = 0.19). The data gathered so far suggest that, while our simulation and training methods may be further improved, this paradigm of nodule localization training may have the potential to improve clinical performance in nodule detection.

23.339 **Perceptual Learning of Optical Coherence Tomography Image Classification** Evan M Palmer[1](evan.palmer@sjsu.edu), Elnaz Amiri[2,3], Patty Sha[3], Sophia Yu[3], Gregory Anderson[3], Gary C Lee[3]; [1]Department of Psychology, San Jose State University, [2]Industrial Systems Engineering, San Jose State University, [3]Carl Zeiss Meditec, Inc., Dublin, CA, United States

Purpose: This study explored how perceptual learning methods may be applied to improve diagnosis of age-related macular degeneration (AMD) in optical coherence tomography (OCT) retinal scan images. Perceptual learning can occur when observers perform rapid image classification tasks with immediate feedback. This study is a first step towards developing software for training optometry students and technicians. Methods: The 189 images used for this study were taken on CIRRUS 5000 HD-OCT (ZEISS, Dublin, CA). Each image was a B-scan selected from 6mm x 6mm cubes of the macula. Twenty participants with no prior training in optometry or medical image diagnosis completed the study. Images were presented on 23" Dell P2317H monitors driven by 1.4 GHz Mac Mini computers running MATLAB (MathWorks, Natick, MA) software with the Psychophysics toolbox (Brainard, 1997; Pelli, 1997). Participants classified each image as either wet or dry AMD via keypress. Classification accuracy and response times were collected pre and post a 15 minute perceptual training session. Accuracy feedback was provided only during the training session. Response times and accuracy of classifications during the pre- and post-test periods were assessed via analyses of variance. Results: Analyses detected a main effect of response time, $p = .002$, such that correct classifications were faster in the post-test than the pre-test. A main effect of image type indicated that observers were more accurate at classifying wet than dry images, $p < .001$. Finally, there was an interaction in the accuracy data, such that accuracy improved for wet AMD images but not for dry AMD images, $p = .034$. Conclusions: These preliminary results suggest that it is possible to improve the speed and accuracy of wet vs. dry AMD classification by novices with a 15 minute training session. We are continuing to collect data to improve our AMD classification training methods.

23.340 **Perceptual learning of chest X-ray images** Sha Li[1](lixx3632@umn.edu), Roger W Remington[2,3], Yuhong V Jiang[1,3]; [1]Department of Psychology, University of Minnesota, [2]School of Psychology, University of Queensland, [3]Center for Cognitive Sciences, University of Minnesota

Extensive research on perceptual learning has shown that adults can readily acquire new perceptual skills. Much of this research, however, has focused on simple properties such as contrast or orientation, and training yields limited transfer to new features or locations. Here we investigated the acquisition and transfer of more complex perceptual skills. We trained novices to identify lung cancer and examined two types of learning: local learning of tumor properties and global learning of the surrounding context. Stimuli were taken from the Japanese Society of Radiological Technology and included both abnormal and normal chest X-rays. Participants underwent 4 days of training (180 trials each), during which they saw a set of 60 images presented multiple times. On each training trial, participants saw a pair of chest X-ray images, one abnormal and one normal, and were asked to choose the abnormal image and localize the tumor. The computer provided feedback regarding the correct tumor location. Both classification and localization accuracy improved across training sessions, indicating the occurrence of learning. We also administered a pre-test before the first training session and a post-test after each training session. The test contained a single image for participants to classify as cancerous or not. It included both trained images and new images, presented in one of three formats – the entire image, just the cutout of the cancerous region or a comparable region in normal images, or just the surrounding region. For trained images, participants were able to classify all three formats at above-chance levels. Learning transferred to untrained images, especially when the entire image was available for classification. Accuracy for classifying just the cutout or the surrounding regions of untrained images was low but above chance. These results showed that moderate amount of training yields transferrable perceptual learning of complex visual stimuli.

Acknowledgement: This work was supported by a seed grant from OFAA-Social Sciences, University of Minnesota to YVJ and Doctoral Dissertation Research Award from American Psychological Association and Doctoral Dissertation Fellowship from the University of Minnesota to SL.

23.341 **Examining Class Dependant Sub-Paths in Deep Neural Networks** Mathew Monfort[1](mmonfort@mit.edu), Kandan Ramakrishnan[1], Alex Andonian[1], Aude Oliva[1]; [1]CSAIL, MIT

Understanding the decision of an artificial neural network is an important task when we consider how these models are being applied to problems such as robotics, autonomous driving and other increasingly important areas where an incorrect inference can leadto costly outcomes. Recent work in the area disentangles the learned representations in order to identify key concepts that are being learned and quantifies the dependence of classes on specific feature directions. Most of these approaches focus on what the models are learning. We propose a method to understand why the models are learning these concepts and feature dependencies. We extend the ideas of feature selectivity and network dissection to identify learned class relationships and build quantifiable feature-class associations based on learned network parameters. This approach allows us to not just understand what a model is learning but to also gain insight into why it is learning these concepts and how it is using them.We apply these methods to multiple network architectures trained for different tasks and explore ways to regularize feature dependency to improve generalization.

23.342 **Category learning enhances visual perception at the boundary** Sean R O'Bryan[1](sean.r.obryan@ttu.edu), Anto Jude Mohan[1], Hao Nguyen[1], Tyler Davis[1], Miranda Scolari[1]; [1]Department of Psychological Sciences, Texas Tech University

Research suggests that category learning can warp visual perception, such that learned category boundaries stretch the psychological distance along relevant stimulus dimensions to facilitate successful categorization. We hypothesized that this perceptual warping may result from a representational sharpening of underlying sensory populations tuned to the category boundary. Furthermore, we expected such sharpening to occur largely during active learning of new categories. To test this hypothesis, we intermittently presented subjects with an orientation discrimination task where they reported the directional offset between two sequentially-presented gratings, while they were primarily engaged in an orthogonal categorization learning task. Subjects were pseudo-randomly assigned to one of eight boundary pairs within orientation space ($n = 72$) or a midpoint boundary within spatial frequency space ($n = 69$) for the categorization task. All subjects encountered randomly interleaved categorization (category A or B?) and orientation discrimination (rotated left or right?) trials; critically, all visual stimuli were physically matched between conditions. Perceptual discrimination performance was assessed for each of 36 possible reference orientations (0-175 degrees). Subjects were well-matched on categorization performance between orientation and spatial frequency conditions. To compare perceptual discrimination results between groups according to distance from the category boundary, we assigned arbitrary orientation boundaries to spatial frequency learners to match the distribution of the orientation group. Moreover, we contrasted subjects who successfully learned the orientation rule with those who failed to learn the rule. Our results revealed significantly greater performance among successful learners in the orientation group only for stimuli near the category boundary (0° and 5°) when compared to both spatial frequency learners and orientation non-learners. These results suggest that category learning temporarily enhances visual perception along dimensions relevant to categorization decisions, with the most prominent effects occurring at or near the category boundaries.

23.343 **Properties of invariant object recognition in human one-shot learning suggests a hierarchical architecture different from deep convolutional neural networks** Yena Han[1](yenahan@mit.edu), Gemma Roig[1,2], Gad Geiger[1], Tomaso A Poggio[1]; [1]MIT Center for Brains, Minds and Machines, [2]Singapore University of Technology and Design

Recognition invariant to transformations can be a significant advantage for a visual system. It is important, however, to distinguish between intrinsic invariance due to the underlying representation and example-based invariance for familiar objects that have been previously seen under different viewpoints. To characterize invariance in humans, we conducted psychophysical experiments measuring object invariant recognition performance in one-shot learning scheme. We report tolerance to scale and position changes by analyzing recognition accuracy of Korean letters presented in a flash to non-Korean subjects, who had no previous experience with Korean letters. We found that humans have significant scale-invariance at the center of the visual field after only a single exposure to a novel object. The degree of translation-invariance is limited, depending on the size and position of objects. We represent the range of invariance as the window of invariance, and compare it with the window of visibility, which is obtained by testing

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Korean subjects under the same experimental conditions as for the one-shot learning task. This comparison revealed that the window of invariance lies within the window of visibility. In addition, to understand the underlying brain computation associated with the invariance properties, we compared experimental data with computational modeling results. For the computational model, we tested Eccentricity-dependent Neural Network (ENN), which we hypothesized it exploits the intrinsic invariance properties observed in the human experiments. Our modeling results suggest that to explain invariant recognition by humans, artificial neural networks require to explicitly incorporate built-in scale-invariance, by encoding different scale channels as well as eccentricity-dependent representation captured with neurons' receptive field sizes that change with eccentricity as in ENN. Our psychophysical experiments and related simulations strongly suggest that the human visual system uses a different computational strategy than current convolutional deep learning architectures, which is more data efficient and strongly reliant on eye-movements.

Acknowledgement: The Center for Brains, Minds and Machines (CBMM), funded by NSF STC award CCF-1231216. Y. Han is a recipient of Samsung Scholarship.

23.344 **Evaluating the performance of the staircase and qCD methods in measuring specificity/transfer of perceptual learning** Pan Zhang[1](zhang2005pan@126.com), Yukai Zhao[1], Barbara Dosher[2], Zhong-Lin Lu[1]; [1]Laboratory of Brain Processes (LOBES), Departments of Psychology, The Ohio State University, Columbus, OH, United States of America, 43210., [2]Department of Cognitive Sciences and Institute of Mathematical Behavioral Sciences, University of California, Irvine, CA, USA, 92697.

The degree of transfer/specificity is a fundamental property of perceptual learning. Many conclusions about the level and mechanisms of perceptual learning depend critically on the accuracy and precision of the estimated transfer/specificity index. Traditionally, the transfer index is derived from learning curves during initial learning and transfer measured with the staircase method. Recently, Zhao et al. (2017) developed and validated a Bayesian adaptive qCD method to measure the trial-by-trial time course of perceptual sensitivity change in dark adaptation. The method was also validated in perceptual learning in a 4-alternative forced-choice (4AFC) global motion direction task, where the qCD methodcharacterized the time course of perceptual learning moreaccurately, precisely and efficientlythan the 3-down/1-up staircase method. Here, we evaluated the qCD and staircase methods in assessing the transfer index in a 2AFC task. Three observers with different time constants (40, 80, and 160 trials) of an exponential learning curve were simulated, with the same time constants and 50% transfer in the transfer phase. Each simulated observer was assessed with the 3-down/1-up staircase (10% step size) and the qCD procedure with a uniform prior of the parameters of the exponential learning curve, each with five initial stimulus levels (+50%, +25%, 0, -25%, and -50% from the true threshold in the first trial). 1000 simulated runs of 1600 trials were tested for eachobserver.Thresholds were estimated every 80 trials in the staircase method. The estimated transfer indexes from the qCD and staircase methods, averaged over starting levels, were 0.39 ± 0.17 (Mean$\pm$SD) and -1.21 ± 4.91 for Observer 1, 0.43 ± 0.14 and 0.25 ± 2.19 for Observer 2, and 0.47 ± 0.09 and 0.46 ± 0.48 for Observer 3, respectively. The results indicated that the qCD method provided more accurate and precise measures on transfer of perceptual learning than the staircase method, especially when the learning is more rapid. The qCD has great potentials in studies of perceptual learning.

23.345 **Generalization of learning in n-AFC orientation identification** Jiajuan Liu[1](jiajuanl@gmail.com), Barbara A. Dosher[1], Zhong-Lin Lu[2]; [1]Department of Cognitive Sciences, University of California, Irvine, [2]Department of Psychology, The Ohio State University

A large classic literature examined specificity and transfer of perceptual learning, virtually always in two-alternative tasks. Recently, we demonstrated learning in n-alternative identification—a task perhaps more typical of real world visual judgments. However, little is known about specificity or generalization for nAFC tasks. In this study, we examined whether learning in 8-alternative orientation identification was specific to the spatial frequency of the training stimuli. Stimuli were Gabors of 8 orientations (-78o to 79.5o relative to vertical, in 22.5o steps) and five spatial frequencies (0.7 to 2.84 cpd, in half octave steps) embedded in Gaussian external noise (sigma=0.33). Observers identified which of the 8 orientations was displayed on each trial. Learning and transfer were evaluated by comparing performance in a post-test after training to a pre-test of orientation identification in all five spatial frequencies. Four different groups were trained for 5 sessions of 960 trials each either with the lowest, highest, middle, or a mixture of spatial frequencies at 3 Gabor contrasts (0.3 0.6, 1.0). In all four groups, training improved performance on the trained stimuli, including the group trained on the mixture of spatial frequencies ("roving" in the judgment-irrelevant spatial frequency dimension). Some of what was learned generalized to all spatial frequencies for all groups. At the same time, training with a single spatial frequency also showed some specificity, especially for the lowest and highest spatial frequencies, yielding a transfer function across spatial frequency. However, a simulation of the n-AFC integrated reweighting theory without spatial frequency invariant representation (IRT, Dosher et al., 2013; Dosher, Liu & Lu, VSS 2017) predicts more specificity than what was observed in the human data. Example simulations suggest a role for spatial-frequency invariant orientation representations that mediate transfer in a way analogous to the possible role of location-invariant representations in transfer over retinal locations.

Acknowledgement: National Eye Institute Grant # EY–17491

23.346 **Cholinergic facilitation of visual perceptual learning of texture discrimination** Kelly N Byrne[1](knhbyrne@berkeley.edu), Michael A Silver[1,2]; [1]Vision Science Graduate Group, School of Optometry, UC Berkeley, [2]Helen Wills Neuroscience Institute, UC Berkeley

Despite extensive research on the properties of visual perceptual learning and its specificity to the stimulus parameters employed during training, few studies have investigated the relevant pharmacological underpinnings. Here, we present results from a double-blind crossover study of the effects of cholinergic enhancement on the magnitude and specificity of texture discrimination learning. Each subject participated in two sets of training and testing sessions during which they self-administered either 5 mg of the cholinesterase inhibitor donepezil, which boosts the signaling of endogenous acetylcholine, or placebo, daily for 10 consecutive days. The two training and testing sets were separated by two weeks to permit complete elimination of donepezil (if present). We found substantial perceptual learning of texture discrimination following training with both donepezil and placebo, and the magnitude of this learning was significantly greater after donepezil training compared to placebo training. We also examined the specificity of learning to both the trained location (visual field quadrant) and feature (background element orientation). Training under donepezil had no effect on location specificity of learning and resulted in reduced specificity for stimulus orientation. These findings suggest that future applications of perceptual learning could benefit from an improved understanding of the associated pharmacological mechanisms.

Acknowledgement: NEI R01 EY025278 (MAS)

23.347 **Different but complementary roles of NREM and REM sleep in facilitation of visual perceptual learning associated with neurotransmitters changes revealed by magnetic resonance spectroscopy.** Masako Tamaki[1](tamaki@brown.edu), Zhiyan Wang [1], Tyler Barnes-Diana[1], Takashi Yamada[1], Edward G Walsh [1], Takeo Watanabe [1], Yuka Sasaki[1]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University

While sleep is known to be beneficial to visual perceptual learning (VPL), the roles of NREM and REM sleep in facilitating VPL remain unclear (Sasaki, Nanez and Watanabe, 2010). It has been demonstrated that NREM sleep plays a role in performance enhancement, while REM sleep makes VPL more resilient to retrograde interference caused by training of a new and different task (Tamaki, Berard, Watanabe and Sasaki, 2018). These results suggest that plasticity of VPL increases for performance enhancement during NREM sleep, while it decreases for stabilization during REM sleep. To test this hypothesis, for the first time using magnetic resonance spectroscopy we measured the concentrations of excitatory (glutamate) and inhibitory (GABA) neurotransmitters in the early visual area (EVA), during NREM sleep and REM sleep. We previously found that the E/I ratio, the ratio of the concentrations of glutamate to GABA in EVA, represents the amount of plasticity of VPL. Thus, in the current experiment, we measured E/I ratios during NREM and REM sleep between two trainings on the texture discrimination tasks (TDT) with orthogonal background elements. Successive trainings on these stimuli are known to cause retrograde interference. The results replicated previous finding that performance on TDT trained before sleep increased without retrograde interference by new training after NREM and REM sleep. Importantly, the E/I ratio significantly increased during NREM sleep while it decreased during REM sleep. Furthermore, the E/I ratio during NREM sleep was correlated with performance enhancement over sleep (r=0.80), while the lower the E/I ratio during REM sleep, the more resilient to retrograde interference (r=-0.62). These results show that NREM sleep increases plasticity to enhance VPL, while REM sleep decreases plasticity to stabilize once enhanced VPL during NREM sleep. In conclusion, NREM and REM sleep play complementary roles for VPL, which are reflected by significantly different E/I ratios.

Acknowledgement: NIH R21EY028329, NIH R01EY019466, NIH R01EY027841, United States -Israel Binational Science Foundation BSF2016058, An Institutional Development Award (IDeA) from NIH P20GM103645, Brown University FY17 OVPR Seed Grant, Brown University Center for Vision Research

23.348 **Evidence Supporting Neuro-modulator Release as a Function Perceptual Learning.** Steven R Holloway[1](srh@asu.edu), José E Náñez, Sr[1], Michael K McBeath[2]; [1]School of Social and Behavioral Sciences, Arizona State University, [2]Department of Psychology, Arizona State University

Watanabe, Náñez, and Sasaki (2001) introduced a phenomenon they named "task-irrelevant perceptual learning" in which near-visual-threshold stimuli that are not essential to a given task can be associatively learned when concurrently paired with the focal task. How the timing of this pairing affects plasticity has been largely unexplored.More precisely, does the non-essential, near-threshold stimulus need to be presented at exactly the moment of focal concentration, or does some level of neural flexibility exist that would allow for pairing to be temporally close, but not simultaneous to the concentration?The present study explores the relation between the timing of the pairing of a dim motion stimulus with a recognition target. Near-threshold motion stimuli were presented concurrently with presentation of focal stimuli and offset from the same by ±350ms. The concurrent and the 350ms after groups performed significantly better than those who were exposed to the dim motion stimuli 350ms before the focal target. These data are consistent with a model of neuro-modulator induced cortical plasticity. Specifically, for the 350ms after condition, neuro-modulators were likely still present when neurons began responding to the dim motion, and, in the 350ms before condition, it is likely that neurons responding to dim motion were still partially active when the participant recognized the target, eliciting the slight improvements that were observed. This finding supports the notion that concentration-induced neuro-modulator release subserves cortical-plasticity.

23.349 **Alcoholic drink preferences modulate acquired salience** Kristen L Sanders[1](ks10psy@gmail.com), Thomas W James[1]; [1]Psychological Brain Sciences, College of Arts and Sciences, Indiana University Bloomington

Perceptual history – learning from perceptual experiences (Jeong et al, 2014) – influences item salience and processing efficiency (Kahnt & Tobler, 2017; James et al. 2000). From the addiction literature, it's found that an addiction-related cue acquires increased neural reactivity in sensory cortex (Hanlon et al., 2014). We hypothesized that repeat exposure to addictive substances induces sensory system plasticity leading to increased salience and sensory processing speed of substance-related items(Robinson & Berridge 2008; Yalechkov et al., 2010). We selected an addictive substance that a majority of the American population engages with: alcohol (Grant et al., 2017). Participants chose three drink types - preferred, aversive, and neutral - from 16 alcohol categories. We predicted that preferred drinks would show faster processing speed because of their enhanced perceptual history. In three experiments, we measured performance with sensory processing efficiency tasks. Experiments 1 and 2 consisted of oddball visual search (VS), where successful localization of the target required processing all images displayed. In homogeneous VS (Exp. 1, n=32), participants searched for the unique image in a visual display of many identical images. In heterogenous VS (Exp. 2, n=31) participants searched for the unique category image (target) in a display of varied images from a distractor category. In task three, multiple object tracking (Exp. 3, n=33), participants visually tracked a subset of moving alcoholic beverage images. In Experiment 1, displays with preferred items had shortest reaction times. In Experiment 2, the same preferred item facilitation was found. In Experiment 3, accuracy was highest when tracking preferred items, while preferred distractors reliably decreased accuracy indicating that processing preferred items was automatic. Overall, task performance was enhanced with task-relevant preferred items and hindered with task-irrelevant. The coupling of perceptual history (preference) with high reward (addictive substances) leads to neuroplasticity observable in measures of sensory salience.

Object Recognition: Features, parts, reading

Saturday, May 18, 8:30 am - 12:30 pm, Banyan Breezeway

23.350 **How are spatial relations among object parts represented? Evidence from a shape recall experiment** Thitaporn Chaisilprungraung[1](tchaisi1@jhu.edu), Gillian Miller[1], Michael McCloskey[1]; [1]Cognitive Science Department, Johns Hopkins University

Successful recognition and interaction with objects requires the ability to perceive and represent how object parts are internally related (e.g., a tea pot's handle is attached to its body, at a location opposite to the spout). Despite an abundance of research on object cognition, little is understood about how the brain represents spatial relations among object parts. The types of information required for representing how two object parts are related (i.e., the relative locations and orientations at which the parts are connected), are the same as those required for representing how an entire object is related to an environment (e.g., the location and orientation of a pen on a table).We investigated representation of relations among object parts by extending a theoretical framework developed for explaining how locations and orientations are represented for whole objects (e.g., McCloskey, 2009). We analyzed the patterns of errors participants made when recalling the arrangements of parts in artificial objects. The objects consisted of a large and a small part that could be joined in different ways to create multiple part configurations (Fig.1).On each trial participants viewed a target object at three different orientations, and then attempted to reproduce the arrangement of parts within the object (Fig.2).We observed an interesting pattern of co-occurrence between certain types of orientation and location errors. Particularly, when participants reflected the location of a smaller part across the elongation axis of the larger part, they also tended to reflect its orientation across the same axis (Fig.3).This error pattern is readily explained by a theoretical framework which assumes that locations and orientations of parts are represented in a unified manner.Together, we suggest a new model for object shape representations, one that is adapted from the framework for representing whole objects' location and orientation.

23.351 **Behavioral and Neural Associations between Object Size and Curvature** Caterina Magri[1](cmagri@fas.harvard.edu), Bria Long[2], Rocco Chiou[3], Talia Konkle[1]; [1]Department of Psychology, Harvard University, [2]Department of Psychology, Stanford University, [3]MRC Cognition and Brain Science Unit, University of Cambridge, UK

Object size is systematically related to shape properties, like curvature—big objects tend to be boxier to withstand gravity, while small objects tend to be curvier for comfortable handling. Here we examined whether internal object representations are sensitive to this typical covariance. To do so, we created a 2x2 stimulus set of big and small, boxy and curvy objects. While big boxy and small curvy objects are more prevalent than the opposite combinations, we ensured that across items, the conditions did not differ by familiarity, and were matched in real-world size and curvy-boxy ratings, aspect ratio, and pixel area. In the behavioral experiment, participants (N=12) were presented with an isolated object and judged its real-world size (small vs large) on some blocks of trials, or its shape (curvy vs boxy) on other blocks of trials. Overall, people were faster and more accurate at judging the typical size-curvature combinations relative to the atypical combinations (mixed-effect model interactions; size judgement: $t = -6.12$, $p< .001$; curvature judgement, $t = -2.59$, $p = 0.01$). In the neuroimaging experiment, participants (N=16) viewed a subset of these images in a blocked design. The typical covariance contrast—big boxy vs. small curvy—yielded more reliable topographies than the atypical covariance contrast—big curvy vs small boxy (typical split-half map correlations: M=0.52, SD=0.13; atypical: M=0.29, SD=0.27; $t(15)=3.87$, $p=0.002$). These two topographies were moderately positively correlated (typical vs. atypical map correlation: M=0.39, SD=0.13), indicating that the size organization is not fully explained by curvature and that other covarying mid-level statistics are required to fully account for the object-size topography. Broadly, these results provide both behavioral and neural evidence that the visual system is sensitive to the natural covariance between object size and curvature, supporting more efficient behavioral judgments and more robust neural responses.

23.352 **Diagnostic Features for Visual Object Recognition in Humans** Quentin Wohlfarth[1](quentin.wohlfarth@umontreal.ca), Martin Arguin[1]; [1]Centre de Recherche en Neuropsychologie et Cognition and Département de psychologie, Université de Montréal, Montréal, Canada

The Bubbles (Gosselin & Schyns, 2001) classification image technique has been used frequently to determine the subset of the available visual information that is effectively used by humans in various face perception tasks.

However, to the best of our knowledge, its application in object recognition has been limited to one study conducted in pigeons (Gibson et al., 2005). Here, human participants recognized objects from collections of six simple visual shapes displayed in one of four different viewpoints. The stimuli were of the same class as Biederman's (1987) geons and participants were initially trained to associate each object with a particular keyboard key. In the recognition task (11520 trials per participant), the single object displayed was visible only through a number of circular Gaussian apertures and the participant indicated its identity by a key press. The classification images were calculated separately for each instance and each participant by subtracting the weighted sum of the bubbles masks leading to errors from that of masks leading to correct responses. An ideal observer was also assessed in the same experiments to determine the spatial location of the objectively most effective information to support the recognition task without the limitations or intrinsic biases of the human visual system. The results show major differences in the classification images obtained from human participants and the ideal observer. Such differences indicate that particular properties the human visual system prevented participants from focusing on the objectively most effective diagnostic information, forcing reliance on alternative sources of information. From the nature of the contrast in the classification images from human and ideal observers, it is proposed that human vision is biased towards the processing of edges and vertices for representing and recognizing the shapes from the class used in the present study.

Acknowledgement: The present research was supported by a grant from the Natural Sciences and Engineering Research Council of Canada to Martin Arguin.

23.353 **The dominance of spatial information in location judgments: A persistent congruency bias even amidst conflicting statistical regularities** Anisha S Babu[1](babu.29@osu.edu), Paul S Scotti[1], Julie D Golomb[1]; [1]Department of Psychology, The Ohio State University

During object recognition, visual features such as shape and location must be integrated. Previous studies investigating object feature binding posit that location plays a unique role in the binding process. Further, a "spatial congruency bias," or a tendency to report objects as the same identity if they are presented at the same location, was discovered (Golomb et al, 2014, JEP:Gen), supporting a privileged role for location in object recognition. The current study investigated the persistence of this bias. Specifically, while maintaining central fixation, subjects were sequentially presented with two objects in the periphery. The objects were novel-object morphs of either the same or different identity, and they appeared at either the same or different location. Subjects were then asked whether the objects were of the same or different identity. To see if we could override the spatial congruency bias, we biased the statistical regularities in the opposite direction, such that 75% of same location trials included different identity objects, and 75% of different location trials included same identity objects. If the spatial congruency bias were still observed, it would indicate that the role of location in object perception is preserved despite contradictory associations. A calculation of d' and response bias revealed that subjects were indeed still more biased to report objects as the same identity when they appeared in the same location compared to different location trials. These results indicate the preservation of the spatial congruency bias even with conflicting statistical regularities, further reinforcing the dominant role of spatial information during object feature binding.

Acknowledgement: NIH R01-EY025648 (JG), Alfred P. Sloan (JG)

23.354 **Expectations modulate the time course of information use during object recognition** Laurent Caplette[1](laurent.caplette@umontreal.ca), Greg L West[1], Frédéric Gosselin[1]; [1]Département de psychologie, Université de Montréal

Prior expectations have been shown to affect object recognition. However, it is unknown whether the expectation of a specific object modulates how information is sampled across time during object recognition. Coarse information (low spatial frequencies, SFs) is typically sampled before more detailed information (high SFs). Some authors have suggested that low SFs processed early activate expectations about the object's identity and that high SFs processed afterwards allow the confirmation and refinement of this hypothesis; an existent expectation could therefore reduce the need for confirmatory high SF information. In this study, we verified whether expectations influenced how SFs are used across time to recognize objects. On each trial, one object was randomly chosen among eighty, and all its SFs were randomly sampled across 333 ms. In half the trials (expectation condition), an object name was shown before the object; in the other half (no-expectation condition), it was shown after. Subjects had to indicate whether the name matched the object; it did so on 50% of trials. We first observed, after reverse correlating accuracy with SFs shown at each moment, that the early use of low SFs (1-30 cycles/image) was increased in the expectation condition. We then found that the late use of high SFs (~35 cycles/image), although not visible in the average results, was correlated with general recognition ability in the no-expectation condition, more so than in the expectation condition. Finally, we found that the early use of high SFs (~35 cycles/image) was affected differently by different expectations (i.e. different object names). Together, these results reveal how the processing of sensory information sampled across time during object recognition is modulated by expectations and they support the hypothesis that low and high SFs are affected differently by this modulation.

23.355 **Impact of Developing Perceptual Expertise on Eye Fixations** Adam H Dickter[1](adam.dickter@nih.gov), Chris I Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health

In cognitive experiments, eye fixation data are often used to determine what information about a stimulus is being analyzed for a given task and thus what underlying processes are occurring in the brain. Perceptual expertise may be based on knowledge about the location of distinguishing features on a set of stimuli (Biederman & Shiffrar, 1987) and we would predict a change in eye fixation patterns toward the distinguishing features as expertise is acquired. In this study we investigated the relationship between eye fixations and the visual information needed to complete a task as participants developed expertise. We used novel real-world stimuli, photographs of whale tails, that were modified to control the location of the critical information. Participants were asked to discriminate the identity of the whales based on the tail features in a forced-choice paradigm and received feedback after each trial. One group of participants completed the experiment with a single informative location on the whale tail, and a second group with two critical locations, where the conjunction of features determined identity. Dependent measures collected included accuracy, reaction time, and eye tracking. As expected, participants' reaction time decreased as accuracy increased. Additionally, fixations changed over time, with an increased likelihood to fixate at the diagnostic locations. For whale tails with a single informative location, fixations were tightly constrained to the diagnostic location. In the two-location condition, we observed two patterns emerge, such that one group of participants fixated on each relevant location in a discrete, sequential fashion, while the other developed a distinct pattern of fixating a single diagnostic location on the whale tail even though both contained information necessary for task performance. These latter results suggest the development of holistic processing during tasks with distributed information. Perceptual expertise may induce a dissociation between fixation patterns and task relevant information.

Acknowledgement: Intramural Program of NIMH

23.356 **The Role of Awareness in Figure-ground Segregation in Human Visual System** Ling Huang[1](2018022906@m.scnu.edu.cn), Xilin Zhang[1,2]; [1]School of Psychology, South China Normal University, Guangzhou, Guangdong, China, [2]Guangdong Provincial Key Laboratory of Mental Health and Cognitive Science, South China Normal University, Guangzhou, Guangdong, China

An essential part of visual perception is segmenting images into figures and background. Previous studies have shown that this segmenting process relies on two complementary processes: boundary detection and subsequent region-filling. However, the neuronal mechanisms for these processes and whether they depend on awareness remain unclear. Here we performed psychophysical and fMRI experiments to examine these issues. In our experiments, each figure-ground stimulus had a regular Manhattan grid of 33 × 45 bars, presented on a dark screen. All bars were identically oriented except for a square figure of bars with another orientation in either the upper left or the upper right quadrant. There were three possible figures: the first and second consisted of 2 × 2 (Small Figure, SF) and 10 × 10 (Large Figure, LF) bars, respectively, and the third was a combination of the two (Combined Figure, CF). Low- and high-contrast masks, which had the same grid as the figure-ground stimuli, rendered the whole stimulus visible (Experiment 1) and invisible (Experiment 2) to subjects, respectively. In the psychophysical experiment, the Posner cueing paradigm was adopted to measure the spatial cueing effect of each figure on an orientation discrimination task with Small or Large Gratings, which had the same size as the SF and LF, respectively. For the Small Grating, there was no significant difference between the LF and CF, and both were significantly lower than the SF in Experiment 1; there was no significant difference between the SF and CF, and both were significantly higher than the LF in Experiment 2. No significant difference was found for the Large Grating in either Experiments 1 or 2. A further fMRI experiment confirmed these findings and suggested that boundary detection is an early, automatic process that is independent of awareness, whereas subsequent region filling is strongly modulated by awareness.

23.357 **Stimulus-specific learning facilitates ensemble processing of cars** Oakyoon Cha[1](oakyoon@gmail.com), Randolph Blake[1], Isabel Gauthier[1]; [1]Department of Psychology, Vanderbilt University

Faces are frequently used to investigate ensemble processing of complex objects, because visual impressions of faces in a crowd can be highly relevant for social interactions. Most of these studies rely on relatively few stimuli created by morphing among a small number of faces. We asked how the repetition of objects over trials influences performance on ensemble judgments. We hypothesized that when provided such repetition, people can learn to process multiple stimuli as an ensemble, regardless of category or adaptive value. We measured participants' ability to extract ensemble information from arrays of car images. On each trial, participants viewed two successive, briefly presented arrays of 6 cars and judged which array contained the more diverse set of cars. The more diverse of the two arrays comprised 6 different cars, and the less diverse array comprised 3 or 4 identical cars plus 3 or 2 different cars. The identical cars in the less diverse array were shown either at neighboring or scattered locations. Half of the participants viewed the same set of 6 cars throughout the experiment, and thus had opportunity to familiarize themselves with that ensemble of cars. The other participants viewed arrays of new cars on each trial, precluding stimulus-specific learning. All participants could perform the diversity judgment task, but those who viewed non-repeating cars performed better when identical cars were neighboring than scattered, suggesting reliance on local information. In contrast, the spatial distribution of identical cars had less influence for participants who viewed repeating cars, suggesting that repetition of cars throughout the task promoted learning of stimulus-specific, ensemble-relevant information. Whether or not stimulus-specific learning facilitates ensemble processing of objects for which people have experience of forming ensembles, such as faces, needs to be explored.

Acknowledgement: This work was supported by the NSF (SBE-0542013 and SMA-1640681) and by the Centennial Research Fund (Vanderbilt University).

23.358 **The effect of spatial properties on trypophobia** Kanichi Fukumoto[1], Mototsugu Hayashi[1], Kenji Yokoi[1]; [1]National Defense Academy of Japan

Aversion to clusters of holes or warts is called as trypophobia. Previous studies have suggested that trypophobic discomfort can be explained by high-contrast energy at midrange spatial frequencies (Cole & Wilkins, 2013; Le et al., 2015; Sasaki et al., 2017). Their spectral analyses, however, were based on an image-dependent unit (cycles per image: cpi). Therefore, the spatial properties perceived by our visual system (e.g., cycles per degree: cpd) should vary depending on the size and the viewing distance of images. To clarify the relationship between spatial properties and discomfort, we manipulated spatial frequencies within the range of two octaves in both units separately by resizing and cropping images while maintaining their appearances. Participants viewed an image which was filled with holes (e.g., lotus, barnacles, sponge) and rated aversion by a 7-point scale. The eye movement including the pupil response was also recorded. In the first experiment, aversion ratings varied regardless of keeping frequencies in cpi or cpd constant individually. Next, we changed the size and the viewing distance while keeping the retinal image identical. The result depended not on the spatial frequency but on the size of images. When the size was kept constant while manipulating the spatial frequencies and the viewing distance, aversion ratings were almost constant with the moderate tendency that the discomfort response to strong trypophobic images was increased as shortening the distance. Our findings suggest that the apparent size of trypophobic images affects aversion greatly and the influence of the spatial frequencies may be overestimated. In addition, the effect of the viewing distance supports the recent idea that trypophobic discomfort is triggered by involuntary avoidance of skin diseases (Imaizumi et al., 2016; Yamada & Sasaki, 2017). The relationship between the subjective rating and the eye movement will be also discussed.

23.359 **Categorical perception in data visualizations** Caitlyn M McColeman[1](cmccolem@sfu.ca), Steven L Franconeri[1]; [1]Department of Psychology, Weinberg College of Arts and Sciences, Northwestern University

When we depict our data as visualizations, we care about how effectively our eye can extract the original data values. That effectiveness is limited by Weber's Law, where error is proportional to a percentage its absolute value (Cleveland & McGill, 1984; Heer & Bostock, 2010). If you can reliably see a 1 pixel change in a 10-pixel dot plot or bar graph, it should take ~10 pixels of change of a 100-pixel bar to match the same level of performance. That absolute value is relative to some baseline value, such as 0-pixels. Little existing work in graphical perception explores how other baselines might affect performance. For example, it's easier to see the difference between two lines differing by 2° when the values are 89 vs 91° (straddling the 90° categorical boundary) than when they are 15 vs 17° (Bornstein & Korda, 1984). Participants saw with 100 randomly-ordered trials where they saw an initial display with a dot of a particular height (X=1, 2, 3, ...100). Viewers then 'drew' the dot again at a new screen location on a subsequent display. When the dot was presented on its own (no y-axis), we replicated the Weber's Law error effect, though with an intriguing propensity to overestimate small values. However, when the dot was presented near or on a y-axis, the error was mirror-symmetric, presumably because viewers chose the closer end of the range as the baseline. We also observed a repulsive bias from responding at 50%, where viewers were more likely to draw a dot of 49% as ~45%, and a dot of 51% as ~55%, suggesting that the midpoint of the axis serves as a categorical boundary. This finding translates categorical perception effects to data visualization, and points a path to work that creates guidelines for more precise, and less biased, data visualizations.

23.360 **Can we improve the perception of crowded digits with a new font using vertical shifts?** Sofie Beier[1](sofie@sofiebeier.dk), Jean-Baptiste Bernard[1]; [1]The Royal Danish Academy of Fine Arts, School of Design

Crowding happens when the perception of multiple objects is impaired by their spatial proximity. It is exacerbated in the visual periphery and affects symbols such as letters or digits. Here, we investigated if crowding of digits could be reduced when a specific vertical shift is applied to each digit. Starting with the DejaVu font, we designed test fonts inspired by the typographic settings of old style numerals with different shifts for 3 groups of digits: null shift (digits 0,1,2), upper shift (digits 6,8) and lower shift (digits 3,4,5,7,9). Five different versions of the font were created with different shift values: 0x (= DejaVu font), 0.1x, 0.2x, 0.4x and 0.8x the x-height. Ten subjects participated in Experiment 1 (lower VF) and Experiment 2 (right VF). For each trial of these experiments, a trigram of random digits was presented for 200 ms at 10° eccentricity. Subjects had to identify all three numerals by selecting them from a response screen. A total of 5 blocks of 20 trigrams were presented for each font in both experiments. We analyzed both correct numeral identification and whether the corresponding vertical shift was perceived. The accuracy of the positional information increased linearly with vertical spacing: from 30% correct localization on average for the 0.1x font to 63% for the 0.8x font. However, our subjects benefited from this new source of information only for the larger shift in the right VF (+5% trigram recognition). This is much less than predicted by an ideal-observer, which would use positional information in addition to other types of visual information (prediction: between +10% and +20% recognition for most conditions). These results suggest that vertical shifts might be a useful source of visual information during digit crowding. However, shifting digits within numerals seems to disrupt other sources of visual information, such as inter-symbol features.

Acknowledgement: This work was supported by the Danish Council for Independent Research [grant number DFF – 7013-00039].

23.361 **Shape features learned for object classification can predict behavioral discrimination of written symbols** Daniel Janini[1](janinidp@gmail.com), Talia Konkle[1]; [1]Department of Psychology, Harvard University

After years of experience, humans become experts at recognizing written symbols. This learning process may form a new visual feature space highly specialized for distinguishing between letters of one's alphabet. Alternatively, recognizing written symbols may simply involve general shape features previously learned for object classification. Here, we assess the plausibility of the latter hypothesis. We measured the perceptual dissimilarity of all pairs of letters using a visual search paradigm. On each trial, participants (n=220) identified a target letter as quickly as possible among five distractors, for example identifying the letter 'a' among five 'b's. This procedure was completed for all letter pairs (325 parings) across twenty fonts. Next, we determined whether general shape features could predict the perceptual similarity space measured by this task. We used AlexNet trained on object classification as a model of a general shape space, as the learned features were never directly trained to distinguish between written symbols. We recorded responses within AlexNet to all 26 letters across the twenty fonts used in the behavioral experiment. Then we constructed a representational

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dissimilarity matrix (RDM) for each layer. Each RDM predicted variance in the perceptual similarity of letters (R2 = 0.21-0.50, noise ceiling = 0.73-0.83), with the best predictions being made with the mid-to-late layers. Next, we predicted the behavioral data using a weighted combination of features across all layers of AlexNet, accounting for most of the explainable variance (R2 = 0.66, noise ceiling = 0.73-0.83). These results provide a plausibility argument that perceiving and distinguishing written symbols can utilize the same general shape features as object recognition. Future work will determine if a feature space highly specialized for representing written symbols can predict human letter recognition as well as the general shape features used here.

23.362 **EEG-based decoding of visual words from perception and imagery** Shouyu Ling[1](shouyu.ling@mail.utoronto.ca), Andy C.H. Lee[1,2], Blair C. Armstrong[1,3], Adrian Nestor[1]; [1]Department of Psychology at Scarborough, University of Toronto, Toronto, Ontario, Canada, [2]Rotman Research Institute, Baycrest Centre, Toronto, Ontario, Canada, [3]BCBL. Basque Center on Cognition, Brain, and Language

Investigations into the neural basis of reading have made considerable progress in elucidating the cortical locus of orthographic representations. However, much less is known about "what" and "when" specific properties of a word are represented. Furthermore, the relationship between perception and imagery for visual words remains to be elucidated. Here, we capitalize on the structure of electroencephalography (EEG) data to examine the neural signature of word processing. Specifically, we investigated whether EEG patterns can serve for decoding visual words from perception and imagery in neurotypical adults. To this end, we collected data corresponding to 80 four-letter high-frequency nouns during a one-back repetition detection task and 8 such nouns during a mental imagery task. Then, EEG pattern analyses were conducted across time and frequency-domain features to classify the identity of the viewed/imagined words. Our results show that classification accuracy was above chance across participants both for perception and imagery. However, perception and imagery-based decoding relied on different information. Specifically, the former relied on spatiotemporal information in the proximity of the N170 ERP component recorded at occipito-temporal (OT) electrodes and on lower-frequency bands (i.e., theta and alpha). In contrast, the latter exhibited marked variability across participants over time and sites while relying predominantly on higher-frequency bands (i.e., beta and gamma). Further, EEG-based estimates of word confusability were well explained by visual-orthographic measures of word similarity, especially for perception. Thus, our results document the ability of EEG signals to support decoding of orthographic information. Moreover, they shed light on differences across the neural mechanisms underlying perception and imagery as well as on the visual-orthographic nature of neural word representations. More generally, the current findings provide a new window into word recognition in terms of underlying features, spatiotemporal dynamics, and neurocomputational principles.

23.363 **Visual Word Recognition as a Means of Addressing Top-Down Feedback** Simon M Kaplan[1](simonkaplan@gwu.edu), Chunyue Teng[1], Dwight J Kravitz[1]; [1]The George Washington University

Top-down feedback is an important yet poorly understood aspect of visual processing, due to an ambiguity in the involvement of bottom-up and top-down information in the processing of complex stimuli. For example, an apparent categorical or conceptual difference may be derivable from a feed-forward process based on simple visual statistics, particularly in familiar stimuli. Convolutional neural networks have evidenced a striking ability to successfully perform such tasks in the absence of any top-down feedback. Here, we present the first steps in a series of studies aimed at disentangling top-down and bottom-up effects by taking advantage of several unique aspects of visual word recognition. Words afford excellent control of their low-level characteristics, unambiguous involvement of non-visual information, and a high degree of localization of their cortical processing. To begin, we examined the word superiority effect (WSE) wherein letters are more quickly and accurately identified in words than pseudowords, taken to be indicative of top-down feedback. The current experiment is the first in a series of studies that will investigate whether WSE is modulated by semantics and direct physiological intervention. We hypothesized that frequency should modulate the strength of connections between every high-level system and the ventral temporal locus of letter recognition. As predicted, we found a strong correlation between word frequency and the strength of the WSE in both accuracy and reaction time. Further, the location within the US where a person lives was found to modulate the WSE by defining their familiarity with regionally specific words. Other manipulations, such as the addition of cognitive load, as well as priming of both orthographic and semantic neighbors, yielded modulations. These results demonstrate the potential utility of studying top-down feedback in the context of visual word recognition.

23.364 **Effort and Effortlessness in Visual Word Recognition** Adi Shechter[1](ashechter05@gmail.com), Tami Katzir[1], David L. Share[1]; [1]Department of Learning Disabilities, Edmond J. Safra Brain Research Center, Faculty of Education, University of Haifa, Israel

Perhaps the most distinctive characteristic of skilled reading is the sheer speed and effortlessness of the word recognition process. Among reading researchers, there is an impressive consensus that fast, near-effortless recognition of printed words (often referred to as "automatic" or "fluent" word reading) is crucial to successful reading development because it enables the reader to devote limited processing resources to text meaning (LaBerge & Samuels, 1974; Perfetti, 1985). In contrast, there is little agreement about how to define automaticity or fluency, or how to operationalize these concepts (Moors & de Houwer, 2006; Stanovich, 1990). We report a study examining the applicability of pupillometry to the study of cognitive effort in word reading. We compared pupil dilation (as well as reading accuracy and pronunciation latencies) for naming familiar and unfamiliar letter strings (varying in length) among university students. Luminance levels, frequency and emotional valence of the target items were matched across conditions. Participants' general mood and reading anxiety were also assessed. As anticipated, our data revealed a greater degree of cognitive effort, as assessed by pupil dilation, as well as lower accuracy and slower pronunciation latencies for unfamiliar (pseudoword) strings compared to familiar (real word) strings. In addition, the pronunciation of 5-letter pseudowords required more effort than 3-letter pseudowords as indicated by both greater pupil dilation and slower naming times. There were no length effects for familiar words. These findings, if replicated, not only open up new possibilities for studying the issue of effort and effortlessness in the field of visual word recognition, but also in clarifying the troublesome concepts of automaticity and fluency in word reading.

23.365 **Training peripheral vision to read: is the improvement due to increased temporal processing?** Deyue Yu[1](deyueyu@gmail.com), Ryan R Loney[1]; [1]College of Optometry, Ohio State University

Speed of information processing (e.g., how quickly letter identity and position is processed) plays an important role in reading. Previous study showed a positive correlation between processing speed of letter recognition and RSVP (rapid serial visual presentation) reading speed in people with central-vision loss (Cheong et al., 2007). When training these patients using RSVP reading task (Nguyen et al., 2011), increased reading speed was found to be correlated with reduced fixation duration. It is possible that faster temporal processing of letter recognition underlies the learning induced by RSVP reading training. To evaluate this hypothesis, we trained seven normally-sighted young adults using RSVP reading task at 10° in the lower visual field on five consecutive days. Each training session contains 130 sentences presented at five different speeds (46 to 732 words/minute). Before and after the training, RSVP reading speed, the size of visual span, and threshold duration for crowded letter recognition were measured at 10° above and below fixation. When comparing post- and pre-test performance, we found significant improvements in RSVP reading speed (90%) and temporal processing speed of crowded letter recognition (a reduction of 84ms in threshold duration) while the change in visual-span size was minimal. As expected, the post-pre ratio of temporal processing speed explained about 50% of the variance of the post-pre ratio of RSVP reading speed at the trained location ($r = 0.69$, $p = 0.045$). Learning also transferred to the untrained (upper) visual field. Our results confirmed the association between the improvement in reading speed and the increase of temporal processing speed in letter recognition. Training paradigm aiming to boost the speed of information processing may be more effective than the one focusing on improving spatial information processing.

Acknowledgement: EY025658

23.366 **Inter-hemispheric comparison of population receptive fields for visual cortical responses to words** Zhiheng Zhou[1](zhzhou44@gmail.com), Lars Strother[1]; [1]Department of Psychology, University of Nevada Reno

The degree to which neural responses in visual cortex vary as a function of stimulus category is a longstanding topic of vision science. The possibility of word-selective processing in visual cortex is supported by the results of numerous behavioral and fMRI studies, many of which suggest left-lateralized visual processing of word stimuli. In the current study, we hypothesized that left-lateralized word-selective visual processing would be reflected

in the results of population receptive field (pRF) modeling. We used fMRI to measure pRF properties in occipitotemporal cortex (OT) in response to words and non-word control stimuli to determine whether or not pRF properties differ between the two hemispheres. We also varied the format in which these stimuli were viewed, either individually or in the context of sentences displayed within a sweeping bar aperture. We found that left OT showed greater word-selective fMRI responses than right OT in the pRF estimation experiments, as well as in corresponding independent fMRI localizer experiments that allowed us to identify word-selective subregions of OT. More voxels in left OT showed pRFs for word than non-word stimuli. Additionally, word-selective subregions of left OT showed greater foveal bias for word stimuli as compared to non-word stimuli. This indicates a correspondence between pRF properties and word-selective visual processing. In contrast, no difference in pRFs was found between word and non-word stimuli in right OT. Word-selective left OT showed evidence of larger visual field coverage than word-selective right OT, which indicates left lateralization of pRFs.Lastly, we observed a greater number of word-selective voxels in left OT and larger coverage for the single word view experiment. These results provide new evidence for stimulus specific brain responses in the OT using pRF modeling, and support the idea that left-lateralized word-selective visual processing can be studied effectively using pRF estimation.

Acknowledgement: Research reported here was supported by the National Institute of General Medical Sciences (P20 GM103650)

23.367 **The spatiotemporal deployment of processing resources in developmental dyslexia** Simon Fortier-St. Pierre[1](simon.fortier-st-pierre@umontreal.ca), Martin Arguin[1]; [1]CERNEC, Département de psychologie, Université de Montréal

Various types of visual impairment have been documented in developmental dyslexia but their relation to the word recognition deficit remains unclear. The present study examined the spatiotemporal deployment of processing resources for visual word recognition in developmental dyslexics and normal reading adults. Participants performed a visual word recognition task using 200 ms stimuli (5-letter words) with randomly oscillating signal-to-noise ratio (SNR; noise component made of white noise) applied independently on each letter position. The total amount of signal over stimulus duration was normalized across letter positions and trials. SNR profiles were generated for each trial by integrating 5-60 Hz sinewaves (5 Hz steps) of random amplitudes and phases. Individual classification images of encoding effectiveness for each letter through time were constructed by the weighted subtraction of SNRs leading to errors from those associated with correct target identification. They were transformed into Z-scores by bootstrapping (1000 iterations) and normalized linearly to a 0-1 range. The same procedure was applied on time-frequency analyses of the SNRs for each trial to obtain a classification image of encoding effectiveness in the time-frequency domain. The mean temporal and time-frequency classification images of adult dyslexics were compared to those of normal readers matched on age and IQ. Temporal domain classification images did not differ between groups. However, a complex pattern of differences between groups was observed in the time-frequency domain, as shown by a significant interaction of group x letter position x time x frequency. The time-frequency classification images were strikingly similar across normal readers (average of pairwise correlations between participants and letters, r = .83) and across dyslexics (r = .86). The present results suggest that the spatiotemporal deployment of processing resources during word recognition, as revealed by the letter-position specific time-frequency profiles, is markedly different between impaired and normal readers.

Acknowledgement: This research was supported by a grant to Martin Arguin and a graduate scholarship to Simon Fortier-St-Pierre from the Fonds Québécois de Recherche en Nature et Technologies (FQRNT)

23.368 **Atypical topography of high-level visual cortex is associated with reading difficulty** Emily Kubota[1,2](ekubota@uw.edu), Jason D Yeatman[1,2]; [1]Institute for Learning & Brain Sciences, University of Washington, [2]Department of Speech & Hearing Sciences, University of Washington

Ventral temporal cortex (VTC) contains a mosaic of regions that selectively respond to specific categories of stimuli such as faces, objects and words. The spatial arrangement of these regions relative to sulcal folding patterns in VTC is highly consistent across individuals. For example, face-selective cortex (i.e., FFA) consists of two regions located on the fusiform gyrus and word-selective cortex (i.e., visual word form area, VWFA) is positioned immediately lateral to the fusiform, within the occipitotemporal sulcus (OTS). Here we test the hypothesis that developmental dyslexia, an impairment in fluid and accurate reading, is associated with an abnormal and sub-optimal layout of these functional regions. To test this hypothesis we used functional magnetic resonance imaging (fMRI) to localize face-, object- and word-selective regions on the cortical surface in 36 children (M = 10.05 years, SD = 1.49 years, n = 16 with dyslexia). We found a canonical topography for individuals with typical reading skills: VWFA was positioned lateral to FFA and located within the OTS. Individuals with dyslexia showed a variable topography: in a subset of subjects, VWFA was was positioned medial to FFA with a variable location, and not consistently within the OTS. This atypical organization has a number of consequences that might interfere with the development of skilled reading including: (1) fewer connections between the VWFA and language cortex as estimated with diffusion MRI, (2) a predominance of peripheral, as oppose to foveal, responsivity as measured with retinotopic mapping and (3) different cytoarchitecture as elucidated from published maps of cytoarchitectonic regions in VTC.

Acknowledgement: NSF BCS 1551330

Perceptual Organization: Figure ground, models, neural mechanisms

Saturday, May 18, 8:30 am - 12:30 pm, Pavilion

23.401 **Exploring perceptual illusions in deep neural networks** Emily J Ward[1](amyunimus@gmail.com); [1]Department of Psychology, University of Wisconsin-Madison

Perceptual illusions -- discrepancies between what exists externally and what we actually see -- tell us a great deal about how the perceptual system functions. Rather than failures of perception, illusions reveal automatic computations and biases in visual processing that help make better decisions from visual information. Recently, deep convolutional neural networks (DCNNs) have been very successful in a variety of complex visual tasks, such as object recognition. This success has inspired researchers to begin comparing internal visual representations of DCNNs to those of humans, and in many respects, these representations turn out to be similar, raising the question of whether DCNNs "experience" some of the same illusions that people do. To investigate this, I presented a DCNN trained for object classification (VGG16, trained on imagenet) with several standard illusions, including the Muller-Lyer illusion and examples of amodal completion. Instead of using object classification, I assessed how the DCNN "perceived" the illusions by computing the similarity between the layer activation response to the ambiguous form of the illusion and to several alternate, disambiguated forms (for example, comparing the response to an occluded shape to the response to the full shape vs. to an incomplete, notched shape). For the Muller-Lyer illusion, in all convolutional layers, the response to lines with two outward tails was more similar to objectively longer lines, compared to shorter lines (p< 0.001), consistent with human perception. However, the response to lines with two inward heads was also more similar to longer lines (p< 0.001), inconsistent with human perception. For amodal completion, the response to occluded shapes was consistently more similar to the incomplete, notched shapes (p=0.003), even when the shapes were real objects. These results suggest that despite human-level performance of DCNNs on object recognition, these networks do not demonstrate some of the fundamental behavior of the visual system.

23.402 **Primary Visual Cortex is Active in Response to Stimulation of Phenomenally Blind Areas of the Visual Field in Patients with Cortical Blindness** Colleen L Schneider[1,2,3](colleen_schneider@urmc.rochester.edu), Emily K Prentiss[4], Ania Busza[4], Kelly Matmati[5], Nabil Matmati[5], Zoe R Williams[4,6,7], Bogachan Sahin[4], Bradford Z Mahon[3,4,7,8]; [1]Department of Brain and Cognitive Sciences, University of Rochester, [2]Medical Scientist Training Program, University of Rochester School of Medicine and Dentistry, [3]Department of Psychology, Carnegie Mellon University, [4]Department of Neurology, University of Rochester Medical Center, [5]Department of Neurology, Rochester Regional Health, [6]Department of Ophthalmology, University of Rochester Medical Center, [7]Department of Neurosurgery, University of Rochester Medical Center, [8]Center for Visual Science, University of Rochester

Geniculostriate pathway lesions disrupt vision in the contralesional visual hemifield. Loss of tissue may not be the only cause of cortical blindness from these lesions. Careful inspection of previous functional MRI (fMRI) studies of patients with visual field defects reveals numerous cases of blind areas of the visual field with a preserved V1 response to visual stimulation ('blind voxels'). Here we describe the characteristics of blind voxels in stroke patients with homonymous visual field defects. We compared V1 activity (fMRI) with visual sensitivity (Humphrey perimetry) in 13 chronic stroke patients with cortical

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blindness. During fMRI, we presented 12 non-overlapping flickering wedges to map the retinotopic organization of visual cortex. The average number of blind voxels in V1 was significantly greater than zero (mean = 27.7, 95%, CI = 15.1-40.4 voxels) and was about one third of the average number of voxels activated for wedges presented in sighted areas of the visual field ('sighted voxels', mean = 96.7, 95%, CI = 81.3–112.2 voxels). These blind voxels were retinotopically organized. In 6 of the 13 patients we found that the number of blind voxels fell within the range of the number of sighted voxels. For example, in one subject, the number of voxels that responded to stimulation of a wedge presented in a blind area of the visual field ranged from 26-69 voxels, whereas this range was 20-274 voxels for wedges presented in sighted areas of the visual field. This observed dissociation between visual perception and V1 activity may be due to disordered information content in peri-lesional voxels such that the signal can no longer be read out as a visual percept. If the visual signal in blind voxels is merely disordered, it is possible that patients could recover some of their lost vision by learning a new read-out strategy.

Acknowledgement: F30EY027988 (CLS), R21NS076176 and R01NS089609 (BZM), Schmitt Program on Integrative Brain Research (BS and BZM), Research to Prevent Blindness to the Ophthalmology Department at the Flaum Eye Institute (ZRW), and P30EY001319 (BZM).

23.403 **Convexity vs. Implied-Closure in Figure-Ground Organization** Tandra Ghose[1](tandraghose@gmail.com), Ananya Mukherjee[1]; [1]TU Kaiserslautern, Germany

Convexity is a well established figural cue for figure-ground organization. However, it has an inherent implicit confound with closure based on the observation that if the shared-contour is extended on the convex side it will form a closed region. Thus, the relative influence of convexity and implied-closure is unknown. Here we describe our attempt to minimize this confound and empirically investigate whether convexity or implied-closure has a greater impact on determining figure-ground organization. The critical segment, "wings", of the contour is the part located near the top and bottom of the shared-contour that slightly curves around to intersect the perpendicular-borders of the bipartite image. We created conflict "incongruent" stimuli by flipping the wings about the vertical axis to imply closure on the side opposite to convexity. Control "congruent" conditions were created by moving the position of the flipped-wings away from the perpendicular-edge towards the center of the contour. This resulted in net convexity matched to the incongruent-condition while congruency between convexity and implied-closure was not affected. Stimuli consisted of 128 bipartite black-white images with: 2 shapes of shared-contour (circle/triangle) of 2 sizes each (small/large); 2 wing sizes depending on the base shared-contour size (range 7%-20% of entire length); position of wings along the shared-contour (1 incongruent "UpDown" and 3 congruent "Up", "Center", "Down"). They were black/white and left/right counterbalanced. The observers made a figure-ground judgment after viewing the stimulus for 1 second and responded with a mouse click on left/right response buttons. Data from 40 participants show that the percentage figural response for the side with both convexity and implied-closure is 70%. However, in case of conflict, figural response fell to 50% for convexity-only-side vs. implied-closure-only-side. We conclude that the convexity reported as the figural cue is effective only when present with implied-closure and not otherwise.

23.404 **Impact of the watercolor illusion on figure-ground reversibility** Ralph G Hale[1](ralph.hale@ung.edu); [1]Department of Psychological Science, College of Arts & Letters, University of North Georgia

Reversible (or unstable) figures such as Rubin's faces-vase (Rubin, 1915/1958) have long been used to probe and increase our understanding of underlying processes related to perceptual organization. Typically the faces-vase stimulus consists of a single central vase and an inward looking face on either side of the center that perfectly abuts the vase so that they share a common border. The reversibility of this stimulus is due to an ambiguous figure-ground organization. When the vase is perceived as the figure (i.e., when the central region is been interpreted as a vase) the faces are perceived as the ground, and vice versa. This results in a perception of either the faces or the vase approximately half of the time. The watercolor illusion (WCI) has been shown to increase the likelihood of a region being perceive as figure – even when that conflicts with various Gestalt cues for figure-ground organization (Pinna et al., 2001). The WCI occurs when a physically non-colored region surrounded by an outer contour and an inner fringe of contrasting hue appears filled in with a pale tint the same hue as the fringe. To test whether the WCI could selectively bias perceptions of the faces or the vase as figure, faces-vase stimuli were created in which the WCI inducing fringe was either in the faces, the vase, or did not exist. We found that participants saw the region containing the WCI as figure more often than the region without regardless of whether the WCI containing region was the faces or the vase, and participants saw the faces and vase approximately equally when no WCI was present. This experiment supports previous work suggesting the WCI has a strong figural component and is the first to incorporate the WCI into reversible figures.

23.405 **The Influence of Semantics on Figure Assignment: Unmasked Primes, Masked Primes, and Context** Rachel M Skocypec[1,2](rachelskocypec@email.arizona.edu), Mary A Peterson[1,2]; [1]Department of Psychology, University of Arizona, [2]Cognitive Science Program, University of Arizona

Can semantic activation before test displays affect figure assignment? Five experiments show the answer is yes, although context matters. Participants viewed black and white displays divided into two equal-area regions by a central border and reported which side they perceived as figure. One side depicted a familiar object (upright or inverted); the complementary side depicted a novel object. A word denoting either the familiar object at a basic level (BL) or an unrelated (UNR) different-category object preceded each display. In Experiment 1, where words were unmasked, Semantic Priming effects were observed: For both upright ($p < .001$) and inverted ($p < .03$) displays, reports of perceiving the figure on the familiar side of the border (Fam = Fig) were significantly greater following BL than UNR primes. Semantic Context effects were also observed: Independent of prime type, Fam = Fig reports were substantially greater for inverted displays than had previously been observed without primes. Thus, processing word meaning induces upweighting of familiarity as a figural prior. In Experiments 2–5 words were masked. Effects observed varied with both prime-display SOA (100ms or 170ms) and whether an induction task preceding the masked word emphasized meaning or perceptual features. For 100ms SOAs, both Semantic Context effects and Semantic Priming effects were observed when the induction task emphasized meaning ($p < .005$; Experiment 2), but not when it emphasized perceptual features ($p > .55$; Experiment 3). For 170ms SOAs, which allowed more time for semantic activation, Semantic Context effects were observed following both induction tasks, suggesting that the semantic induction task in Experiment 3 speeded semantic processing of the prime. These results suggest that (a) expectations regarding specific objects can increase the probability of perceiving a region suggesting that object as figure, and (b) the familiarity prior is upweighted in contexts where meaning is emphasized.

Acknowledgement: ONR 00014-14-1-067

23.406 **Further exploration of antagonistic interactions in figure-ground perception** Jaeseon Song[1](jaeseon.song@uga.edu), James M Brown[1]; [1]Department of Psychology, University of Georgia

Weisstein, Maguire, and Brannan (1992) proposed antagonistic interactions of dorsal-M and ventral-P streams both within a region and between regions play a central role in figure-ground perception. Based on this model, a region with a stronger ventral-P biased "Figure Signal" is perceived as figure, whereas a region with a stronger dorsal-M biased "Ground Signal" is perceived as ground. Last year we reported results supporting their model using an artificial scotoma paradigm where a small, peripherally viewed target figure fades into the background. Using red and blue light to reduce dorsal-M activity, fade times for color combinations involving red or blue were longest whether those colors were in the target, strengthening its Figure Signal, or in the background, weakening its Ground Signal (Plummer, Brown, & Song, VSS, 2018). In the present study, we tested their model further using figure-ground reversible Maltese crosses. The crosses were either figure-ground ambiguous consisting of left- and right-tilting sectors of equal area (Exp 1) or figure-ground biased consisting of small sectors oriented vertical/horizontal, biased to be seen as figure, compared to larger, obliquely oriented sectors biased to be seen as ground (Exp 2). We measured the duration the alternate crosses were perceived as figure, testing every possible color combination of red, blue, green, and gray. Red and blue were expected to reduce dorsal-M activity thereby strengthening the Figure Signal/weakening the Ground Signal in those sectors resulting in them being seen more often as figure compared to green and gray. Red sectors were perceived as figure more often compared to the other colors in both experiments. Blue sectors were not. The present results provide further support for Weisstein et al's model while also indicating red was more effective than blue at reducing dorsal-M activity for our centrally viewed figure-ground stimuli.

23.407 **Response dependence of reversal-related ERP components in perception of Ambiguous Figures** Diane Abdallah[1](da401@kent.ac.uk), Joseph Brooks[2]; [1]School of Psychology, University of Kent, [2]School of Psychology, Keele University

Perceptual multi-stability is characterized by alternating interpretations of stable stimulus input. The time-course and nature of neural processes related to these endogenous perceptual reversals have been studied with event-related potentials by measuring the Reversal Negativity (RN) and the Reversal Positivity (RP) components. However, it is debated to what extent these components reflect perceptual processes or top-down, task-related processes. To address this issue, we presented ambiguous Necker Lattice and Rubin's Faces-Vase stimuli under two different task conditions. In the standard reversal task used in previous studies, participants indicated whether or not they saw a perceptual reversal on each trial. In contrast, in the identity task, participants reported the perceived orientation of the stimulus in the Necker Lattice experiment and whether they saw faces or a vase in the Face Vase experiment without any reference to reversals. We found that the RN component appeared independently of the task and for both stimuli. However, the early latency RP component was only present on trials where participants responded manually. For non-response trials, the polarity of this effect was reversed. Our results suggest that the early RP component is sensitive to response-related processes and thus is not a neural signature of pure stimulus processes related to endogenous perceptual reversals.

23.408 **Concentric Bias of Surround Suppression in Early Human Visual Cortex** Juhyoung Ryu[1](jh67753737@gmail.com), Sang-Hun Lee[1]; [1]Brain & Cognitive Science, Seoul National University

It is important to detect meaningful objects rapidly and accurately in a natural scene, which is typically cluttered with many distracting stimuli. Here we focus on image statistics that concentrically orientated contours become prevalent as a meaningful object enters the foveal region of the visual field during visual search. This is so because typical meaningful objects (e.g., fruits in foraging context or human faces in social context) are likely to have edges consisting of concentric contours. One possible strategy of exploiting this natural prior at the low level of visual system is to enhance the salience of concentric contours either by facilitating neural responses to those contours, or by suppressing responses to distractors, or both. To explore these neural implications of concentric contour processing, we acquired fMRI response timeseries of human early visual cortex (V1-3, n=29) to concentrically and radially oriented Gabor patches that drift slowly along the polar axes over the visual field (8° in eccentricity). We then compared the amounts of surround suppression between the 'concentric' and 'radial' conditions by fitting a difference-of-Gaussian receptive-field model (Dumoulin and Wandell, 2012) to the fMRI timeseries separately to concentric and radial Gabor patches. Surround suppression effects were greater in the concentric than in the radial condition. The multiple regression analysis further showed that the concentric bias in suppression was quite robust yet substantively modulated by the retinotopic position of local cortical sites: the concentric bias was pronounced around the foveal region and along the oblique meridian in the lower visual field. Our results suggest that the visual cortical system forms salient representations of concentrically oriented edges at its earliest stage by augmenting its suppressive responses to the surround.

Acknowledgement: Supported by the National Research Foundation of Korea (NRF-2015M3C7A1031969, NRF-2018R1A4A1025891)

23.409 **Dissociable properties of gamma range activity in human early visual cortex when viewing gratings and natural images** Eleonora Bartoli[1](eleonora.bartoli@bcm.edu), William Bosking[1], Ye Li[1], Michael Beauchamp[1], Daniel Yoshor[1], Brett Foster[1]; [1]Neurosurgery Department, Baylor College of Medicine

'Gamma' range activity is often proposed to support perceptual processes by coordinating neural activity within and between visual areas. Historically, studies using non-human primate electrophysiology have repeatedly observed narrowband gamma oscillations (30-70 Hz) within early visual cortex in response to visual stimuli. In contrast, studies using human intracranial electrophysiology have often emphasized a broadband 'high-gamma' range activity (e.g. 70-150 Hz). Growing evidence suggests that these two signals in the gamma range reflect different biophysical processes and display distinctive stimulus dependencies. To quantify these differences, we employed high-density intracranial recordings from human visual cortex. We presented participants (n=7) with large field static grating stimuli (1 cycle/degree) at three contrast levels (20, 50, 100%). A subset of participants (n=5) also viewed grey-scale natural images from several visual categories (faces, houses, etc.). Spectral analyses revealed that grating stimuli induced both narrow and broadband gamma activity. Broadband gamma activity was transiently increased at stimulus onset and offset, with a fast onset time (~80ms). Signals in the narrowband gamma range occurred later (~130ms) and were sustained throughout stimulus presentation. In addition, narrowband gamma showed a clear central frequency (spectral peak), which was dependent on stimulus contrast, and increased with higher contrast levels (36 Hz at 20%; 40 Hz at 50%; 44 Hz at 100%). However, mean responses to naturalistic images displayed large broadband gamma range increases, but lacked narrowband gamma spectral peaks. Overall, our findings further develop prior observations made in human and non-human primate visual cortex, suggesting highly dissociable and stimulus dependent properties of narrow and broadband gamma activity. These findings have important implications for the functional significance of gamma range activity and how signals in this range should be quantified and interpreted.

Acknowledgement: R00MH103479 R01MH116914

23.410 **Defining the locus of adaptive changes in visual cortex during associative learning** Maeve R Boylan[1](mboylan@ufl.edu), Harold A Rocha[1], Andreas Keil[1]; [1]Department of Psychology, College of Liberal Arts and Sciences, University of Florida

Decades of research have shown that different stimulus dimensions engage different cortical areas along the traditional visual hierarchy. For example, neuronal populations in the primary visual cortex strongly respond to oriented gratings while more complex stimuli, such as dot motion kinematograms or faces, engage higher level visual areas like area MT+/V5 and occipito-temporal face-sensitive areas, respectively. Extensive associative learning (e.g., fear conditioning), with exemplars taken from a specific stimulus dimension, systematically alters visuocortical responses to this dimension. Electrophysiological studies in humans, however, tend to conflate area-specific effects with stimulus onset effects, i.e., responses to low-level contrast or luminance changes associated with stimulus presentation over a blank screen. Thus, alternative hypotheses exist stating that associative learning (i) always involves changes in primary visual areas, irrespective of the feature dimension manipulated, versus (ii) selectively involves the tissue most sensitive to the feature dimension relevant for learning. In the present study, we used the steady-state potential technique and a classical aversive conditioning paradigm in which one exemplar from three stimulus dimensions along the visual hierarchy were selectively paired with an aversive outcome: sinusoidal gratings (Gabor patches), dot motion kinematograms, and faces. We minimized luminance changes across the trial by adding the stimuli to visual Brownian noise which was regenerated before each trial. We estimated the sources of the ssVEP using an L2 (minimum norm) inverse projection (n = 22) and examined the differences between conditioned stimuli paired (CS+) or not paired (CS-), with an aversive loud noise, using mass-univariate permutation-controlled F-tests. Results indicate that associative learning effects (measured as the difference between CS+ and CS-) involve separate and distinct brain regions: calcarine cortex for Gabor patches, mid-occipital gyrus for visual motion, and temporal cortex for faces. Thus, adaptive changes in visual cortex selectively occur in areas most sensitive to the critical stimulus dimension.

23.411 **Attenuated brain responses to Gestalts at threshold: differential predictive processing behind Gestalt phenomena?** Thiago L Costa[1, 2](thiago.leiroscosta@kuleuven.be), Andrey R Nikolaev[2], Cees van Leeuwen[2], Johan Wagemans[1, 2]; [1]Laboratory of Experimental Psychology, KU Leuven - Belgium, [2]Brain and Cognition research unit, KU Leuven - Belgium

The aim of this work was to assess bias and expectation effects towards Gestalts and their corresponding neural correlates, in a task with minimal visual search or salience confounders. We presented stimuli at threshold to equate task difficulty and salience between different stimulus types. By making target discrimination more demanding, we make room for stronger expectation effects. We used a change detection task to measure responses to the emergent features of proximity and orientation. The base stimulus was a pair of dots. The dots could change in their configuration (orientation / proximity, i.e. Gestalt conditions) or change location without changing configuration (two control conditions, moving horizontally or vertically). To assess expectations, we had two types of blocks: blocks where only one stimulus type was presented (blocked condition) and blocks where all stimuli were presented with equal likelihood (mixed condition). We performed a QUEST psychophysical procedure (manipulating the amount of displacement of the dots) prior to the EEG recording to ensure that all stimulus types were presented at 81% correct performance levels for each participant. In summary, the task measures implicit expectations, without substantial target selection or distractor suppression demands and requires no classification

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of stimulus type: responses are based on change of location. As planned, we found no relevant significant differences between stimulus types at accuracy or RTs (except for proximity being different from control in one of the blocks). Analyses of the P1, N1, P2 an P3 event-related potentials showed that Gestalt conditions generally led to smaller responses than control conditions (significant from N1 to P3). This effect was larger in the mixed condition and also larger for orientation. Analyses of prestimulus activity will be performed, but these results already provide initial support for the hypotheses derived from reverse hierarchy theory and predictive coding models of visual processing.

Acknowledgement: EU Marie Sklodowska-Curie Fellowship #795043 granted to TLC and METH/14/02 awarded to JW.

23.412 **Word signs recruit the visual word form area in proficient signers** Jodie Davies-Thompson[1,2,3](jdthompson@eyecarecentre.org), Carly Anderson[2], Douglas EH Hartley[2], Olivier Collignon[3,4]; [1]Swansea Univeristy, School of Psychology, College of Human and Health Sciences, [2]Nottingham Biomedical Research Centre, University of Nottingham, [3]Crossmodal Perception and Plasticity Lab, Centre for Mind/Brain Sciences, Trento, [4]Psychological Sciences Research Institute, Université Catholique de Louvain, Belgium

Background: The inferotemporal cortex contains a specific region that preferentially respond to written words (the visual word form area; VWFA); however, it is unclear what drives the functional development of this region. It has been suggested that reading recruits this left inferotemporal region because it originally implements a perceptual repertoire of junction detectors applied on information coming from foveal vision. Here, we investigate the contrasting hypothesis that the functional preference of VWFA is partially independent of the low-level properties of the visual input, and is more dependent on its connections with language regions. To do so, we tested whether VWFA shows functional tuning to written and signed words in proficient signers - two highly different visual symbolic codes that deliver linguistic content in separate format. Methods: We presented hearing participants (n=12), deaf participants who were fluent sign language users (n=12), and hearing participants who were fluent sign language users (n=12), with short videos of written words and signed words using an fMR-adaptation design. Results: We found adaptation to written words in the VWFA, as well as adaptation to signed words, in both deaf signers and hearing signers. Interestingly, the absence of crossmodal adaptation between signs and words suggest that they rely on partially different brain representation in these two groups of signers. In contrast, participants who did not know sign language only showed adaptation to written words. Conclusion: Our results indicate that the development of word-selectivity in VWFA does not dependent on specific low-level visual information (e.g. edges, high-spatial frequencies, or foveal vision), but rather support the theory that the primary role of this region might be to provide a representation that is suitable for mapping visual word forms onto linguistic representation, even in people without aural experience.

23.413 **What can be inferred about independence and invariance of brain representations from fMRI decoding studies?** Sanjay Narasiwodeyar[1](snara025@fiu.edu), Fabian A. Soto[1]; [1]Department of Psychology, Florida International University

Many research questions in vision involve determining whether stimulus properties are processed independently in visual cortex. Unfortunately, most previous research has only vaguely defined what is meant by "independence," which hinders its precise quantification and testing. Here, we develop a new framework that links general recognition theory from psychophysics and encoding models from computational neuroscience. We focus on separability, a form of independence equivalent to the concept of "invariance" often used in vision science. This new framework allows us to precisely define separability of neural representations and to theoretically link such definition to psychophysical and neuroimaging tests of independence and invariance. In particular, the theory identifies exactly what valid inferences can be made about independent encoding of stimulus dimensions from the results of multivariate analyses of neuroimaging data. In addition, two commonly used operational tests of independence are re-interpreted within this new theoretical framework, providing insights on their correct use and interpretation. We validated this extended general recognition theory in an fMRI study involving gratings varying in orientation and spatial position. Participants completed 4 two-hour sessions in the MRI scanner, in which they were presented with oriented gratings varying in orientation in 45-degree steps (0, 45, 90, and 135 degrees) while they fixated to the center of the screen. Stimuli were presented in 3 different spatial positions in the visual field. The known features of receptive fields in the primary visual cortex led us to expect that changing the position of stimuli should systematically change encoding separability of orientation, with lower separability for stimuli positioned farther apart. Our results show that decoding tests developed within the proposed framework can validly detect failures of encoding separability, but decoding tests in general (including tests in the literature) cannot validly detect presence of encoding separability, or "invariance," without producing false positives.

23.414 **Perception of Apparent Motion is Constrained by Geometry, not Physics** Yaxin Liu[1](yliu668@emory.edu), Stella F. Lourenco[1]; [1]Department of Psychology, Emory University

Apparent motion is a robust perceptual phenomenon in which observers perceive a stimulus traversing the vacant visual space between two flashed sitmuli. Despite a wealth of research on apparent motion, it remains unknown whether the underlying perceptual mechanism is constrained by principles of geometry or physics. We tested the geometry hypothesis against Newtonian mechanics in two experiments. Experiment 1 used a modified "window" paradigm (McBeath & Shepard, 1989), in which participants adjusted the position of a gap to indicate their perception of apparent motion. A Pacman-shaped object was presented in succession across two positions for 550 ms, differing by 0° to 120° in steps of 30°. Participants adjusted gap position to allow the object to pass through it smoothly. We found that adjusted gap position increased linearly with angular disparity, consistent with a curved path of motion defined by the unique center of rotation, as predicted by kinematic geometry, rather than a straight path constrained by the object's center of mass, as predicted by Newtonian mechanics. This finding suggests that the perception of apparent motion abides by kinematic geometry. To test this conclusion more directly, participants in Experiment 2 were given a target detection task in conjunction with concurrent apparent motion (Yantis & Nakama, 1998). Similar to Experiment 1, a Pacman-shaped object was briefly presented in alternation (90° differences). Participants were instructed to respond as soon as they detected the target. We found that participants' RTs were significantly longer when a target appeared on a curved path, compared to a straight path, suggesting that apparent motion, as predicted by geometry, disrupted target detection. Taken together, our findings suggest that the "filling-in" perception of apparent motion is guided by principles constrained by geometry but not physics.

23.415 **An image computable model of visual shape similarity** Yaniv Morgenstern[1](yaniv.morgenstern@psychol.uni-giessen.de), Filipp Schmidt[1], Frieder Hartmann[1], Henning Tiedemann[1], Eugen Prokott[1], Guido Maiello[1], Roland Fleming[1]; [1]Psychology, Justus-Liebig-Universität Gießen

Shape is one of the most important sources of visual information about objects. When presented with sets of unfamiliar objects, we can usually judge how similar or different they are from one another. Yet there are many possible features that could provide the basis for such judgments. How does the visual system compute similarity relationships between shapes? Here, we developed and tested a model of human visual shape similarity ('ShapeComp'), based on 94 image-computable shape features (e.g., area, compactness, shape context, Fourier descriptors). To test the model, we trained Generalized Adversarial Networks (GANs) on thousands of silhouettes of animals. Drawing samples from the latent space learned by the network allows us to synthesize novel 2D shapes that are related to one another in systematic ways. We created 8 sets of 24 shapes of novel naturalistic shapes. Using a multi-arrangement method (Kreigeskorte and Mur, 2012), observers dragged shapes into spatial configurations in which distances represent perceived shape similarity within each set. Representational Similarity Analysis revealed that human shape similarity was highly correlated with feature distance in the GAN's latent space. We then compared human shape similarity judgements to the predictions of ShapeComp, where the weights of the model's features were established by fitting on a training set of human judgements. In untrained test sets, the results reveal that ShapeComp accounts for most of the variance in human shape similarity. Using carefully selected stimulus sets, we can tease apart the relative importance of different features in the model, and evaluate the successes and failures of ShapeComp in predicting a host of phenomena related to shape, materials and visual appearance more generally. Together, these findings show that ShapeComp is a powerful tool for investigating the representation of shape and object categories in the human visual system.

Acknowledgement: This research was supported by an ERC Consolidator Award (ERC-2015-CoG-682859: 'SHAPE') and by the DFG (SFB-TRR-135: 'Cardinal Mechanisms of Perception'). Guido Maiello was supported by a Marie-Skłodowska-Curie Actions Individual Fellowship (H2020-MS-CA-IF-2017: 'VisualGrasping' Project ID: 793660).

Visual Memory: Encoding, retrieval

Saturday, May 18, 8:30 am - 12:30 pm, Pavilion

23.416 **An investigation on the influence of prior experience on working memory representations** Diana C Perez[1](dianaperez@email.arizona.edu), Mary A Peterson[1,2]; [1]Department of Psychology, University of Arizona, Tucson, AZ, [2]Cognitive Science Program, University of Arizona, Tucson, AZ

Previously we showed that familiar objects appear sharper than equally blurry novel objects when presented simultaneously. We hypothesized that the perceived sharpening of the familiar object results from the integration of long-term memories (LTM) (likely to be sharper on average) with the input, resulting in a percept that is sharper than what was presented on the screen. Such integration could not occur for novel objects, lacking previous experiences. Schurgin et al. (2018) showed that long-term memories (LTM) can replace active maintenance in working memory (WM). In the present study, we investigated whether the substitution of sharper LTMs for familiar than novel objects can alter matches in a WM task. Participants saw a blurry object for 180ms (standard); after a 500ms ISI, a test version of the same object was shown (180ms). The standard blur level was 5, 7, or 9; the test blur level was either equal to the standard or one or two levels above or below it. Participants' task was to report whether the test object was the same or different level of blur as the standard. Trials testing perception of a familiar object (a lamp) or a novel object created by spatially rearranging the parts of the familiar stimulus were intermixed. We expected that if LTM replaced the standard in WM, test object choices would be sharper for familiar objects than for novel objects. Preliminary results show no significant difference between the blur value at which the familiar and novel test objects are perceived as equal to the standard ($p=0.15$, $n=19$). We plan to test whether the lack of an effect is due to the long ISI, to using the same object as standard and test, or to interference with WM caused by presenting the standard and test stimuli in the same location.

Acknowledgement: Office of Naval Research

23.417 **Comparing the categorical structure of perceived and recalled images in visual cortex and hippocampus** Wilma A Bainbridge[1](wilma.bainbridge@gmail.com), Elizabeth H Hall[2,1], Chris I Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, [2]Department of Psychology, University of California Davis

When we view an image, visual regions of the brain automatically respond to various properties of the image, including its category, size, and content. Recent work has shown that the visual information we freely recall from memories is highly detailed (Bainbridge et al., 2018). However, it is still largely unknown how content-based representations of stimuli during perception compare to those of free recall in the brain. In this study, participants (N=22) in a 7T MRI performed a free recall task in which they studied an image for 6s, followed by a 6s distractor task with separate images, and then were asked to freely recall the original image (6s) and then indicate vividness of their memory. In contrast to many prior studies, the recall did not require the learning of any stimulus associations and all stimuli were trial-unique. The 192 stimuli were organized in nested categorical structure: objects varying along two factors of big/small and tool/non-tool, and scenes varying along the factors of open/closed and natural/manmade. Each of these categories contained three object or scene types (e.g., guitar, living room), with eight exemplars of each type. Following the scan, participants were given a surprise recognition memory test. We find that key visual regions (e.g., the parahippocampal place area, lateral occipital cortex) contained information during encoding predictive of recognition and recall performance, while the hippocampus reflected recall vividness. Visual regions also showed categorical structure at all levels (object vs. scene; open vs. closed; guitar vs. cupcake) during both encoding and recall. Interestingly, while the hippocampus showed sensitivity to broad stimulus category during encoding, it did not show clear evidence for sub-categorical structure. In sum, we find preserved fine-grained categorical representations in visual regions during both encoding and recall, while the representational structure may change in more memory-related regions.

Acknowledgement: Intramural Research Program (IRP) at the National Institutes of Helath

23.418 **Temporal Boundary Extension in the Representation of Actions** Gennady Erlikhman[1](gennady@ucla.edu), Hongjing Lu[1,2]; [1]Department of Psychology, UCLA, [2]Department of Statistics, UCLA

We sometimes remember more than what we have seen: in the Boundary Extension effect we remember a wider view of a scene than the original image. We examined temporal boundary extension (TBE) in action perception: do observers remember seeing more frames of a movie than was shown? In Experiment 1, observers viewed short YouTube movies of solo actions, human-object interactions, or human-human interactions. After a mask, a test clip was shown from either long before the start of the first movie, right before the start, right at the start, halfway through middle, right before the end, right after the end, or long after the end. Observers reported their confidence in whether or not the test clip was seen in the first movie. We found more false memories for test clips of single actors for events before the movie started, and more false memories for clips of human interactions of events from after the movie ended. Memories of events were extended to the past for solo actions, but extended to the future for interactive activities. As a control condition, the same movies and test clips were also shown backward in time, which revealed no difference between the movie types, suggesting that extension was not due to local motion prediction. In Experiment 2, we used point-light actors without scene backgrounds. Videos depicted either two people performing one of four interactions or only showed one of the two individuals in action. As in Exp. 1, backward TBE to the past was observed for solo actions, while forward TBE to the future for two-person actions. These results suggest that action representations encoded in memory are extrapolated beyond the visual input, and the temporal direction of such extrapolation depends on the degree of action prediction evoked by the stimuli.

Acknowledgement: NSF grant BCS-1655300 to H.L.

23.419 **More than statistics: Active hypothesis testing during visual learning** Kathryn N Graves[1](kathryn.graves@yale.edu), Nicholas B Turk-Browne[1]; [1]Yale University

Regularities in visual experience allow learning of relationships between objects over space and time.Such visual statistical learning (VSL) is typically viewed as relying on incremental accumulation of evidence about object co-occurrence.However, because of the large number of objects we encounter, the number of potential co-occurrences is astronomical.Here we test an alternative learning algorithm involving "hypothesis testing", in which associations encountered even once are presumed real. These hypotheses become a source of predictions that refine learning: when the predictions are fulfilled, the current hypotheses are retained; when violated, hypotheses are dropped and new ones adopted.To evaluate how this algorithm supports VSL, we presented participants with a series of scenes and objects.On double-object trials, always following trials with one scene, participants chose which of the two objects "went with" the preceding scene (their hypothesis).Each scene appeared three times and participants were instructed that the correct object would be consistently shown after the same scene. Crucially, there were no correct object-scene pairings.On the second scene presentation, half of object hypotheses proposed on the first presentation were violated.On the third presentation, half of these revised hypotheses were again violated and half of the hypotheses that had been verified on the second presentation were now violated.Memory was tested by cuing with scenes and having participants choose with which objects they had appeared.Choice behavior was explained by both joint probabilities (irrespective of choice) and hypothesis testing, with a slight advantage to hypothesis testing. Memory accuracy tracked what happened on the final scene presentation, with increasing accuracy from baseline to proposed to verified, but no difference between verified and reverified (implying that a single verification can saturate a hypothesis with evidence). These findings suggest hypothesis testing is a rapid but rigid alternative to brute force statistical learning.

Acknowledgement: NIH R01 MH069456

23.420 **Encoding context overlap facilitates learning of common structures among similar visual events** Ghootae Kim[1](kimghootae@gmail.com), Su Keun Jeong[1], Brice Alan Kuhl[2]; [1]Cognitive Neuroimaging Lab., Korea Brain Research Institute, [2]Department of Psychology, University of Oregon

Our experience is highly repetitive, with similar events appearing repeatedly over time in different contexts. While it is crucial to form and maintain separate visual long-term memories of similar experiences, the memory system should also be able to learn structures common to those experiences. How does the memory system balance forming separate memories vs. extracting

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commonalities across overlapping experiences? Here we tested whether overlap of encoding contexts facilitates integration of similar events, leading to greater structural knowledge of related experiences. We tested this idea in a series of behavioral studies consisting of encoding and memory test phases. In the encoding phase, four similar exemplars from each of different scene categories were presented (e.g., factory1, ..., factory4). Crucially, for half of the categories, the exemplars were presented within the same encoding run (Within-context condition); for the other half of the categories, the exemplars were encoded across different runs (Across-context condition). In the subsequent memory test administered a day later, participants performed an old/new recognition test for a subset of the previously presented exemplars (old items) with novel exemplars from the same categories serving as lures. We specifically hypothesized that the encoding context overlap in the within-context condition would promote categorical knowledge compared to the across-context condition. This hypothesis was strongly supported by behavioral results. Namely, the within-context condition was associated with increased false memory for lures as well as increased true memory for the old items, suggesting a general strengthening of category-level information. However, this pattern was eliminated in a separate study when the memory test was administered immediately after the encoding phase, suggesting that encoding context overlap between similar experiences, rather than initial encoding strength, affects learning of categorical knowledge. These findings shed light on how the memory system acquires structural knowledge across overlapping visual experiences.

Acknowledgement: 18-BR-01-07 & IBS-R001-D1-2018-b01

23.421 **Are eye movements beneficial for memory retrieval?**
Hikari Kinjo[1,2](kinjo@psy.meijigakuin.ac.jp), Jolande Fooken[2,3], Miriam Spering[2,4]; [1]Faculty of Psychology, Meiji Gakuin Universtiy, Tokyo, Japan, [2]Dept. Ophthalmology & Visual Sciences, University of British Columbia, Vancouver, Canada, [3]Graduate Program in Neuroscience, University of British Columbia, Vancouver, Canada, [4]International Collaboration on Repair Discoveries, Institute for Computing, Information and Cognitive Systems, and Djavad Mowafaghian Center for Brain Health, University of British Columbia, Vancouver, BC, Canada

When remembering an object at a given location, observers tend to return their gaze to this location even after the object has disappeared, known as the Looking-at-Nothing (LAN) phenomenon. However, it is unclear whether the LAN phenomenon is associated with better memory performance. Previous studies reporting beneficial effects of LAN have not systematically assessed eye movements. Here we related memory performance to eye movements during memory retrieval— saccades in a free-viewing condition and microsaccades in a fixation condition. In each trial, observers (n=19) had to remember eight images of objects shown for 5 seconds, during which observers could freely move their eyes. Object pairs were shown at 12, 3, 6 and 9 o'clock at a distance of 6 degrees from screen center. At the end of each trial, observers indicated by button press whether an auditory statement about an object's location (e.g., "Pineapple up") was correct, incorrect, or whether the prompted object had not been shown. Results show similar memory accuracy in free-viewing and fixation conditions (85% vs. 88%). Our eye movement analysis revealed that in only 62% of free-viewing trials observers made saccades. Yet, memory accuracy did not differ between free-viewing trials in which observers did or did not move their eyes (82% vs. 89%). Similarly, in the fixation condition we did not find a benefit of microsaccades (88% memory accuracy with vs. 89% without microsaccades). The LAN phenomenon was observed in free-viewing trials in which observers made saccades, and performance tended to be superior in those trials. However, given the global lack of memory performance differences between eye movement conditions we conclude that eye movements are not necessary for accurate memory retrieval. These results may explain why previous literature shows contradictory findings on beneficial effects of LAN.

Acknowledgement: NSERC Discovery Grant and Accelerator Supplement to MS

23.422 **Low-level object properties impact memory reconsolidation**
Jean-Maxime Larouche[1](jean-maxime.larouche1@uqac.ca), Frederic Gosselin[1]; [1]Department of Psychology, University of Montreal

When a consolidated memory is reactivated, it becomes unstable and can be modified before being reconsolidated (e.g. Schiller & Phelps 2011; Elsey, Van Ast et al., 2018). In the new learning paradigm—the most commonly used in human studies of memory reconsolidation— a new learning interferes with an old one when learned as long as a 6 hours after the reminder of the old learning (Nader et al., 2000). This interference increases with the similarity between old and new learning sets on a number of high-level attributes (for a review, see Crowder, 2014). Here, we tested for the first time if this extends to the similarity between low-level visual properties of objects from an old and a new learning set. Two subject groups learned to discriminate two sets of target from non-target faces over 3 sessions 24 hours apart: on day 1, subjects learned face set A; on day 2, they recalled face set A and learned face set B; on day 3, they recalled face set A again. Stimuli were 185 filtered neutral faces from the Chicago Face Database. In subject group 1, the spatial frequencies of face set A and face set B were filtered with the same log-polar checkerboard in the Fourier domain (like the one described in Yue et al., 2006) whereas, in subject group 2, the spatial frequencies of face set A and face set B were filtered with complementary log-polar checkerboards in the Fourier domain. Results indicate that the similarity of orientations and frequencies between face sets increases significantly the number of interferences.

23.423 **The effect of unprovoked eye movements during visual working memory retention**
Carly J. Leonard[1](carly.leonard@ucdenver.edu), Alexander S. Morales[1]; [1]Department of Psychology, University of Colorado Denver

Visual working memory is a limited-capacity system which can represent information over brief time periods in the absence of the visual stimuli. How the mechanisms responsible for this working memory maintenance relate to the systems of visual attention that are involved in eye movement generation has long been investigated. However, the vast majority of this research has measured memory performance under a steady-fixation condition compared to other conditions that either required eye movements or intentionally induced eye movements by presenting stimuli. In the current experiment, our goal was to examine the natural occurrence of eye movements in a VWM task in which participants were given no specific instructions regarding eye movement behavior. Participants completed a typical visual working memory task in which a number of colored squares (2, 4, or 6) appeared briefly. After a 1-second delay period, a single item reappeared and participants had to judge whether its color was the same or different as the object previously at that location. In a critical analysis, we examined the mean number of eye movements that occurred during the blank delay period as a function of subsequent accuracy. Trials that were ultimately correct had significantly fewer unprovoked eye movements during the delay than those trials that were ultimately inaccurate. Generally, this finding supports overlap between some component of eye movement generation and/or production and memory maintenance. Such differences in eye movement behavior across trials and between participants may be an important contributor to working memory performance overall. However, the degree to which this behavior is strategic will require further investigation.

23.424 **Unintentional forgetting is beyond cognitive control**
Emma Megla[1](megla.3@buckeyemail.osu.edu), Bernadette Dezso[1], Ashleigh M Maxcey[1]; [1]The Ohio State University

Intentional forgetting refers to the attempt to marshal top-down control to purposefully forget, and has been demonstrated in the laboratory using directed forgetting paradigms. Here we asked whether the mechanisms of top-down control can run in the opposite direction to prevent the forgetting of information. That is, can we actively resist unintentional forgetting. Recognition-induced forgetting is an unintentional forgetting effect in which accessing one memory leads to the forgetting of related memories. We showed subjects a ten-minute video to teach them about the recognition-induced forgetting paradigm and how recognition of certain objects unintentionally leads to forgetting of semantically related objects. After testing their comprehension of the video, we conducted a typical recognition-induced forgetting experiment and challenged the subjects to resist this form of unintentional forgetting. Despite their knowledge of the forgetting effect, and the challenge to subjects to resist the forgetting induced by the paradigm, recognition-induced forgetting persisted. We found that a minority of subjects were able to resist the forgetting effect but this resistance was not enough to eliminate the effect when averaging across subjects. These results show that knowledge of this unintentional forgetting phenomenon and the challenge to resist forgetting do not eliminate it, suggesting that it is cognitively impenetrable.

23.425 **Younger and older adults utilize dissociable neural mechanisms to up-regulate encoding of visual long-term memory.**
April E Pereira[1](april.pereira@mail.utoronto.ca), Caitlin Tozios [1], Keisuke Fukuda [1]; [1]University of Toronto, Mississauga

Despite the virtually unlimited capacity of visual long-term memory (VLTM), our ability to encode new visual information into this offline storage fluctuates from moment to moment, thus rendering some information forgotten later in time. Is there any way to monitor this moment-to-moment fluctuation and correct them when needed in real time? Previously we have demonstrated that we can monitor this fluctuation from multiple electroencephalograms (EEG) measures of memory encoding in real time and intervene failed memory encoding by cueing participants to up-regulate (i.e.,"try harder") memory encoding on the spot, particularly when the ongoing frontal theta (5-7Hz) amplitude was low (Pereira & Fukuda, 2018) . In the current study, we examined whether older adults were capable of exerting the same up-regulatory control on VLTM encoding. Interestingly, although older adults exhibited the equivalent efficacy for voluntary up-regulation of VLTM encoding, the underlying neural correlates were qualitatively different from those for younger adults. More precisely, unlike younger adults, the older adults' efficacy of voluntary up-regulation of VLTM encoding did not depend on the amplitude of ongoing frontal theta activity. Moreover, while the amplitude of the cue-elicited late posterior positivity predicted successful up-regulation of VLTM encoding in younger adults, it was not the case for the older adults. Taken together, our results demonstrate that younger and older adults recruit dissociable neural mechanisms to voluntarily up-regulate VLTM encoding, and thus suggest the importance of age-specific calibration of EEG-based real-time memory intervention.

Acknowledgement: NSERC, Connaught Fund

23.426 **Consolidating Multiple Items Into Visual Working Memory is a Parallel and Remarkably Fast Process** Michael S Pratte[1](prattems@gmail.com), Marshall L Green[1]; [1]Mississippi State University, Department of Psychology

Understanding how we consolidate visual information into working memory is critical for our understanding of any subsequent mechanism, such as memory storage or retrieval. However, here we suggest that the current, prominent understanding of how items are consolidated is incorrect. In particular, we find evidence against the influential claim that increasing the number of to-be-consolidated items slows the consolidation process. The time course of consolidation was examined in a novel paradigm in which an array of colored stimuli was presented for a variable amount of time. At the end of this stimulus period one item was immediately replaced with a mask, which also served as a cue, drawing attention to that item in the same moment it was masked. Participants then reported the color of the cued/masked item, and using a mixture model analysis we found that only a few items were available in memory after the cue/mask. This limited capacity existed even though there was effectively no memory retention interval, and even when the stimuli were presented for an entire second. Critically, however, shortening the stimulus period from 1000 ms to as little as 100 ms had almost no effect on performance. Moreover, although further shortening the stimulus duration below 100 ms did hurt performance, these effects did not interact with set size, implicating visual masking rather than an interruption of the consolidation process. We suggest that the previous demonstration of such an interaction did not in fact reflect encoding processes. Instead, we show that this result reflects a surprising effect whereby memory for masked items in a multi-item display continues to decay after the mask. These results suggest that visual encoding is capacity limited, but extremely fast and operates in parallel across items.

Acknowledgement: NIH NIMH Grant R15MH113075

23.427 **Is "confirmation bias" always a bad thing?** Cheng Qiu[1](chengqiu@sas.upenn.edu), Long Luu[1, 2], Alan A Stocker[1]; [1]Department of psychology, University of Pennsylvania

Humans have the tendency to perceive the world the way they expect it to be. These prior expectations usually reflect knowledge about the statistical structure of the world that, if learned correctly, can help to improve the accuracy of the percept. Recent results suggest that these prior expectations can also be self-generated by a preceding categorical or structural interpretation of the sensory evidence by the observer (Stocker & Simoncelli 2007; Ding et al. 2017; Luu & Stocker 2018). In this case, however, these self-generated expectations should decrease perceptual accuracy as sensory information is counted twice, leading to a form of confirmation bias. Why, then, do people use this self-consistent conditioning strategy? To answer this question, we characterized perceptual accuracy for different inference strategies. We considered a perceptual task where an observer estimates the value of a stimulus feature that belongs to one of two categories with overlapping distributions. Using model simulations, we demonstrated that although an observer that conditions feature estimation on the self-generated expectation of the feature category is generally suboptimal, the decrease in accuracy is not homogeneous across the entire feature range. In fact, compared to a full Bayesian observer, the accuracy is better for feature values where the uncertainty of a correct categorical assignment is relatively low. That is to say, if an observer is reasonably certain about the categorical assignment of the feature, estimation accuracy is improved by fully committing to that particular category instead of considering both categories according to their posterior probabilities. Furthermore, these benefits of conditioning are substantially increased if additional noise is deteriorating sensory information after the categorical commitment (e.g. during retention in working memory). Our results suggest that inference strategies that rely on self-generated expectations (i.e. confirmation bias) can be beneficial and maximize the accuracy.

23.428 **Spatial biases in visual working memory encoding persist despite controlled gaze position** Colin Quirk[1,2](cquirk@uchicago.edu), Albert Chen[2], Edward K Vogel[1,2]; [1]Department of Psychology, University of Chicago, [2]Institute for Mind and Biology, University of Chicago

In everyday life, goal-driven selection processes allow us to selectively encode the most critical items into working memory. However, in traditional visual working memory experiments we frequently overload capacity without providing information about which items are relevant. It is often assumed that when all items are equally likely to be tested participants select a random subset, but recent findings have instead shown that individuals tend to store items from a particular area of the visual field. One potential explanation for these findings is that subjects move their eyes in preparation for an upcoming trial, suggesting the spatial bias is driven by gaze position. For example, Chokron & Imbert (1993) showed that initial gaze position determined bias direction in a bisection task. To test whether gaze position causes encoding biases in change detection, we recorded gaze position while participants (N=22) completed 800 change detection trials. On half of these trials, fixation was maintained on the center of the visual field while the to-be-remembered items were displayed; on the other half of trials, no constraints were placed on gaze position. Despite participants maintaining fixation in the center of the visual field, accuracy was still biased in a particular area of the visual field. This result suggests that gaze position alone cannot explain the encoding biases previously observed in change detection.

Spatial Vision: Neural mechanisms

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23.429 **Perceived metamorphopsia and orientation discrimination threshold before and after the surgical removal of epiretinal membrane** Ruijing Xia[1,2](rx0@mynsu.nova.edu), Binbin Su[1], Tianyu Chen[1], Jia Zhou[2], Hua Bi[2], Bin Zhang[2]; [1]Optometry Department, Eye Hospital of Wenzhou Medical University, Wenzhou, Zhejiang, China, [2]College of Optometry, Nova Southeastern University, Fort Lauderdale, FL

Purpose: To quantify the changes in perceived metamorphopsia and orientation discrimination threshold (ODT) before and after surgical removal of idiopathic epiretinal membrane (ERM), and to investigate the association to pre and post-surgical changes in the thickness of retinal layers. Method: A prospective study, a total of 17 subjects with idiopathic ERM were recruited. Best-corrected visual acuity (BCVA) was evaluated with EDTRS chart. Metamorphopsia was measured with Amsler grid. The ODT was quantified with groups of briefly displayed short line segments in 3-donw-1-up staircase algorithm. Inner and outer retinal layer thickness (IRLT and ORLT) was measured with spectral domain optical coherence tomography. All measured were done before and after surgical removal of the ERM. Results: With surgical removal of the ERM, the BCVA significantly improved (0.468±0.304logMAR vs 0.202±0.190logMAR, before and after respectively, p=0.002).In five subjects who reported subjective distortion with Amsler grid before the surgery, three stayed positive and two turned negative after the surgery. However, two subjects who were Amsler grid negative pre-surgery became positive post-surgery. In 14 subjects, ODT values reduced after the removal of ERM, with the mean ODT was significantly went from 10.6±2.8 degree from surgery to 8.0±2.7 degree after surgery ($p < 0.01$). Inner retina layer thickness greatly decreased after the surgery (390.4±126.9 um vs. 254.4±64.7 um, before and after respectively, $p < 0.01$), while out retina layer thickness did not show significant change (87.8±6.9 um vs. 87.8±7.6 um, before and after respectively, p=0.972).The improvement in ODT significantly correlated with the thinning of the IRLT ($p < 0.05$).Conclusion: In patients who received surgical removal of ERM, changes in ODT reflects the functional changes better than Amsler grid and correlates with changes in inner retina layer thickness well.

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23.430 **The relation of individual variation in total retinal ganglion cell layer thickness to post-retinal anatomy**

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Introduction: There is individual variation in both the thickness of the retinal ganglion cell (RGC) layer of the eye, and in the relative size of anatomical components of the post-retinal visual pathway. In ophthalmologic disease, congenital RGC loss shrinks the geniculo-striate pathway (although increases apparent V1 thickness). We tested if normal variation is shared in retinal and post-retinal visual anatomy. Methods: Forty subjects were studied with SD-OCT, anatomical MRI scanning, and ocular biometry. Macular OCT was performed on the right and left eye, and with horizontal and vertical B-scan orientations (width 30º visual angle). The RGC+IPL layer (hereafter "RGC") was segmented and edited using OCT-Explorer v5.0. The acquisitions were combined into a single, pseudo-right eye. The mean RGC layer thickness was obtained for each subject. T1 brain images were acquired at 3T and analyzed with the HCP pipeline. We obtained the volume of the optic chiasm and lateral geniculate nucleus, and the surface area and thickness of area V1 gray matter. Results: The correlation between the left and right eye RGC thickness was r=0.98, suggesting low measurement noise. As has been reported previously, axial length was negatively related to RGC thickness, accounting for 26% (+-9% quartile by bootstrap resampling) of across-subject variance in RGC thickness. There was no effect of subject age in these data. The volume of the optic chiasm and LGN, relative to total supra-tentorial volume, were positively related to RGC thickness (13+-4% additional variance explained). There was no relationship between RGC thickness and either V1 surface area or thickness. Conclusion: There is a modest relationship between individual differences in total RGC layer thickness and the size of the optic chiasm and LGN. It remains to be seen if differences in the distribution of RGC density across the retina, independent of overall thickness, are related to post-retinal organization.

Acknowledgement: U01EY025864

23.431 **Surface area and cortical magnification of V1, V2, and V3 in a large sample of human observers**

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How variable is the topological structure of early visual areas in human cortex? The Human Connectome Project 7T Retinotopy Dataset (Benson et al., 2018) can potentially answer this question as it contains the world's largest collection of retinotopic measurements. We trained two anatomists to trace iso-eccentricity and iso-angle contours on the retinotopic maps of each subject. The contours followed the representations of 5 eccentricities (spanning 0.5–7°) and the horizontal and vertical meridians. These contours were used to calculate the mid-gray surface areas of V1, V2, and V3. Surface area estimates were extremely reliable across anatomists (r=0.95). Analyses were performed on 166 subjects (15 of 181 subjects with poor data quality were excluded). The median bilateral surface area of V1 (0–7° eccentricity) was 15.66 cm2 with a standard deviation of 2.91 cm2, and the maximum V1 size was 3.01-fold larger than the minimum. For V2, these values were 14.95, 2.56, and 3.16, respectively; for V3 they were 12.82, 2.27, and 2.93. The sizes of V1 and V2 were highly correlated across subjects (r=0.74) while V2 and V3 (r=0.57) and V1 and V3 (r=0.39) were less correlated. All surface areas (V1–V3) were only weakly correlated with total cortical surface area (r≈0.2-0.3). In V1, cortical magnification was, on average across subjects, well fit by mLH=(16.9/(0.50+e))2 and mRH=(18.0/(0.63+e))2 where e is eccentricity. Our measurements of V1, V2, and V3 sizes are broadly consistent with past reports. However, our estimates of cortical magnification near the fovea are slightly higher than found by Horton and Hoyt (1991) in lesion observations. The three-fold difference in minimum and maximum area of these regions mirrors the three-fold differences found in photoreceptor density (Curcio et al., 1987). These results provide a robust population benchmark against which new individuals and developmental and clinical populations can be compared.

Acknowledgement: R01 EY027401, R01 EY027964, R01 MH111417, NSF SMA1757390

23.432 **Heritability of V1/V2/V3 surface area in the HCP 7T Retinotopy Dataset**

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The size of early visual areas differs greatly among individuals: how much of this variability is genetically determined? We analyzed 86 monozygotic (mz) and 58 dizygotic (dz) twins from the Human Connectome Project 7T Retinotopy Dataset (Benson et al., 2018, JOV). Based on the polar angle and eccentricity estimates in these data, we manually defined the extent of V1–V3 between 0.5 and 7 degrees eccentricity. We then quantified the surface area of these regions with respect to the mid-gray cortical surface. Individual differences in V1 surface area varied 3-fold and were highly heritable: r2 between twins was 46.5% and 36.5% for monozygotic and dizygotic pairs, respectively. Comparable levels of heritability were found for V2 (mz 50.9%, dz 25.4%) and V3 (mz 43.3%, dz 31.3%). Individual variability in V1/V2/V3 surface area might be predictable simply from overall brain size or the local anatomy (e.g., calcarine sulcus surface area). While total cortical surface area is highly heritable (mz r2=91.0%, dz 51.7%), it is not highly predictive of V1/V2/V3 surface area (r2=9.5%/16.2%/22.0%). We fit a multiple regression model including regressors for total cortical surface area, area of each subject's calcarine sulcus, and V1 surface area measured in the paired twin. This model revealed that V1 surface area is best predicted by a combination of calcarine sulcus area and twin V1 surface area. These results quantify the heritability of functionally defined regions in a part of the brain that is known to be highly heritable (Patel et al, 2018). Yet only about half of the surface area variance in V1/V2/V3 is explained by genetics, suggesting substantial environmental influences on the topography of the earliest sensory maps in the human brain.

Acknowledgement: R01 EY027401, R01 EY027964, R01 MH111417, NSF SMA1757390

23.433 **A cell population model of retinal ganglion cell layer thickness**

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Purpose: The thickness of the retinal ganglion cell (RGC) layer of the eye is readily measured using optical coherence tomography, and is observed to vary across individuals in overall size and distribution of tissue. To relate this variation to computational models of psychophysical performance, we require a means of estimating the classes of RGCs and their quantities that contribute to the observed layer thickness. Using results from prior histology studies, we have developed a model of RGC layer thickness that is based upon the volume occupied by retinal ganglion cells of different classes across the retina. Methods: We took an estimate of total RGC density as a function of eccentricity (Curcio & Allen 1990) and determined the proportion of midget (Dacey 1993) and bistratified cells (Dacey 1993); the parasol fraction was assumed to be the remainder. The density of displaced amacrine cells was also modeled (Curcio & Allen 1990). Estimates of cell body size as a function of eccentricity were obtained from human (Liu et al 2017; Dacey 1993; Perry, Oehler, Cowey 1984) and macaque studies (Dacey 1990). We assumed spherical cell bodies and Keppler's limit (0.74) for packing density. We compared the predicted thickness of the RGC layer to empirical measures (Curcio et al 2011). Results: In histology, the maximum thickness of the RGC layer in the temporal meridian is 61 microns at 4.4° eccentricity. Our model returns a maximum thickness of 44 microns at 3.3°. Improved agreement between the predicted and observed RGC layer thickness is obtained if the assumed fraction of midget cells is reduced by ~5% (commensurately increasing the parasol fraction). Conclusion: A model of RGC cell population

density accurately models layer thickness. The model is sensitive to the assumed midget fraction, and thus provides another means of specifying this elusive value.

Acknowledgement: U01EY025864

23.434 **Comparing Visual Evoked Potentials between Prosthetic Vision, Normal Vision, and Simulated Acuity Reduction**

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The recording of visual evoked potentials (VEPs) is a quantitative method to evaluate the functionality of the visual pathway. However, when blind patients regain sight from retinal prostheses, what characterizes their VEPs? Here, we recorded pattern-reversal VEPs in blind patients who received the Argus II retinal prosthesis, and compared that to VEPs of sighted controls with normal vision and simulated acuity reduction.Visual stimuli were comprised of 2 cycles of full-contrast square waves that reversed contrast polarity, and were presented on a visual display unit (VDU). Patients viewed the pattern via the Argus II camera and the position of the VDU was adjusted such that two full cycles were within the implant's field-of-view, with a spatial frequency of approximately 0.1 cycle/degree. Control subjects viewed the pattern either with normal vision or wearing blurry goggles to simulate acuity of 20/900.Since implants were only in one eye of the patients, control subjects were recorded monocularly, with the non-dominant eye occluded. Data was band-pass filtered from 1-300 Hz and notch filtered to eliminate electromagnetic interference (60 Hz) before averaging. Each response consisted of 128 trials.Initial results from one patient and one control subject revealed clear pattern VEPs from all three visual conditions (prosthetic/normal/blurry), resembling the typical pattern-reversal VEP. More importantly, the P1 components in both prosthetic and blurry VEPs have earlier onsets and lower peaks compared to the normal VEP. Since the P1 component is known to be sensitive to defocus, the observed variation in its onset and peak may reflect differences in visual acuity. Our protocol provides a reliable way to record and evaluate VEPs in patients with retinal prostheses. This objective way of assessing prosthetic vision is important for understanding how visual information is processed in these patients after years of blindness.

Acknowledgement: University of Minnesota MnDrive Fellowship Vitreo-Retinal Surgery Foundation University of Minnesota Center for Applied and Translational Sensory Science Research Fund Minnesota Lions Vision Foundation Research to Prevent Blindness

23.435 **Estimating the bandwidth of tuned normalization within human visual cortex**

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Normalization within visual cortex is modulated by contextual influences; stimuli that share similar features tend to suppress each other more than those containing dissimilar features. This form of orientation tuned normalization is typically observed when collinearly oriented gratings arranged in a center-surround configuration evoke greater attenuation of each other than when they are oriented orthogonally to each other. While numerous studies have examined the nature of surround suppression at these two extremes (collinear vs orthogonal), much less is known about how the strength of tuned normalization varies as the orientation similarity between the center and surround is parametrically manipulated. Here, we set out to characterize the bandwidth of orientation-tuned suppression within human visual cortex using fMRI. Specifically, we examined how the strength of orientation-tuned surround suppression is attenuated when parametrically manipulating the orientation similarity between stimuli. A narrow bandwidth suggests that only a small deviation in orientation similarity leads to a large change in the BOLD response, while a broader bandwidth suggests smaller changes. Participants viewed a full-field circular stimulus composed of wedges filled with orientation-bandpass filtered noise, all presented at 50% contrast. This stimulus configuration allowed us to vary the orientation difference between neighboring wedges in 15° steps, spaced between collinear and orthogonal. We measured BOLD responses to these 7 different orientation similarity conditions in a blocked design, while participants performed a demanding task at fixation. Our results reveal a gradual decrease in the BOLD response as a function of orientation similarity, with lower BOLD responses for configurations that were perfectly matched in their orientation content and higher BOLD responses as the orientation differences increased. We then quantified the bandwidth of tuned normalization, and found that the bandwidth broadens along the visuocortical hierarchy, pointing to differences in the strength of tuned normalization across visual areas.

Acknowledgement: National Institutes of Health Grant EY028163 to S. Ling

23.436 **Improved methods for decoding sensory uncertainty from activity in the human visual cortex**

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Noise in the nervous system makes it impossible to infer with absolute precision the presented stimulus from a cortical response. Rather, the information contained in neural activity is uncertain. How best to characterize this uncertainty in cortical stimulus representations? We recently demonstrated that the trial-by-trial imprecision in perceptual representations can be reliably extracted from the human visual cortex, using fMRI in combination with a novel probabilistic decoding approach (van Bergen, Ma, Pratte & Jehee, 2015, Nature Neuroscience). Here, we present two new developments in this probabilistic analysis technique, which yield impressive improvements in decoding performance. First, we improved the estimation of an important component of the decoding model, namely the spatial noise correlation structure between fMRI voxels. Second, we implemented sampling techniques to appropriately account for the full range of decoding models that are plausible given a set of (noisy) training data. We applied this augmented decoding algorithm to cortical activity measured in an fMRI experiment, in which human participants viewed grating stimuli and reported their orientations. We found that the ability to decode stimulus information from visual cortex improved markedly on several fronts. First, the decoder's estimates of the presented orientations were much more precise than observed previously, with mean errors decreasing by about 30%. Second, the augmented decoder was better able than its predecessor to gauge the uncertainty with which stimulus information is represented in cortical activity. Specifically, we observed a significantly stronger link between the degree of uncertainty decoded from visual cortex and variability in the observers' behavioral responses. Together, these findings indicate that the augmented probabilistic decoder provides an exceptionally clear window onto the precision with which stimulus information is encoded in cortical activity.

Acknowledgement: This work was supported by ERC Starting Grant 677601 to J.J.

23.437 **Population contrast response functions in human visual cortex**

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Neurons within early visual cortex exhibit a well-characterized relationship between stimulus contrast and neural response: firing rates initially increase in a relatively linear fashion, but eventually saturate, evoking little-to-no change between higher contrast levels. While this neural contrast response function (CRF) has been demonstrated to have a monotonic relationship with behavioral performance, it remains controversial whether the same holds for population-based CRF measures obtained with human neuroimaging. In this fMRI study, we utilized an adaptation paradigm to capture the nonlinearity of the population contrast response function (pCRF). In a first experiment, we measured BOLD responses in early visual cortex (V1-V3) using a traditional fast event-related design, while participants viewed stimuli varying in contrast intensity throughout a scan (9 contrast levels, spaced between 3%-96% Michelson contrast). Stimuli were composed of equally-spaced apertures arranged in five concentric ring patterns. Each aperture contained a grating stimulus that scaled in size and spatial frequency with eccentricity, oriented along the radial axis out from fixation. Using conventional deconvolution analyses to estimate the pCRF, we were able to capture nonlinear pCRFs of individual voxels within each visual area. In a second experiment, we asked whether we could obtain similar pCRF estimates in a more flexible and timely manner by employing a model-based encoding approach. We measured BOLD responses while participants viewed the same stimuli, except that they were presented in a rapid manner (0.5s presentation duration). Utilizing this approach, we were able to predict BOLD responses for these rapidly presented contrast stimuli, and reliably reconstruct the pCRF. The results reveal that estimated pCRF parameters were highly comparable to those obtained using conventional methods. Overall, our results demon-

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strate that fMRI-based pCRF estimates do exhibit canonical non-linearities, and furthermore we propose a method that allows for a more flexible mapping of the pCRF in human visual cortex.

Acknowledgement: National Institutes of Health Grant EY028163

23.438 **Distinct mechanisms limit contrast sensitivity across retinal eccentricity and polar angle** Antoine Barbot[1,2](antoine.barbot@nyu.edu), Jared Abrams[1,3], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University, [3]Center for Perceptual Systems, University of Texas at Austin

Goal: Visual perception is heterogeneous across the visual field. Contrast sensitivity (CS) varies as a function of radial (eccentric) and polar (isoeccentric) position. CS decreases with eccentricity. At isoeccentric locations, CS is higher on the horizontal than the vertical meridian, and is higher along the lower than the upper vertical meridian. Here, using the external noise paradigm, we assess whether variations in sensitivity with eccentricity and polar angle are due to differences in processing efficiency or internal noise, and how endogenous (voluntary) covert attention affects CS differences at these locations. Method: In each trial, participants reported the orientation of a ±45º-oriented Gabor (5 cpd) presented at one of 9 possible locations along the horizontal (left/right) and vertical (up/down) meridian, at 3 eccentricities (0, 4 and 8º). A response cue indicated the target location, which was embedded in different levels of Gaussian white noise. Using symbolic precues, endogenous attention was either focused at the upcoming target location or distributed across all locations. We computed threshold versus noise contrast functions to estimate differences in processing efficiency and internal noise as a function of eccentricity and polar angle. Results: Thresholds increased with eccentricity under low external noise, but were similar across eccentricity (0-8º) under high external noise. Conversely, CS differences at isoeccentric locations remained similar across external noise levels: thresholds were better along the horizontal than the vertical meridian, and better at the lower than the upper vertical meridian. Endogenous attention lowered thresholds across all external noise levels similarly at different eccentricities and polar angles. Conclusion: These findings demonstrate that variations in CS with eccentricity and polar angle are mediated by distinct mechanisms. Internal noise differences underlie the effect of eccentricity. However, differences across isoeccentric locations result from reduced efficiency along the vertical meridian, particularly along the upper vertical meridian, even when attended.

Acknowledgement: NIH NEI RO1-EY027401 to MC

23.439 **Contrast-dependent spatial frequency selectivity in macaque V1 neurons explained with tuned contrast gain control** Paul G Levy[1](paul.levy@nyu.edu), Eero P Simoncelli[1, 2], J. Anthony Movshon[1]; [1]Center for Neural Science, New York University, [2]HHMI, New York University

Neurons in primary visual cortex (V1) show contrast-dependent spatial frequency tuning: at low contrasts, they tend to prefer lower spatial frequencies. A linear spatial filter followed by a nonlinearity cannot explain this behavior, unless that nonlinearity is spatial frequency dependent. One well known nonlinearity in cortical cells is contrast gain control. Here, we show that spatial frequency tuned contrast gain control can explain the contrast-dependent tuning of V1 neurons. We measured responses to optimally-oriented sinusoidal gratings and grating mixtures presented at a range of contrasts to well-isolated single neurons recorded from opiate-anesthetized paralyzed macaque monkeys. The responses to mixtures helped us to dissociate the linear and non-linear components of the response. We fit individual cell responses with a model consisting of a linear spatial filter whose output is divided by a gain control signal computed from the weighted sum of the squared responses of a pool of similar filters tuned to a range of spatial frequencies, plus a small adjustable parameter. We compared the performance of the model with and without spatial frequency dependent pooling. For most cells, spatial frequency dependent pooling improves the fits; for 25% of cells, the improvement is significant. The tuned gain control often captures the contrast dependence of spatial frequency tuning, including shifts towards lower preferred frequency at lower contrasts. This is achieved by preferentially weighting the responses of filters with frequencies below the preferred spatial frequency of the cell. This demonstrates that a tuned normalization can account for contrast-dependent changes in spatial frequency tuning.

Acknowledgement: Simons Foundation, NIH, HHMI

23.440 **Normalization by the variance across orientation channels in human V1-V3** Jonathan Winawer[1,2](jonathan.winawer@nyu.edu), Zeming Fang[1,2], Wei Ji Ma[1,2]; [1]Psychology, New York University, [2]Center for Neural Science, New York University

An influential account of neuronal responses in primary visual cortex is the normalized energy model. This model is often implemented as a two-stage computation. The first stage is the extraction of contrast energy, whereby a complex cell computes the squared and summed outputs of a pair of linear filters in quadrature phase. The second stage is normalization, in which a local population of complex cells mutually inhibit one another; as a result, responses are effectively normalized by the local stimulus contrast. Here, using evidence from human functional MRI, we show that the classical model fails to account for the relative responses to two classes of stimuli: straight, parallel, band-passed contours (which we call 'sparse gratings'), and curved, band-passed contours ('sparse patterns'). The second class of stimuli elicits fMRI responses that are about twice as large as the first class, yet traditional energy models, including normalized energy models, predict responses that are about the same. We propose a novel computational model, in which responses are normalized not by the sum of the contrast energy, but by the variance in contrast energy, computed across orientation channels. We first show that this model accounts for the responses to these two classes of stimuli. We then show that the model successfully generalizes to a large number of other band-pass textures, both in V1 and in extrastriate cortex (V2 and V3). We speculate that the variability in the output of orientation channels reflects the pooled activity of neurons that analyze the outputs of V1, and that this signal normalizes the V1 responses via feedback.

Acknowledgement: R01 MH111417

23.441 **Neural correlates of the double-drift illusion** Noah J. Steinberg[1](noah.steinberg@nih.gov), Zvi N. Roth[1], J. Anthony Movshon[2], Elisha P. Merriam[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, Bethesda, MD, [2]Center for Neural Science, New York University, New York, NY

In the "double-drift" illusion, local motion within an eccentrically viewed moving contrast window alters the window's perceived path. The illusion is strong even when the eyes track a target whose motion matches the window so that it remains stable on the retina, suggesting that the illusion engages position encoding not tied to retinal coordinates. We reasoned that different responses for different illusory motion paths, given identical retinal input, might identify the basis for this encoding. The stimulus consisted of a vertically-oriented Gabor that contained both local and global motion. The Gabor envelope moved vertically up and down across the screen as the carrier grating drifted to the left or right. Under these conditions, the perceived stimulus' motion path differed from its actual motion path by several degrees. Observers pursued a fixation dot that moved smoothly and predictably alongside the Gabor, so that the Gabor remained at a constant retinal location throughout the experiment. We measured BOLD fMRI responses (7T, 1.2 x 1.2 x 1.2 mm voxels) under three stimulus conditions which shared the same physical motion path but differed in perceived motion. In two conditions, the conjunction of local and global motion produced illusory motion paths that were rotated to the left or right of vertical. In the third, control condition, the direction of local motion was randomized every 250 ms – this did not produce an illusory motion path. Several cortical areas had larger BOLD responses during the illusory conditions than during the no-illusion control condition, potentially reflecting attentional enhancement or responses to local motion. But multivariate pattern analysis revealed a number of cortical areas that could discriminate between the two illusory directions. This result is not easily explained by low level factors and may reveal the cortical loci of non-retinal position computation.

Acknowledgement: Intramural Program of NIMH

23.442 **Impaired egocentric spatial representations by congenital deafness: neural evidence from a multimodality neuroimaging study** Hui Li[1,2](648086188@qq.com), Xiaolin Zhou[3], Qi Chen[1,2]; [1] Center for Studies of Psychological Application and School of Psychology, South China Normal University, Guangzhou, 510631, China, [2]Guangdong Key Laboratory of Mental Health and Cognitive Science, South China Normal University, Guangzhou 510631, China, [3]Department of Psychology, Peking University, Beijing 100871, China

The spatial location of an object can be represented relative to two types of reference frames: allocentric and egocentric. The allocentric reference frame encodes object positions relative to another background object independent of observers' body effectors while the egocentric reference frame encodes

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object positions relative to observers' own body effectors. At the behavioral level, recent evidence from our lab suggested that congenital deafness is associated with significantly impaired (slowed) egocentric judgments, compared to the healthy hearing control group. It remains unclear, however, the neural mechanisms underlying the impaired egocentric judgements after early congenital deafness. Here, we investigated this issue by using structural, functional MRI, and diffusion tensor image (DTI). Behaviorally, we replicated previous behavioral evidence by showing that egocentric judgments were significantly slower than allocentric judgments in the congenitally deaf subjects while were comparable in the healthy hearing controls. At the neural level, compared to the hearing controls, the bilateral medial frontal gyrus in default mode network was specifically activated by the allocentric task, and the left superior parietal gyrus was specifically activated by the egocentric task in the deaf subjects. Structurally, by using T1-weighted MRI and surface-based morphometry of the gray matter, we found that the cortical thickness of the bilateral primary auditory cortex in the Heschl's gyrus was thicker in the deaf than in the control group. Furthermore, by using DTI and tract-based spatial statistics of the white matter, we found that the mean fractional anisotropy values in the bilateral parietal cortex and the right temporal cortex were significantly reduced in the deaf group, compared to the hearing controls. Taken together, functional and structural neural evidence consistently suggested that the impaired egocentric spatial representations in the congenitally deaf subjects are associated with neural changes in the dorsal visual stream and the auditory cortex.

Acknowledgement: Natural Science Foundation of China grant Number 31871138 to QC

23.443 **Saliency and the population receptive field model to identify images from brain activity** Alex Hernandez-Garcia[1](alexhg15@gmail.com), Wietske Zuiderbaan[2], Akhil Edadan[2], Serge O. Dumoulin[2,3,4], Peter König[1,5]; [1]Institute of Cognitive Science, University of Osnabrück, Germany, [2]Spinoza Centre for Neuroimaging, 1105 BK Amsterdam, Netherlands, [3]Department of Experimental and Applied Psychology, VU University Amsterdam, Netherlands, [4]Department of Experimental Psychology, Helmholtz Institute, Utrecht University, Netherlands, [5]Institute of Neurophysiology und Pathophysiology, University Medical Center Hamburg-Eppendorf, Germany

One of the goals of visual neuroscience is to develop predictive models of brain activity to better understand the underlying mechanisms of the visual cortex. One example is the identification of presented images from fMRI recordings. Recently, Zuiderbaan et al. (2017) used the population receptive field (pRF) model and image contrast information to identify the presented stimulus from a set of natural images. Here, we extend the study by analyzing the predictive power of saliency-related information. Ultimately, we seek answers to these questions: What fraction of the responses is driven by saliency? Where in the visual cortex is saliency most represented? We test the Deep Gaze II and ICF (Kümmerer et al., 2017) saliency models. Deep Gaze II predicts the fixation density by using high-level features computed from a deep artificial neural network, while ICF uses only intensity and contrast features. We calculate the prediction response profile of every image as the summed overlap of its saliency map with the pRF at each cortical location. Then, we compute the correlation between the fMRI recordings and the prediction profiles of all images. An image is correctly identified if its predicted response elicits the highest correlation of the set. We find that ICF achieves the highest performance with a median correlation of .44 and 46.7 % accuracy (baseline 2.2 %) on V1, while Deep Gaze and the contrast model achieve .34 and .26 median correlation and 34.4 and 33.3 accuracy, respectively. On higher visual areas the performance gradually decreases. Both saliency models seem to be therefore better predictors of the presented stimuli than contrast information. The better performance of ICF might be explained because, while the pRF model only captures contrast energy information, the ICF maps may contain other information present in the measured responses, hence increasing the correlation of the predictions.

Acknowledgement: This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 641805

23.444 **The north effect is more pronounced for orientation discrimination than simple detection of spatial frequency gratings.** Leslie Cameron[1,2](lcameron@carthage.edu), Michael W Levine[2,3], Jennifer E Anderson[4]; [1]Department of Psychological Science, Carthage College, [2]Department of Psychology, University of Illinois at Chicago, [3]Laboratory of Integrative Neuroscience, University of Illinois at Chicago, [4]Department of Behavioral Sciences, Purdue University Calumet

INTRODUCTION: Several studies have reported that performance in the upper visual field is poorest at locations directly above fixation (the north effect).This phenomenon is thought to be due to the pooling of orientation mechanisms in the early stages of cortical visual processing.Performance in studies of the north effect typically involve orientation discrimination. However, we have previously confirmed that this effect exists even for simple detection tasks (VSS, 2016).In this study we directly compare performance on detection and orientation discrimination tasks. METHOD: We measured performance on a yes-no detection task and a 2AFC orientation discrimination task for 2 and 8cpd Gabors (2 deg., 10 deg tilt).Targets were presented at one of 8 possible locations, equally spaced at 4.5 deg. eccentricity.Target contrast was determined for each observer in pilot tests, such that overall performance was maintained at about 80% correct in the discrimination task.The identical stimulus parameters were then used to measure target detection.Visual performance fields were fit with hemi-ellipses (Anderson, Cameron & Levine, 2014) and we computed difference ratios (predicted performance based on the hemi-ellipse fit minus observed performance, at the north location). RESULTS: We found that the north effect exist for both detection and discrimination.However, the north effect was larger for orientation discrimination than for detection. CONCLUSION:We confirm that the north effect is not solely dependent on orientation mechanisms and may also include more primitive mechanisms.However, these results indicate that the cortical mechanisms are not necessarily limited by the targets' detectability but apparently provide a second stage that is orientation selective and also shows a north effect.

23.445 **Differential involvement of EEG oscillations in identity vs. spatial-relation reasoning tasks** Andrea Alamia[1](artipago@gmail.com), Matthew Ricci[2], Junkyung Kim[2], Thomas Serre[2], Rufin VanRullen[1]; [1]Cerco, CNRS Université de Toulouse, Toulouse 31055 (France), [2]Brown University, Department of Cognitive, Linguistic and Psychological Sciences. 190 Thayer Street. Providence, RI 029012 (USA)

Visual reasoning is the process of analyzing visual information to solve problems. A recent study (Kim, et al., Interfocus, 2018) demonstrated that state-of-the-art vision algorithms (i.e. deep convolutional neural networks or DCNs) encounter severe limitations when faced with certain visual reasoning tasks, such as determining whether two items are the same or different (SD tasks), but can successfully accomplish tasks based on spatial relationships between items (SR tasks). Here, we investigated the human neural and cognitive processes involved in SD and SR tasks, with the long-term goal of improving vision algorithms by implementing brain-inspired solutions. We hypothesized that distinct brain oscillations may be involved in the two tasks. We recorded EEG signals of 14 participants performing both SD and SR tasks in the same session. In both conditions, two stimuli were simultaneously displayed for 30ms on opposite sides of the screen. One second later, participants were instructed to report whether the two stimuli were identical (in the SD condition), or whether they were aligned closer to the horizontal or vertical meridian (in the SR condition). The results revealed higher activity in the alpha (8-12Hz) and low beta (13-20Hz) bands from ~500ms post-stimulus until the participants' response. As behavioral performance differed between the two conditions, we performed a more controlled, between-subject analysis on a subset of participants from each condition, matching the two groups for accuracy; this confirmed that occipital and frontal beta oscillations are significantly higher in SD than in SR conditions. We surmise that beta-band modulations may reflect the involvement of memory processes required to perform the SD task. Ongoing work aims to replicate these results in a within-subject design, equating behavioral accuracy in both conditions. Altogether this result suggests that current DCNs models may benefit from computational strategies that, in the human brain, rely on beta-band oscillatory mechanisms.

Acknowledgement: ERC 614244 P-CYCLES

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23.446 **Sharpening Vision by Adapting to flicker** Derek H Arnold[1](darnold@psy.uq.edu.au), Eleanor Moses[1], Melvyn A Goodale[2]; [1]School of Psychology, The University of Queensland, Australia, [2]Brain and Mind Institute, Western University, Ontario, Canada

Spatial form and stimulus dynamics were once thought to be encoded by independent visual processes. However, a wealth of physiological (see Lennie, 1998, Perception) and psychophysical (e.g. Nishida, 2004, Current Biology) evidence has now established co-joint encoding of form and motion. Notably, visual mechanisms responsive to dynamic inputs tend to encode spatial form at a low spatial resolution. Recently, we showed this coupling can be leveraged to transiently sharpen spatial vision (Anold et al., 2016, PNAS). Here we replicate a core finding of that investigation, and explore its neurophysiological underpinnings via EEG. Again, we find that people are able to read finer text after adapting to dynamic visual white noise. In this study, people adapted and read text in positions centred above or below fixation. Behaviourally, adaptation was advantageous only for fine text presented below fixation, and this was associated with reduced responses recorded via occipital sensors from ~140 to 210ms post word presentations. Our data are consistent with flicker adaptation transiently reducing the magnitude of a low-spatial-resolution form signal in occipital cortex that would normally sum with higher-spatial resolution signals. This and similar observations suggest a need for more nuanced accounts of the functional architecture of human vision – which encompass both co-joint encodings of visual attributes, and allow for the wealth of evidence substantiating functional specialisation.

Acknowledgement: The Australian Research Council

Attention: Features and objects 1

Saturday, May 18, 8:30 am - 12:30 pm, Pavilion

23.447 **Feature-based attention resolves differences in target-distractor similarity through multiple mechanisms** Angus F Chapman[1](afchapman@ucsd.edu), Frederik Geweke[2], Viola S Störmer[1]; [1]Department of Psychology, University of California, San Diego, [2]Department of Psychology, Humboldt-Universität zu Berlin

Attention to a specific feature (e.g., the color red) has been shown to increase neural population responses tuned to the attended feature value, while decreasing population responses tuned to other feature values. However, similarity between features can differ greatly across feature space, and it is not known how feature-based attention resolves this problem. We collected EEG from 16 participants while they selectively attended to one of two colored dot arrays to detect brief intervals of coherent motion. Distractor dots were either similar (60° apart in CIElab color space) or distinct (180° apart) from the target color, and performance was matched across the conditions using a thresholding procedure. We used steady-state visual evoked responses (SSVEPs) to track how feature-based attention modulates neural responses of targets and distractors.First, we measured the signal-to-noise ratio (SNR) of the SSVEPs and found a reliable attentional modulation for targets when distractors were distinct ($p = .007$) but not when similar ($p = .200$). Next, we fit an inverted encoding model to the SSVEP responses. Attention increased the fidelity of the reconstructed target responses when distractors were distinct ($p = .027$, one-tailed), but not when distractors were similar ($p = .180$), consistent with the SNR measures. However, when the distractor was similar to the target color, there was a shift in the center of the reconstructed color responses ($p = .003$) such that target reconstructions were biased away from the distractor color. No such bias was observed when distractors were distinct from the target ($p = .649$). This suggests that similarity between targets and distractors affects feature-based attentional modulations: when targets are sufficiently different from distractors, attention increases their gain and fidelity, however when targets are more similar to distractors, attention acts to increase the distinctiveness of targets by biasing neural populations away from distractors.

23.448 **Does Global Precedence Occur with Displays of Multiple Hierarchical Objects?** Jong Han Lee[1](lee84@mail.usf.edu), Thomas Sanocki[1]; [1]Psychology, College of Arts & Sciences, University of South Florida

The present study revisits the global precedence literature by examining search through multiple hierarchical objects (e.g. G made of small H's). Are global advantages prominent when the display contains multiple hierarchical objects? In the study, each object was a large letter (one of a set of ten) made of smaller letters (one of the same ten), thus having a global and local level of structure. Display set size varied from one to four of these hierarchical objects, and observers searched for one letter at a specified level (large or small). At display size one, the study replicates traditional global precedence displays. Consistent with many previous studies, there was a substantial global advantage — faster searches at the global level compared to the local level. At larger display set sizes, search continued at a faster rate (lower slope) for global letters than for local letters. Reasons for the global advantages will be discussed. The present study helps to extend the global precedence literature into the world of multiple hierarchical objects.

23.449 **Feature-specific preparatory signals across the visual hierarchy** Taosheng Liu[1,2](tsliu@msu.edu), Mengyuan Gong[1]; [1]Department of Psychology, Michigan State University, [2]Neuroscience Program, Michigan State University

Selective attention can facilitate perceptual processing of features and objects. Observers can often prepare for a specific feature before the arrival of the sensory stimulus. Whether overlapped or separate mechanisms of feature-based attention exist for preparatory activity and stimulus-evoked activity remains unclear. In an fMRI experiment, we used a feature cueing paradigm to assess how preparatory attention leads to selective processing of subsequent stimuli. Each trial began with a colored cue informing participants to attend to one of the two motion directions (i.e., 45° or 135°). After a delay period, two superimposed moving dot fields (along the 45° and 135° direction) were briefly presented. Subjects were asked to perform a threshold direction discrimination task on the cued direction (e.g., was the attended direction clockwise or counterclockwise relative to 45°?). We examined multi-voxel neural patterns as an index of the neural representation of the attended feature, by training a classifier to decode the attended direction for both the cue and stimulus periods. We found above-chance classification accuracy across the visual hierarchy in both the cue and stimulus periods. Compared to the cue period, classification accuracy was further improved in the stimulus period for early visual areas, but not for frontoparietal areas. The equivalent strength of attentional signals between cue and stimulus periods in frontoparietal areas is consistent with these areas maintaining signals for top-down control of feature-based attention. Furthermore, a classifier trained on the cue period did not generalize to the stimulus period, suggesting different coding mechanisms underlying preparatory attention and feature selection.

23.450 **Surface-Object Interactions in Object-Based Attention** Taissa Lytchenko[1](taucua@nevada.unr.edu), Genna Erlikhman[1,2], Nathan H Heller[3], Marvin R Maechler[3], Gideon P Caplovitz[1]; [1]Department of Psychology, University of Nevada, Reno, [2]Department of Psychology, University of California, Los Angeles, [3]Department of Psychological and Brain Sciences, Dartmouth College

When a part of an object is cued, targets presented in other locations on the same object are detected more rapidly and accurately than targets on other objects. Oftentimes in such experiments the cues and targets appear not only on the same object, but also on the same surface. In classic paradigms, the objects are often defined by a single closed surface (i.e. a rectangle). It is therefore unclear whether the 'object' of attentional selection is truly the object itself or simply one of its surfaces. In four psychophysical experiments, we examined whether the facilitating effects of attentional cuing extend to other non-cued surfaces on the same object or on different objects. In Experiment 1, facilitation effects were found for targets on non-cued, adjacent, bounded surfaces on the same object, even when the cued and uncued surfaces were oriented in different directions in depth. This suggests that the 'object based' benefits of attention are not restricted to individual surfaces. We further confirmed this finding in two control experiments. A fourth experiment examined the interaction of perceptual grouping and object-based attention. This experiment found that the benefit of cueing an object defined by one closed-contour surface can extend to another non-contiguous object if they are presented in a configuration that facilitates perceptual grouping. This suggests that the objects of attention do not necessarily map onto discrete physical objects defined by closed contours. Instead, attentional selection can be allocated to perceptual groups of surfaces and objects in the same way as it can to a location or to groups of features that define a single object.

Acknowledgement: National Science Foundation: NSF 1632738 and NSF 1632849

23.451 **Understanding failures to replicate the influence of grouping cues on the flanker-congruency effect** Cathleen M Moore[1](cathleen-moore@uiowa.edu), Sihan He[1], J Toby Mordkoff[1]; [1]University of Iowa

In spatial filtering tasks, observers respond to the stimulus in one location (the target) while ignoring stimuli in other locations (the flankers). However, flankers that are sufficiently close to the target cause response-congruency effects (Eriksen & Eriksen, 1974). Specifically, responses to targets near flankers associated with a competing response are slower and less accurate than responses to targets near flankers associated with the correct response. Nearly 30 years ago, an influential set of papers reported that perceptual manipulations designed to facilitate the grouping of the target with a specific sub-set of the flankers (e.g., common fate, color similarity, good continuation) yielded larger congruency effects for the grouped flankers than for the ungrouped flankers. Strikingly, this held even when the ungrouped flankers were closer to the target than the grouped flankers (Driver & Baylis, 1989; Baylis & Driver, 1992). These findings challenged the dominant "spotlight" view of attention under which visual selection is mediated only by space, and they are still frequently cited despite two published failures to replicate the common-fate version of the experiment (Berry & Klein, 1993; Kramer, Tham, & Yeh, 1991). We sought to further assess the replicability of the original results using grouping cues other than common fate. When we manipulated grouping by color-match, we failed to replicate the dominance of grouped flankers over spatially closer flankers. Moreover, we even failed to replicate the dominance of same-color flankers over different-color flankers when all flankers were equally distant from the target. Only when color uniquely distinguished the target from the flankers did color-match moderate the congruency effect. We suggest that grouping cues influence the parsing of the target from the flankers, rather than altering the amount of filtering applied to the flankers.

23.452 **Semantic Associations Between Scenes and Objects Bias Attention Even When Task-irrelevant** Joseph C Nah[1](nah@gwu.edu), George L Malcolm[2], Sarah Shomstein[1]; [1]The George Washington University, [2]University of East Anglia

Recent behavioral evidence suggests that the influence of semantic relationship between objects on attentional allocation is independent of task-relevance (Malcolm, Rattinger, & Shomstein, 2016). Additionally, neuroimaging data from our most recent work demonstrates that the semantic association between objects modulate spatial attention and strengthens the neural representation of objects in the early visual cortex. These results demonstrate that high-level relationships among objects continuously affect attentional selection. However, these findings are drawn from paradigms examining the influence of semantic relationships between two, maximum three, real-world objects. Since objects are always part of a scene, it is critical to understand whether the semantic properties of a scene have a continuous influence on attention. Here, we investigated the influence of task-irrelevant semantic properties of scenes on attentional allocation and the degree to which semantic relationships between scenes and objects interact. In Experiments 1 and 2, participants were presented with a scene followed by two objects appearing on either side of fixation. Next, two target Gabor patches appeared, one on fixation and one on top of an object, and a checkerboard distractor on the other object. Participants reported whether the orientation of two targets Gabors matched. Critically, only one of the objects was semantically related to the scene and the peripheral target was equally likely to appear on either object, rendering semantic relationships task-irrelevant. Faster RTs were observed for peripheral targets that appeared on the semantically related object. Importantly, RTs were directly predicted by the strength of scene-object relatedness (assessed by a questionnaire). In Experiment 3, the semantic relationship between objects and scene were systematically manipulated and measured using multi-dimensional scaling (MDS) methods. Results suggest that task-irrelevant semantic relationships between scenes and objects continuously influence attention and this influence is directly predicted by each individual's perceived strength of semantic associations.

Acknowledgement: NSF BCS-1534823 to S. S.

23.453 **Object-based Attentional Modulation of EEG Alpha is Related to Task Difficulty** Sean L Noah[1](seannoah@gmail.com), Travis Powell[1], Natalia Khodayari[1], Diana Olivan[1], Mingzhou Ding[2], George R Mangun[1]; [1]Center for Mind and Brain, University of California, Davis, Davis, CA, [2]J. Crayton Pruitt Family Department of Biomedical Engineering, University of Florida, Gainesville, FL

Object-based attention is the selection of visual information from an object or object category. It may be deployed in anticipation of a task-relevant object or as a template during visual search. In this study, we investigated whether object-based attention modulates electroencephalographic (EEG) alpha-band activity across the scalp, analogously to observed alpha modulations in spatial and feature-based attention experiments. If endogenous visual attention operates by a common mechanism throughout visual cortex, alpha modulation should occur whenever selective control is exerted over any visual-cortical activity. To test this hypothesis, we collected EEG data from 10 human participants performing an anticipatory object-based attention task with three categories of objects: faces, places, and tools. These object categories were chosen on the basis of their differentiated cortical representations. We observed reduced reaction time for validly compared to invalidly cued trials across all object conditions, suggesting that our task produced the intended attention effect. Although it is not possible using scalp EEG to unambiguously localize an alpha topography to specific brain regions, large changes in the underlying loci of alpha activity corresponding to effects in face, place, and tool regions would be expected to yield different patterns of alpha over the scalp. Using a random cluster analysis over alpha power, we identified electrodes and time points that differed significantly between object conditions, suggesting that alpha topography is modulated by attention to specific categories of objects. Using support vector machine binary classification as an additional measure of alpha topography modulation, we found above-chance decoding of attend-face anticipatory alpha, but no above-chance classification for attend-scene or attend-tool conditions. The ability of a classification algorithm to detect a systematic alpha topography only among the attend-face data dovetails with variation we observed in the reaction time data across object conditions, with the fastest reaction times in the attend-face condition.

23.454 **How to create objects with your mind: From object-based attention to attention-based objects** Joan Danielle K Ongchoco[1](joan.ongchoco@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

A curious thing can happen when you stare at a regular gridlike pattern — e.g. a piece of graph paper, or the tiles on a bathroom floor.Although such patterns contain no structure, you may often begin to see structure anyway (e.g. a block '+' shape).This phenomenon appears to be based on attention to relevant squares of the grid, and previous (older, underappreciated) research demonstrated that these squares do indeed accrue attentional benefits, such as faster probe detection.We will call this phenomenon scaffolded attention, because of how the grid provides a scaffold for selection.(Note that you cannot see these same shapes when staring at a blank page.) Here we asked whether this form of attention actually creates bona fide object representations that go on to enjoy object-specific effects.In essence, whereas previous work explored many cues to 'object-based attention' (e.g. involving continuity and closure), these current studies ask whether attention can be object-based even with no cues to objecthood at all.In several experiments (each with a direct replication), observers viewed 3x3 grids, and attended to particular squares until they could effectively see shapes such as two vertical (or horizontal) lines, or a block-letter H (or I).As they engaged in this form of scaffolded attention, two probes appeared, and observers simply reported whether they were the same or different.Remarkably, this produced a traditional 'same-object advantage': performance was enhanced for probes presented on the same (purely imagined) object, compared to equidistant probes presented on different objects — while equating for spatial factors.Thus, attention to the relevant squares effectively groups them, forming object representations out of thin (scaffolded) air.In other words, this demonstrates an unexpected inversion of the typical relationship between objects and attention: there is not only object-based attention, but also attention-based objects.

Acknowledgement: BJS was supported by ONR MURI #N00014-16-1-2007.

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23.455 **effects of semantic information on task-irrelevant attentional processing** Ellie R Robbins[1](erobbins105@gwu.edu), Andrew J Collegio[1], Joseph C Nah[1], Dick Dubbelde[1], Sarah Shomstein[1]; [1]Department of Psychology, The George Washington University

In addition to low-level features, all objects in our environment readily elicit high-level content, such as meaning (semantic information). It has been demonstrated that both low-level (e.g., color, shape) and high-level (e.g., semantics) features of objects influence attentional allocation. Most evidence for semantic guidance of attention, however, has been garnered from tasks rendering semantic information task-relevant. Whether semantic information of task-irrelevant objects guides attentional allocation remains to be an open question. It is hypothesized that, given its availability and strength of representation, semantic information may bias attention even when such information has no predictive value for the task, or is task-irrelevant. Specifically, when presented with multiple task-irrelevant objects, attention is guided, or prioritized, to a subset of objects that are semantically related creating a grouping-like effect. If grouping is driven by semantic relatedness, then performance should be directly related to the size of the group, such that performance should decrease as the number of related objects within a group increases. In the present study, four objects were presented on a screen equidistant from a central fixation point. The number of semantically related objects varied, from none related to all related. After a set time, a target appeared randomly on one of the four objects, not predicted by semantic relatedness. Individuals' perceptions of semantic relatedness and its effect on semantic grouping was assessed through multidimensional scaling (MDS) (Kriegeskorte & Mur, 2012). It was observed that as the number of semantically related objects increased, accuracy for identifying a target presented on one of the semantically related objects decreased. This result suggests that attentional grouping is modulated by high-level semantic information, even for task-irrelevant objects.

Acknowledgement: NSF BCS-1534823 to S.S.

23.456 **The binding between representations of own team and self in perceptual matching** Yang Sun[1,2](luciferjingqi@gmail.com), Wei Huang[2], Haixu Wang[2], Changhong Liu[3], Jie Sui[4]; [1]Department of Biomedical Engineering, Medical College,Tsinghua University, Beijing, 100084, China, [2]Department of Psychology, School of Social Sciences,Tsinghua University, Beijing 100084, China, [3]Department of Psychology, Bournemouth University, Poole, BH12 5BB, UK, [4]Department of Psychology, University of Bath, Bath, BA2, 7AY, UK

People tend to respond faster to stimuli associated with themselves and their own team compared to stimuli relevant to other people and rival team. There is well-established evidence on these effects of self-bias and in-group bias, but little evidence for the relationship between such biases. This question was tested in the present studies by utilising a perceptual matching paradigm with a Posner's Cueing task. In each experiment, we had participants tagging neutral geometric shapes to different labels – self, own team, another person (in a rival team), rival team and neutral team and then completed in a shape-label matching task where they had to judge whether shapes and labels matched. Once learnt the shape-label associations, the participants were only presented with the shapes as cues and targets in the Posner's Cueing task, and participants had to identify the target as being self vs. other or own term vs. rival team. Four experiments consistently showed the self- and ingroup-bias effects in the perceptual matching task. Importantly, the ingroup cue promoted responses to the self-related target relative to the target associated with other people when the target fell in the location of the cue, but this was not the case for the rival team cue. The effect occurred regardless of the relative size of cues and targets in Studies 1 and 2. However, the self-related cue facilitated performance to the target associated with the ingroup team compared to the rival team exclusively when the target was smaller than the size of the cue in Study 3, and the effect disappeared when the target was larger than the cue in Study 4. The results indicated a natural binding conceptual representations of self and ingroup. The implications of these results are discussed.

Acknowledgement: National Nature Science Foundation of China (Project 31371017).

23.457 **Object-based templates for rejection** Tomoyuki Tanda[1](t-tmyk-04-26@eis.hokudai.ac.jp), Jun Kawahara[1]; [1]Department of Psychology, Hokkaido University

Our visual system can prioritize target-relevant features and also suppress features related to nontargets during visual search. Although prioritization and de-prioritization using attentional templates have been found in color (Arita et al., 2012; Reeder et al., 2017) and shape (Tanda & Kawahara, 2018) domains, the paradigms used to demonstrate these findings have raised concerns that such apparently feature-based (de)prioritizations might be achieved indirectly by location-based templates. Specifically, participants might encode where items containing specific features (e.g., color or shape) are located and then construct spatial (de)prioritization maps in which search items are arranged spatially. The present study bypassed this concern by using object-based arrangements of search items and examined whether nonspatial (de)prioritization facilitates visual search. Participants identified the color of a target cross among nontarget crosses distributed along the edges of two overlapping geometric shapes (e.g., circle and triangle). This arrangement discouraged space-based (de)prioritization strategies. Every trial was preceded by a positive, negative, or neutral cue. A positive cue indicated that the target would appear on the cued shape, a negative cue indicated that it would appear on the non-cued shape, and a neutral cue indicated that the cued shape would never appear during the trial. Among the three conditions, the mean reaction time was shortest under the positive cue condition and longest under the neutral cue condition, indicating that object-based prioritization and deprioritization occurred. An identical pattern of results was found in a subsidiary experiment in which an outlined shape that carried half of the search items along its edge rotated clockwise, and the other shape carrying the remaining items rotated counterclockwise, further discouraging space-based inhibition. These results suggest that the visual system can prioritize and deprioritize multiple search items based on nonspatial, shape-based features.

23.458 **Gaze attraction toward higher-order image features generated by deep convolutional neural network** Rina Watanabe[1](r.watanabe@uec.ac.jp), Tomohiro Nishino[1], Kazuaki Akamatsu[2], Yoichi Miyawaki[2,3]; [1]Faculty of Informatics and Engineering, The University of Electro-Communications, [2]Graduate School of Informatics and Engineering, The University of Electro-Communications, [3]JST, PRESTO

Humans acquire visual information of the external environment while moving their eyes sequentially from one location to another. Previous studies showed that salient locations attract human gaze frequently (Itti, Koch, 1998), but more recent evidence suggests that higher-order image features might have higher predictability of gaze frequency (Kümmerer et al., 2016) and temporal characteristics (Kümmerer et al., 2017; Akamatsu, Miyawaki, 2018) than the classical saliency theory. However, it remains unclear whether higher-order image features per se serve as strong gaze attractors because previous experiments used natural scene images and the results could be influenced by semantic information from object categories and scene contexts. To resolve this issue, we designed a new experiment using "feature images" that can contain a pre-specified order of image features while suppressing object-categorical and scene-contextual information. The feature images were artificially generated so that they selectively maximized the response of a specific layer of a pre-trained deep convolutional neural network (DCNN), using gradient ascent optimization of image pixel values. Subject's eye movement was recorded while they were observing a pair of feature images, each of which corresponded to a different layer of DCNN. Results showed that feature images corresponding to a higher layer of DCNN (higher-layer feature images) attracted the gaze more frequently than the simultaneously-presented lower-layer feature images, and the gaze frequency progressively increased as the DCNN layer tied to feature images. Control analyses confirmed that higher-layer feature images did not possess higher saliency and thus classical saliency theory is unlikely to explain the observed gaze frequency bias. These results suggest that higher-order image features serve as a significant gaze attractor independently of semantic information embedded in natural scenes.

Acknowledgement: JST PRESTO (JPMJPR1778), JSPS KAKENHI (17H01755)

23.459 **Costs of attentional set-shifting during dynamic foraging, controlled by a novel Unity3D-based integrative experimental toolkit** Marcus R Watson[1](watsonmr@yorku.ca), Benjamin Voloh[2], Christopher Thomas[2], Asif Hasan[3], Thilo Womelsdorf[1,2,3]; [1]Department of Biology, Centre for Vision Research, York University, [2]Department of Psychology, Vanderbilt University, [3]Department of Electrical Engineering and Computer Science, Vanderbilt University

Introduction: There is an increasing demand for experiments in which participants are presented with realistic stimuli, complex tasks, and meaningful actions. The Unified Suite for Experiments (USE) is a complete hardware and software suite for the design and control of dynamic, game-like behavioral neuroscience experiments, with support for human, nonhuman, and AI agents. We present USE along with an example feature-based learning experiment coded in the suite.Methods: USE extends the game engine Unity3D with a hierarchical, modular state-based architecture that supports

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tasks of any complexity. The hardware, based around an Arduino Mega2560 board, governs communication between the experimental computer and any experimental hardware. Participants in our task had their eyes tracked as they navigated via joystick through a virtual arena, choosing between two objects on each trial, only one of which was rewarded. Objects were composed of multiple features, each with two possible values. Each context, signaled by the pattern of the floor, had a single rewarded feature value (e.g. red objects might be rewarded on a grass floor, pyramidal objects might be rewarded on a marble one). Results: USE's hardware enables the synchronization of all data streams with precision and accuracy well under 1 ms. Gaze was classified into behaviors (e.g. fixations/saccades) which displayed appropriate characteristics (e.g. velocities/magnitudes), and demonstrated ecologically meaningful characteristics when re-presented over task videos. Rule learning was all-or nothing, moving from chance to near-perfect performance in one or two trials. Participants displayed standard effects of set switching, including worse performance when contexts differed from the previous trial, and when rules involved an extra-dimensional shift from the previous block. Conclusions USE enables the creation and temporally-precise reconstruction of highly complex tasks in dynamic environments. Our example task shows that costs associated with attentional set-switching generalize to such dynamic tasks.

Acknowledgement: Grant MOP 102482 from the Canadian Institutes of Health Research (TW) and by the Natural Sciences and Engineering Research Council of Canada Brain in Action CREATE-IRTG program (MRW and TW).

23.460 **Averaging is not a coarse processing** Jihong Lee[1](stellamea@yonsei.ac.kr), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

The visual system has well adapted to process complex information efficiently to compensate for its limited capacity. We form a gist of a scene at a glance (Alvarez, 2011) by representing statistical properties of the scene. Due to the summary aspect of the scene, forming statistical representations is sometimes considered to be a coarsely occurring processing, during which fine-details of individual stimuli are not accessed. Thus, we tested if statistical properties were computed based on low spatial frequency (LSF) information. It has been known that the magnocellular (MC) adaptation reduces the impact of LSF information, suggesting that the precision of mean discrimination should decrease after the adaptation if mean computation is based on LSF information. We tested this idea in three experiments. Twelve young adults participated in each experiment including adaptation and no adaptation conditions. During adaptation trials, participants were presented with flickers prior to mean discrimination tasks. This fast flicker adaptation paradigm (Arnold, Williams, Phipps, & Goodale, 2016) was designed to adapt the MC pathway and showed participants dynamic noise patterns rapidly updated at the refresh rate of 85 Hz. Across the experiments, participants discriminated means of orientations (Experiment 1), of circle sizes (Experiment 2), and of emotions on facial expressions (Experiment 3). We fitted psychometric functions to individual data and averaged them in the two adaptation conditions, yielding the widths of the functions in the two conditions. We found that the widths of the functions in the adaptation condition were significantly narrower than or at least comparable to the width of the function in the no-adaptation condition, indicative of higher or at least similar precision after the adaptation. These results suggest that averaging is not merely a coarse processing relying on LSF information. It is still precise only with high spatial frequency information after the MC adaptation.

Acknowledgement: This work was supported by National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (NRF-2016R1A2B4016171).

Temporal Processing: Mechanisms

Saturday, May 18, 8:30 am - 12:30 pm, Pavilion

23.461 **Less Efficient Magnocellular Processing: A Common Deficit in Neurodevelopmental Disorders** Alyse C Brown[1](ac-6brown@students.latrobe.edu.au), Jessica Peters[1], Carl Parsons[2], David P Crewther[3], Sheila G Crewther[1]; [1]School of Psychological Science and Public Health, La Trobe University, [2]Port Philip Specialist School, Port Melbourne, [3]Centre for Human Psychopharmacology, Swinburne University of Technology

Motion is processed within the visual dorsal stream that receives 80% of its input from the rapid processing magnocellular (M) pathway, a pathway critical for the discrimination of rapidly presented sequential stimuli and tracking rapid motion. Deficits in global motion processing are observed in several neurodevelopmental disorders (NDD) leading to our hypothesis that weak motion processing is due to temporal deficiency in M pathway. Thus, M pathway efficiency was behaviourally measured in a sample of NDDs and neurotypicals (mean age 10, range 7-21 years, n=71) via two 4AFC achromatic flicker fusion threshold (FFT) tasks modulated at low and high contrast. The main NDD diagnoses tested were singular or comorbid combinations of Dyslexia, ASD, ID, as well as ADHD which to date have not been reported to have visual anomalies. Autistic tendencies (AQ) was measured in all participants. Diagnosed NDD without ID were individually matched on both chronological age and nonverbal intelligence with typically developing (TD) while ID was matched solely on chronological age. Results showed that young participants with ASD and Dyslexia (aged 7-15yr) including those with comorbid ADHD demonstrated comparable FFTs that were significantly lower than their matched control. However, FFT in the older ASD participants (16+yrs) was only significantly lower at high contrast. Participants with an ID diagnosis which included ASD+IDhad inconsistent FFT profile with a large range of thresholds achieved. Interestingly, participants with ADHD alone had significantly higher FFT at high contrast compared to their TD group, possibly due to ADHD prescribed stimulant medication.Higher AQ score was found to correlate with lower FFT ($r = -.269$, $p < .005$ $n=71$). In conclusion, an ID diagnosis was not predictive of a temporal M deficiency however, there was strong evidence for a less efficient M pathway in the ASD and dyslexia diagnoses that could go towards explaining their weak motion processing profiles.

23.462 **Visual discrimination of spatiotemporal average orientation.** Hiromi Sato[1,2](satou.hiromi@gmail.com), Takumi Oide[3], Ryuto Yashiro[4], Isamu Motoyoshi[4]; [1]Department of Informatics, Kogakuin University, [2]JSPS Research Fellow, [3]Department of Integrated Sciences, The University of Tokyo, [4]Department of Life Sciences, The University of Tokyo

A number of studies have revealed that the visual system can rapidly compute average orientation in stochastic stimuli. The recent studies have also analyzed how humans estimate the average orientation in dynamic stimuli across time. The present study investigated visual mechanisms underlying the discrimination of average orientation over space and time. Visual stimulus was a dynamic texture, in which 4 or 32 frames of texture patterns were serially presented with a framerate of 33 ms. Each frame of texture was composed of 70 Gabor elements (2.3 c/deg) that were randomly distributed within a circular window of 10.7 deg diameter. The orientation of elements in each texture frame was varied according to a Gaussian distribution with a standard deviation (spatial SD) of 0, 4, 8, or 16 deg, and the spatial mean orientation of each texture frame was varied according to a particular mean and a standard deviation (temporal SD) of 0, 4, or 8 deg. Five observers viewed the dynamic texture at fovea, and indicated whether its spatiotemporal average of orientation was tilted clockwise or counter-clockwise. The spatiotemporal mean of dynamic texture was controlled by a staircase procedure, and the discrimination thresholds was estimated. It was found that discrimination threshold increased as a function of spatial SD when temporal SD is small. When temporal SD is large, however, threshold was nearly constant over a wide range of spatial SD, or even decreased as spatial SD increased in some observers. This is clearly inconsistent with the assumption that threshold is determined by spatiotemporal SD of orientation in the dynamic texture. The results suggest distinct mechanisms involved in computation of spatial average and temporal average of orientation.

Acknowledgement: Supported by the Commissioned Research of National Institute of Information and Communications Technology, and by JSPS KAKENHI JP15H05916, JP15H03461 and JP16J07259.

23.463 **Measuring the Information Content of Visually-Evoked Neuroelectric Activity** Michelle R Greene[1](mgreene2@bates.edu), David J Field[2], Bruce C Hansen[3]; [1]Program in Neuroscience, Bates College, [2]Department of Psychology, Cornell University, [3]Department of Psychological & Brain Sciences, Neuroscience Program, Colgate University

This study addresses a fundamental question regarding the amount information contained in neuroelectric signals. More specifically, we ask the question of how many bits of information are carried by SSVEP and VEP signals regarding a particular population of natural scenes. In two experiments, observers (N=13 and N=23, respectively) viewed 150 grayscale, contrast-normalized natural scene images (subtending 18.5 deg.) while undergoing 128-channel EEG. In Experiment 1, the images were presented in a steady-state paradigm (SSVEP, 5 Hz sinusoidal contrast modulation for 6 s) and were repeated four times across the experiment. Experiment 2 was a visually-evoked potential (VEP) paradigm in which images were presented

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for 500 ms each and repeated six times across the experiment. For both experiments, we expressed neuroelectric responses as points in a state-space defined by the first two principal components of all responses (which capture 95%+ of the variance). If EEG signals (either SSVEP or VEP) contain reliable information about scene identity, then repeated presentations should tightly cluster in the space. We operationalized this using mutual information, which examines the relative spread of points from the same image to the spread from all points overall. Although 150 images can be expressed with 7.23 bits, we found that the SSVEP signals carried an average of 2.1 bits per image of mutual information. The VEP signals contained 1.8 bits per image when averaged across observers, and 1.0 bits when no averaging was applied, highlighting the importance of averaging to de-noise the signal. Although these conclusions are a function of the particular stimuli used in our study (normalized grayscale natural scenes) and are dependent on assumptions regarding the noise distributions, we believe our results provide an important insight into the information present in this non-invasive signal, and offer a framework for characterizing the information content of other imaging modalities.

Acknowledgement: National Science Foundation (1736274) grant to MRG National Science Foundation (1736394) and James S. McDonnell Foundation (220020439) grants to BCH

23.464 **Entrainment of brain oscillations persists after the entrainer removal** Mónica Otero[1,2](monicaot2001@gmail.com), Pavel Prado[2], Alejandro Weinstein[2,3], María-José Escobar[1,2], Wael El-Deredy[2,3]; [1]Universidad Técnica Federico Santa María, [2]Advanced Center for Electrical and Electronic Engineering, [3]Universidad de Valparaíso

Neural oscillations have been suggested to be involved in basic mechanisms which allow the synchronization of neural activity within and across brain regions. Neural entrainment has been defined as the synchronization of neural responses to an external stimulus. Perceptual detection of target stimuli presented right after the entrainment offset, depends on the time between the entrainment offset and the target presentation. These results suggested that entrainment persists after visual stimulation removal. We tested this hypothesis by characterizing the generation and persistence of steady-state visual evoked potentials (SSVEP) in 24 healthy volunteers. SSVEP were elicited by visual stimuli modulated in amplitude using the subject´s resting-state peak frequency. The electrophysiological signal was narrow-band filtered (± 1Hz around the entrainer frequency) and the envelope of the resulting signal was calculated using a Hilbert transform. The period between the stimulus offset and the time at which the brain oscillations returned to the pre-stimulus stage was defined as the duration of the entrainment persistence. Neural generators involved in the entrainment persistence were estimated using low resolution electromagnetic tomography analysis (LORETA). Our results demonstrate that visual entrainment can be generated using continuous amplitude-modulated sinusoidal stimulation. More important, visual entrainment can persist up to 400 ms after the stimulus offset, which corresponds to 4 cycles for 10-Hz stimulation. The neural entrainment was associated with the increased activation of the visual primary cortex (bilateral) and temporal and parietal areas involved in processing temporal and spatial visual information (left hemisphere). Occipital, temporal and parietal activations decreased after the entrainer offset. Nevertheless, significant increased activity of frontal areas was obtained during the persistence stage, mainly in the superior and medial frontal gyri. Our results suggest that persistence of the neural entrainment is mediated by fronto-occipital connections which might modulate the detection of target stimuli after the entrainer offset.

Acknowledgement: Advanced Center for Electrical and Electronic Engineering, AC3E, Basal Project FB0008, CONICYT, CONICYT-PFCHA/Doctorado Nacional/2017- 21171741_Mónica Otero Ferreiro, FONDECYT REGULAR 1161378 a cargo del profesor Wael El-Deredy, UTFSM (ELO), Valparaíso, Chile.

23.465 **Behavioural oscillations in subjective timing: the intentional binding effect modulates over time** Huihui Zhang[1](zhanghuihui.cn@gmail.com), David Alais[1]; [1]School of Psychology, The University of Sydney

In a phenomenon called 'intentional binding,' the perceived temporal interval between a voluntary action (e.g., a button press) and a subsequent sensory event (typically 250 ms later) is subjectively compressed. We investigate this effect in light of recent work showing that perceptual sensitivity oscillates over time, exhibiting peaks and troughs, and that the phase of the perceptual oscillation is aligned with a voluntary action. We examined whether the 'intentional binding' effect oscillates over time after a voluntary action by measuring the effect with a fine-grained time course. Participants viewed a rotating clock-hand and voluntarily pressed a button to start a trial, after which a brief tone sounded at a random time (0-800 ms, in 5 ms steps). Participants reported the clock position when they heard the tone. The clock rotation period was either 2.5 s/cycle (Experiment 1) or 5 s/cycle (Experiment 2) and we measured the clock-reading error as a function of the time interval between the voluntary action and the tone. Consistent with previous 'intentional binding' results, both experiments showed that the perceived time of the tone (inferred from the clock position) was attracted towards the voluntary action. In general, the magnitude of 'intentional binding' decreased as the action/tone interval increased. Interestingly, the 'intentional binding' effect oscillated along this linear decreasing trend, oscillating at 1.8 Hz in Experiment 1 and 1.6 Hz in Experiment 2 within the time course of 800 ms. Our results suggest that the oscillations of 'intentional binding' may reflect the intrinsic dynamic modulation of attentional tracking which is not modulated by the speed of clock rotation.

23.466 **Dissociable effects of attention and expectation on perceptual decision making** Nuttida Rungratsameetaweeman[1,2,3](nrungrat@ucsd.edu), Sirawaj Itthipuripat[2,4], John T. Serences[1,2]; [1]Neurosciences Graduate Program, University of California, San Diego, [2]Department of Psychology, University of California, San Diego, [3]U.S. Army Research Laboratory, Aberdeen Proving Ground, [4]Department of Psychology, Center for Integrative and Cognitive Neuroscience, and Interdisciplinary Program in Neuroscience, Vanderbilt University

Directing attention based on behavioral relevance and prior expectations about regularities in the environment both impact perceptual decision-making (Summerfield & de Lange, 2014). Some suggest that attention and expectations both impact early sensory processing, whereas others suggest that expectations only influence later stages of decision-making. However, to date, only a few studies have examined these two modulatory factors within the same experiment to determine if they operate via similar or independent mechanisms. In the present study, participants viewed a display containing flickering iso-oriented lines, half of which were blue and half of which were red. On each trial, some percentage of the lines were rendered in the same orientation (forming a 'coherent' global orientation). We manipulated attention (behavioral relevance) by cueing participants to monitor either the red or blue lines (focused attention) or to monitor both (divided attention). Expectation of the target-defining coherent orientation was manipulated by varying the probability of a given target orientation within a block of trials. Finally, we examined interactions between stimulus strength and attention/expectation by manipulating the fraction of flickering lines that define the target orientation (low/high coherence). Participants indicated their response using a flight-simulator joystick, while EEG data were recorded. We found that attention modulated EEG signals (the visual negativity and the centro-parietal positivity) by improving sensory encoding and the rate of sensory evidence accumulation in the same manner as increasing stimulus strength. In contrast, expectation selectively modulated EEG markers of the later stages of decision-making including executive control and response selection, without affecting early markers associated with early sensory processing. These results suggest that attention and expectation have a separable impact on decision-making, and that expectation, in the absence of changes in behavioral relevance, does not impact early sensory processing.

Acknowledgement: NEI R01EY025872 and James S. McDonnell Foundation awards to J.T.S., HHMI International Predoctoral Fellowship and a Royal Thai Scholarship from the Ministry of Science and Technology in Thailand to S.I., and mission funding from the U.S. Army Research Laboratory

23.467 **cTBS to V1 alters GABA and Glx** Karlene Stoby[1](kssstoby@gmail.com), Sara Rafique[1], Georg Oeltzschner[2], Jennifer Steeves[1]; [1]Centre for Vision Research and Department of Psychology, York University, [2]Department of Radiology and Radiological Science, The Johns Hopkins University

Theta Burst Stimulation (TBS), an increasingly popular non-invasive neuromodulation technique, is used in a variety of experimental research exploring its effects on healthy controls as well as a number of neurological disorders including depression and schizophrenia. TBS can produce similar effects as repetitive transcranial magnetic stimulation (rTMS) but has the advantage that stimulation can be achieved in a much shorter amount of time. Our lab previously investigated the effects of single and accelerated (multiple) sessions of low-frequency (1 Hz "inhibitory") rTMS to V1 on levels of the inhibitory neurotransmitter GABA and excitatory neurotransmitter Glutamate (Glx) using magnetic resonance spectroscopy (MRS). We found that the single session protocol had little effect on GABA and Glx, while accelerated sessions unexpectedly decreased GABA levels compared to baseline for 24 hours following stimulation. Here, we sought to measure the effects of cTBS ("inhibitory" TBS) to V1 on GABA and Glx compared to a sham cTBS condition. Our data show that cTBS increases GABA levels and decreases Glx levels. This contrasts our previous finding where accelerated 1 Hz rTMS reduces GABA levels. While 1 Hz rTMS and TBS may share similar behavioural inhibitory effects, they have comparatively different effects on neurotransmitter levels. This study demonstrates the short-term neural mechanisms of cTBS at V1 and highlights critical neurochemical differences between TBS and rTMS at the visual cortex.

Acknowledgement: NSERC, CFREF

23.468 **Occipital Alpha-TMS causally modulates Temporal Order Judgements: Evidence for discrete temporal windows in vision** Samson Chota[1,2](samson.chota@googlemail.com), Phillipe Marque[3], Rufin VanRullen[1,2]; [1]Université de Toulouse, UPS, Centre de Recherche Cerveau et Cognition, 31052 Toulouse, France, [2]CerCo, CNRS UMR 5549, 31052 Toulouse, France, [3]Médicine Physique et de réadaption, CHU Rangueil, 31062 Toulouse, France

Recent advances in neuroscience have challenged the view of conscious visual perception as a continuous process. Behavioral performance, reaction times and some visual illusions all undergo periodic fluctuations that can be traced back to oscillatory activity in the brain. These findings have given rise to the idea of a discrete sampling mechanism in the visual system. In this study we sought to investigate the causal relationship between occipital alpha oscillations and temporal order judgements (TOJ) using neural entrainment via rhythmic TMS. 10 participants received 5 TMS pulses (100 ms ISI) per trial leading to neural entrainment at 10 Hz. Directly following the TMS entrainment we presented a sequence of two distinct Gabor patches (68 ms ISI) at varying SOAs (25 to 158 ms after last pulse, 9 SOAs) and asked participants to report the temporal order of the Gabors. This dense sampling method allowed us to probe TOJ performance as a function of SOA: By collecting ~1035 trials per subject over the course of 3 sessions we calculated a TOJ time-series that covered 4/3 of an entrained alpha cycle. A subsequent power analysis of the TOJ time-series revealed a significant modulation at 10 Hz, only for sequences presented contralateral to the cortical TMS site. Furthermore the analysis of the 10 Hz components of individual TOJ time-series showed significant phase clustering between participants. In conclusion we find that certain phases of the entrained oscillation facilitate temporal order perception of two visual stimuli, whereas others hinder it. Our findings support the idea that the visual system periodically compresses information into discrete packages within which temporal order information is lost, in line with the idea of discrete perception. To our knowledge this is the first study providing causal evidence via TMS for a periodic modulation of time perception.

Acknowledgement: DAAD, ERC P-CYCLES

23.469 **An EEG investigation of tactile duration adaptation** Baolin Li[1,2](lblpsy@pku.edu.cn), Lihan Chen[1,2,3], Jianrong Jia[1,2,4,5]; [1]School of Psychological and Cognitive Sciences, Peking University, [2]Beijing Key Laboratory of Behavior and Mental Health, Peking University, [3]Key Laboratory of Machine Perception (Ministry of Education), Peking University, [4]Peking-Tsinghua Center for Life Sciences, Peking University, [5]IDG/McGovern Institute for Brain Research, Peking University

Repetitive exposure to relatively long or short sensory events has been shown to shorten or lengthen the perceived duration of a subsequent event, which is referred to as the repulsive duration aftereffect. Duration aftereffect in vision has received much attention, but little work has been done on the tactile duration aftereffect. Here, we used electroencephalography (EEG) to investigate how the tactile duration adaptation modulates the subsequent temporal encoding represented by the contingent negative variation (CNV). Participants compared the durations of the test vibrotactile stimulus (500 ms) and the visual disk (370, 450, 500, 550, or 630 ms) after adapting to short (200 ms) or long (800 ms) vibrotactile stimulus. The test vibrotactile stimuli were always presented on the left or right index fingertip, while the adapting vibrotactile stimuli could be presented on the same index fingertip (same location), or the middle fingertip of same hand (adjacent location), or the index fingertip of different hand (homologous location). Behavioral results showed that the aftereffect magnitudes, indexed by the arithmetic differences between the PSEs after short and long adaptations, were significantly larger than zero at the same and adjacent locations, but not at the homologous location. Importantly, the simultaneously recorded event-related potentials (ERPs) revealed that the test vibrotactile stimuli evoked clearly identifiable CNV components both in fronto-central and contralateral post-central scalp regions. However, only in the contralateral post-central scalp, the significant aftereffects (indexed by the arithmetic differences between the CNV amplitudes after long and short adaptations) were observed at the same and adjacent locations, but not at the homologous location. These findings suggest that topographic distances between the adapting and test fingers modulate the neural correlates of tactile duration aftereffect.

23.470 **fMRI signatures of perceptual echoes in early visual cortex** Canhuang Luo[1,2*](luocanhuang@gmail.com), Sasskia Brüers[1,2*], Isabelle Berry[1,2,3], Rufin VanRullen[1,2], Leila Reddy[1,2]; [1]Université de Toulouse, Centre de Recherche Cerveau et Cognition, Université Paul Sabatier, 31062, Toulouse, France, [2]Centre National de la Recherche Scientifique, Unité Mixte de Recherche 5549, Faculté de Médecine de Purpan, 31052, Toulouse Cedex, France, [3]Toulouse NeuroImaging Center, INSERM, U825, Toulouse, France

The visual Impulse Response Function (IRF) can be estimated by cross-correlating random luminance sequences with concurrently recorded EEG. It typically contains a strong 10Hz oscillatory component, suggesting that visual information reverberates in the human brain as a "perceptual echo" (VanRullen & Macdonald, Curr. Biol. 2012). The neural origin of these echoes remains unknown. To address this, we conducted an fMRI experiment. Instead of concurrently recording EEG and fMRI, which often leads to artifacts and spurious correlations, we recorded EEG and fMRI in two separate sessions. In both sessions, a disk whose luminance followed a random (white noise) luminance sequence was presented in the upper left quadrant. Participants (N=16) detected a rare near-threshold target embedded in the disk. Individual IRFs were derived from the EEG session. Then, these IRFs were used as "response templates" (Brüers & VanRullen, eNeuro, 2017) to reconstruct an estimate of the EEG during the fMRI session, by convolution with the corresponding random luminance sequences. The 7-14Hz (alpha) envelope of the reconstructed EEG was finally used as an fMRI regressor, to determine which brain voxels co-vary with the oscillations elicited by the luminance sequence, i.e. the "perceptual echoes". The reconstructed envelope of EEG alpha (but not other frequencies like delta=2-4Hz, theta=4-8Hz or beta=14-28Hz) was significantly correlated with BOLD responses in V1 and V2. Surprisingly, this correlation was visible outside, but not within the directly (retinotopically) stimulated region. We tentatively interpret this lack of alpha modulation as a saturation effect, since the overall stimulus-induced BOLD response was inversely related, across voxels, to the signal variability over time. In conclusion, our results suggest that perceptual echoes originate in early visual cortex, driven by wide-spread activity in V1 and V2, not retinotopically restricted but possibly reflecting the propagation of a travelling alpha wave (Lozano-Soldevilla & VanRullen, bioRxiv 2018). *equal contribution

23.471 **Predictive coding reduces metabolic costs** Blake W Saurels[1](blake.saurels@uq.net.au), Derek H Arnold[1]; [1]School of Psychology, The University of Queensland, Australia

The human brain makes predictions about upcoming input (Friston, 2018, Nature Neuroscience; Rao & Ballard, 1999, Nature Neuroscience). This allows it, for instance, to anticipate the trajectory of moving objects. It has been suggested the brain expends less energy when input conforms to predictions (Friston, 2010, Nature Reviews Neuroscience). We used the brain's intuitive understanding of physics (MacNeilage & Glasauer, 2018, Current Biology) to examine this idea. Participants viewed short basketball videos that were presented upright or inverted, while their eye movements were tracked. Videos culminated in successful or unsuccessful jump shots. We found people were less effective at predicting shot outcomes when footage was inverted, and this was associated with greater evoked responses, recorded via EEG. We explore the processes underlying this outcome. Our data is suggestive of metabolic cost reduction for predictable input – a central tenant of predictive coding, whereby successful predictions generate less activity.

Acknowledgement: ARC Discovery Project Grant awarded to DHA

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Perception and Action: Locomotion, wayfinding

Saturday, May 18, 2:30 - 4:15 pm, Talk Room 1

Moderator: Jeffrey Saunders

24.11, 2:30 pm **Modeling Gaze and Foothold Selection in Outdoor Walking** Dawei Liang[1](dawei.liang@utexas.edu), Ruohan Zhang[1], Jonathan S. Matthis[1], Karl S. Muller[1], Edison Thomaz[1], Dana H. Ballard[1], Mary M. Hayhoe[1]; [1]The University of Texas at Austin

Modeling and interpreting human gaze behaviors in natural environments is challenging, partly because of the complexity of natural stimuli. We recorded subjects' gaze and body movements while walking on a rocky path (Matthis et al 2018). Gaze and foothold selection are tightly linked, but it is unclear what features attract gaze in this context. We leveraged the recent development of convolutional neural networks (CNN's) and designed a convolution-deconvolution network to predict gaze using the collected data. This model is able to achieve high accuracy (AUC = 0.94, compared with 0.6 for saliency models). Thus gaze behavior in such a visually demanding task cannot simply be predicted by traditional, manually crafted saliency features. Presumably, the high accuracy of the trained network model indicates that the network has learned important features that capture human gaze. However, the model itself is a complex system with millions of neurons hence not directly interpretable. To address this challenge and study the learned features, we devised a methodology to test hypotheses on what visual features are most predictive of gaze location, and to identify model "neurons" that have the most diagnostic activity. We present visual stimuli of different spatial frequencies and orientations, as well as selected image patches from the dataset, to the trained neural network, and record the activities of the neurons in the network. The activation map on the input visual stimulus can be directly visualized to identify patterns that the whole network favors. We observed that the model is selective for regions with particular spatial frequencies that are likely suitable for foot placement. Consistent with this, regions that have higher uncertainty in gaze prediction also have higher uncertainty in foot placement. Thus CNN's can help identify visual features that determine gaze and foothold selection in complex natural terrain.

Acknowledgement: The authors are very grateful for support by NIH grant NIH EY05729 and K99 grant 1K99EY028229-01A1.

24.12, 2:45 pm **The Embodied Semantic Fovea - real-time understanding of what and how we look at things in-the-wild** Aldo A Faisal[1,2,3,4](aldo.faisal@imperial.ac.uk), John A Harston[1,2], Chaiyawan Auepanwiriyakul[1,3], Mickey Li[1,3], Pavel Orlov[1,2]; [1]Brain & Behaviour Lab, [2]Dept. of Bioengineering, [3]Dept. of Computing, [4]Data Science Institute

Natural gaze behaviour is highly context-driven, controlled both by bottom-up (external visual stimuli) and top-down saliency (task goals and affordances). Whilst quantitative descriptions are easily obtainable in highly constrained tasks, ecological validity is an issue as gaze behaviour is richer in natural environments with free locomotion, head and eye movements. Whilst much work has been done on qualitative description of these natural dynamics, quantitative analysis of the spatiotemporal characteristics of natural gaze behaviour has proven difficult, due to the time-intensive nature of manual object identification and labelling. To address this issue we present 'Embodied Semantic Fovea', a proof-of-concept system for real-time detection and semantic labelling of objects from a head-mounted eye-tracker's field-of-view, complemented by SLAM-based reconstruction of the 3D scene (Li et Faisal, ECCV WS, 2018) and 3D gaze end-point estimation (Orlov et Faisal, ETRA 2018). Our system reconstructs the entire visual world from surface elements (surfels), allowing us to understand not just how gaze moves across specific surfels, but also how surfels aggregate for a given object class. With this it is possible to track eye movements that land on an object, even as the wearer moves freely around the object, allowing us to understand eye movements from perspectives that are usually not possible (e.g. understanding that we are engaging with the same tree but from opposing directions). This allows systematic measurement of real-world scenario inter-object affordances for people in freely-moving environments. Using pixel-level object labelling with depth estimation from an egocentric scene camera, with simultaneous pupil tracking, we can superimpose gaze vectors over 3D-reconstructed object surfaces, providing the first three-dimensional object gaze reconstruction in freely-moving environments. We thereby produce 'object maps' of objects' locations in relation to other objects, and understand how gaze moves between them, allowing true interrogation of three-dimensional gaze behaviour in freely-moving environments.

Acknowledgement: EPSRC & H2020 Project Enhance www.enhance-motion.eu

24.13, 3:00 pm **Effects of head and body orientation on center bias and serial dependence in heading perception** Qi Sun[1,2](979493161@qq.com), Li Li[1,2]; [1]Neural Science Program, NYU-ECNU Institute of Brain and Cognitive Science, New York University Shanghai, Shanghai, PRC, [2]Department of Psychology, The University of Hong Kong, Pokfulam, Hong Kong SAR

Previous studies have shown that self-motion (heading) perception is biased toward display center (center bias) and affected by recently-seen stimuli (serial dependence). Here, we examined effects of head and body orientations on center bias and serial dependence in heading perception. The display (80°x80°) simulated observer translation (3m/s) through a 3D random-dot cloud (depth range: 0.57-2.0m) consisting of 200 dots. On each 500-ms trial, heading direction was randomly chosen from -24° (left) to +24° (right) with respect to display center (0°) in steps of 4°. Participants judged direction of heading with a mouse-controlled probe under three conditions: (1) head and body orientations were aligned with display center, (2) head was rotated 10° away from body midline that was aligned with display center, and (3) head and body midline were aligned and rotated 10° from display center. To evaluate center bias, we performed a linear regression between perceived and actual heading. To evaluate serial dependence, we combined a first derivative of Gaussian function with a sinusoidal function to fit residual heading error (difference between perceived and predicted heading with center bias in the current trial) as a function of relative heading offset (difference in actual heading of previous trial and current trial). We found: (1) an overall bias in heading judgments toward head and body orientation direction; when head and body orientations were not aligned with display center, (2) a decrease in center bias, (3) an increase in the range of central attractive serial dependence, and (4) an increase in the amplitude of peripheral repulsive serial dependence in heading judgments. Our findings show both egocentric and world-centric centers contribute to center bias in heading perception. When world-centric center is not aligned with egocentric center, people increase their reliance on recently-seen heading directions for heading judgments.

Acknowledgement: the National Natural Science Foundation of China (31741061), Shanghai Science and Technology Committee (15DZ2270400, 17ZR1420100), and NYU-ECNU Joint Research Institute

24.14, 3:15 pm **Predicting driving impairment from visual and oculomotor impairment after alcohol intake** Jing Chen[1,2](chenjingpku@gmail.com), Yinghua Yang[3], Rui Jin[4], Leland S Stone[5], Li Li[1,2]; [1]Faculty of Arts and Science, New York University Shanghai, Shanghai, China., [2]NYU-ECNU Institute of Brain and Cognitive Science at New York University Shanghai, Shanghai, China, [3]School of Psychology and Cognitive Science, East China Normal University, Shanghai, PRC, [4]Department of Psychology, The University of Hong Kong, Pokfulam, Hong Kong SAR, [5]Human Systems Integrations Division, NASA Ames Research Center, Moffett Field, CA, USA

Driving under the influence of alcohol has serious adverse individual and societal consequences. While the legal limit of blood alcohol content (BAC) is typically 0.08% and many people subjectively feel capable of driving unimpaired after 2-3 drinks, it is reasonable to think that any amount of alcohol in the bloodstream could impact driving ability to some degree. Here we examined the relationship between low-level neural impairment (as evidenced from visual and visuomotor testing using an ocular tracking task) and operational driving impairment (as evidenced from performance testing and modeling using a simulated lane-keeping task) after alcohol intake. For the lane-keeping task, the display (95°x63°) simulated a participant driving a virtual vehicle down a lane while facing crosswind perturbations (sum-of-sines motion: 0.1-2.19Hz). Participants (n=23, 13 females) used a steering wheel to control heading of the vehicle to keep it centered in the lane. For the ocular tracking task, the same participants tracked the step-ramp motion

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of a target dot (diameter: 0.64º) with its speed (16°/s-24°/s) and direction (0°-360°) randomly varied from trial to trial. We tested four BACs (0, 0.02%, 0.04%, & 0.08%). Model-independent analyses show that, while precision of lane-keeping (measured by RMS error) was affected only at the highest BAC tested (0.08%), significant effects of alcohol on visual and oculomotor function (measured by a composite ocular tracking index) are evident at the lowest BAC (0.02%). Furthermore, several ocular tracking parameters are significantly correlated with the phase lag of lane-keeping at 0.08% BAC (r2 >0.22). Model-dependent analyses however show that, while reaction time and neuromuscular stability appear degraded starting at the lowest BAC, the ability of our participants to generate compensatory lead control for lane-keeping appears to increase with BAC. This counterintuitive finding may explain the subjective, yet false, confidence in driving ability at 0.08% BAC (about 3 standard drinks).

Acknowledgement: Supported by research grants from the National Natural Science Foundation of China (31741061), Shanghai Science and Technology Committee (15DZ2270400, 17ZR1420100), and NYU-ECNU Joint Research Institute at NYU Shanghai.

24.15, 3:30 pm **The relative rate of optical expansion controls speed in 1D pedestrian followin** Jiuyang Bai[1](jiuyang_bai@brown.edu), William H Warren[1]; [1]Department of Cognitive Linguistic and Psychological Science, Brown University

Last year, we compared six models of speed control for a pedestrian following behind a leader (Bai & Warren, VSS 2018). The results showed that Rio, Rhea & Warren's (JoV, 2014) optical expansion model best fit the data, and explained the decreasing response with distance. The model uses the rate of expansion (or contraction) of the target's visual angle to control the follower's deceleration (acceleration), thereby canceling the optical expansion. However, the model predicts that a larger target should produce a greater acceleration, because the rate of expansion is a monotonically increasing function of target size (over a moderate range of target sizes). Here we propose an alternative model in which the relative rate of expansion (expansion rate/visual angle) controls acceleration, which mitigates the sensitivity to target size. To compare the two models, we asked participants to follow a moving target, the size of which varied randomly on each trial (width = 0.2, 0.6, 1 m, height = 3 m).12 participants walked in a virtual environment wearing a head-mounted display, while head position was recorded at 90 Hz. They were instructed to follow a virtual target (a green cylinder) on a textured ground plane. In each trial, the target appeared in front of the participant (distance = 1, 3, 6 m) and started to move on a straight path at a constant speed (1.2 m/s). After 3-4 seconds, the target changed its speed (+0.3, 0, -0.3 m/s). Bayesian model comparison revealed that the relative expansion model had a lower RMS error (.085 m/s2) and BIC value (-284.88) than the expansion model (0.094 m/s2, -272.15), which exhibited larger error for the extreme target sizes (0.2 and 1 m). The results provide 'very strong' support that the relative rate of expansion is used to control speed in pedestrian following.

Acknowledgement: Supported by NSF BCS-1431406

24.16, 3:45 pm **Collective Decision Making in Human Crowds: Majority Rule Emerges From Local Averaging** Trenton D Wirth[1](trenton_wirth@brown.edu), William H Warren[1]; [1]Cognitive, Linguistic, and Psychological Sciences, Brown University

Collective motion in human crowds emerges when each pedestrian averages the motion of their neighbors (Warren, CDPS, 2018). Previously, we found that a participant is influenced by a weighted average of visible neighbors, with a weight that decays exponentially with distance (Rio, Dachner & Warren, PRSB, 2018). Yet crowds also make collective decisions, such as whether to follow a subgroup, that seem to imply a nonlinear decision rule (Pillot, et al., 2011; Leonard, et al., 2012).Faced with such a decision, does a pedestrian follow the group average, a quorum, the majority, or the minority?Our neighborhood model seems to suggest they would average the two groups. To test the question, we asked participants to "walk with" a virtual crowd (N=8 or 16) that split into two subgroups.Participants walked in a 12x14m tracking area while wearing a head-mounted display, and head position was recorded. On each trial, the virtual crowd walked forward (1-2 s), then a subgroup turned left (50%, 63%, 75%, 88% of the crowd) and the rest turned right by the same amount (angle between them α = 10°, 15°, 20°, 25°, 30°). Interestingly, both the participants and the neighborhood model tend to follow the majority. A regression analysis shows that the neighborhood model accounts for 42% of the variance in the human final heading. Thus, an apparently nonlinear decision does not require a nonlinear decision rule. Rather, the nonlinearity stems from the spatial separation of the two groups over time:The initial response is biased by the majority of near neighbors, who pull the participant away from the minority and increasingly dominate the neighborhood. To test this explanation, Exp. 2 eliminates the spatial separation by using two continuous streams of virtual neighbors. Conclusion: nonlinear decision-making emerges from spatial averaging over a small neighborhood.

Acknowledgement: NSF BCS-1431406

24.17, 4:00 pm **Updating Perception and Action Across Real-World Viewpoint Changes** Andrew Clement[1](as.clement@utoronto.ca), James R Brockmole[2]; [1]Department of Psychology, University of Toronto, [2]Department of Psychology, University of Notre Dame

According to the action-specific account of perception, performing actions can distort our visual perception of the world. For example, using a reach-extending tool leads people to underestimate the distances to objects. Unlike many real-world situations, these action-specific distortions have largely been studied under stationary viewing conditions. Here, we tested whether these distortions persist when observers move to new viewpoints. Participants stood at one end of a table and viewed as an object was projected onto the table. Participants reached for the object with their index finger or a metal baton, and touched the object if it was within reach. Although all objects were beyond reach of participants' index finger, all objects were within reach of the baton. After reaching for the object, participants stood in place or moved to a new viewpoint, then estimated the object's distance from their current viewpoint. In our first two experiments, when participants stood in place, using a tool led them to report shorter distance estimates. However, when participants moved to a new viewpoint, using a tool did not influence their distance estimates. Thus, action-specific distortions did not persist when observers moved to new viewpoints. In our next three experiments, we tested whether these distortions persist when observers produce other types of movement. Specifically, participants rotated in place, took a step backward, or simply walked in place. In all three experiments, using a tool did not influence participants' distance estimates. Thus, the present findings were not simply due to changes in viewpoint, and could be observed when participants only received sensorimotor feedback from movement. Together, these findings suggest that action-specific distortions may not be as persistent as many theoretical accounts assume. Indeed, because observers are often free to move and observe objects from multiple viewpoints, these distortions may not be observed in many real-world situations.

Attention: Shifting, tracking

Saturday, May 18, 2:30 - 4:15 pm, Talk Room 2

Moderator: Brian Anderson

24.21, 2:30 pm **Hemifield-specific information is exchanged as targets move between the hemifields** Roger W Strong[1](rstrong@fas.harvard.edu), George A Alvarez[1]; [1]Department of Psychology, Harvard University

Tracking moving targets with attention is more difficult when targets cross between the left and right visual hemifields (compared to when targets move within their original hemifields), providing evidence for separate control of attentional tracking in each hemifield (Strong & Alvarez, VSS 2018). There are at least two possible explanations for this between-hemifield cost. One possibility is that hemifield-specific attentional spotlights inefficiently exchange target information as targets cross between hemifields; this explanation predicts that tracking accuracy should decrease with increasing numbers of between-hemifield crosses. A second possibility is that hemifield-specialized attentional spotlights continue to track their original targets after the targets cross between hemifields, but do so less effectively; this explanation predicts that tracking performance should decrease as the time targets spend in a new hemifield increases. To test these two possibilities, observers tracked two targets (one in each hemifield) that varied in A) the number of times they crossed between hemifields and B) the time they spent within a new hemifield (Experiment 1). Tracking accuracy decreased as the number between-hemifield crosses increased, but was not influenced by the time targets spent in a new hemifield. These results indicate that the between-hemifield tracking cost occurs because of an inefficient information exchange between hemifield-specific attentional spotlights. Experiment 2 explored whether this information exchange is aided or hindered by the vertical midline between hemifields, an area represented by both cerebral hemispheres during tracking (Drew et al., 2014). The between-hemifield cost increased when targets "teleported" through occluders (Scholl & Nevarez, 2002) at the vertical and horizontal midlines, suggesting that the exchange of target information is aided by tracking at the vertical midline. Together, these experiments show that hemifield-specific attentional spotlights exchange

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their representational content during between-hemifield movements, and suggest that this exchange is enabled by representational overlap at the vertical midline between hemifields.

24.22, 2:45 pm **Assessing the Competition Between Location-Based Selection History and Explicit Goals** Nick Gaspelin[1](gaspelin@binghamton.edu), Travis N. Talcott[1], Steven J. Luck[2]; [1]Department of Psychology, Binghamton University, State University of New York, [2]Center for Mind and Brain, University of California, Davis

Previous research on visual search has focused on the role of explicit goals on attentional guidance. However, there is now considerable evidence that visual attention is also influenced, in a seemingly unconscious and automatic manner, by recent experience (called selection history). In the current study, we investigated whether attention is automatically biased to the location of the target from the previous trial (called location priming) even when the actual target is at a different location.Previous studies investigating this question have mostly used manual RTs and manual accuracy to show that faciliatory effects on target detection when the target location is repeated. In the current study, we provide more direct evidence of location priming by measuring eye movements.This allowed us to precisely quantify the relative likelihood that a search item attracted visual attention depending on whether or not its location was primed.Surprisingly, we found that first eye movements were strongly biased toward the target location from the previous trial, even though this location was completely nonpredictive of the upcoming target location.The amount of location priming varied parametrically as a function of how difficult the current target was to locate. Altogether, these results suggest that recent experience can overpower explicit goals in guiding visual attention, especially when the target is difficult to find via explicit goals.

Acknowledgement: National Institutes of Mental Health, National Eye Institute

24.23, 3:00 pm **Distinguishing Between Punishment vs Negative Reinforcement in the Control of Attention** Brian A Anderson[1](brian.anderson@tamu.edu), Haena Kim[1], Mark K Britton[1], Andy J Kim[1]; [1]Department of Psychological & Brain Sciences, Texas A&M University

Stimuli associated with aversive outcomes such as shock and monetary loss automatically capture attention. In many common experimental paradigms, aversive outcomes can be either avoided with fast and accurate responses or are unrelated to behavior and probabilistic, meaning that the stimuli associated with such outcomes are also associated with the occasional withholding of an anticipated aversive event. It therefore remains unclear whether the resulting attentional biases are driven by learning from trials on which aversive outcomes are delivered (punishment learning) or withheld (negative reinforcement), and by extension what mechanism of learning is responsible shaping the attention system. In the present study, we provide two sources of converging evidence demonstrating that learning from punishment dominates over learning from negative reinforcement when the two sources of learning compete against each other. First, in an antisaccade task, one target color predicted a possible shock, which could be averted by a fast and accurate eye movement away from the stimulus. Thus, rapid eye movements away from the stimulus were negatively reinforced. A subsequent test phase involving prosaccades to a shape-defined target provided strong evidence for a bias towards the shock-associated color--with participants making slower and more frequently erroneous saccades to the target when coupled with a previously shock-associated distractor--even though such behavior was opposite that which was previously required to avert shock. In a second experiment, participants probabilistically received a shock immediately upon fixating one of two color distractors in an additional singleton task. Rather than this contingency reducing distractor fixations, which would have been the adaptive behavioral response, aversive outcomes ironically led to greater interference from, and more frequent saccades on, the shock-associated stimulus, directly leading to more total shocks. Altogether, our findings highlight a powerful role for learning from punishment in the shaping of attentional priority.

Acknowledgement: NARSAD Young Investigator Grant 26008

24.24, 3:15 pm **A delay in sampling information from temporally autocorrelated visual stimuli** Chloe Callahan-Flintoft[1](ccallahan-flintoft@gmail.com), Alex O Holcombe[2], Brad Wyble[1]; [1]Pennsylvania State University, [2]University of Sydney

Understanding when the attentional system samples from continuously changing input is important for understanding how we build an internal representation of our surroundings. Previous work looking at the latency of information extraction has found conflicting results. In paradigms where features such as color change continuously and smoothly, the color selected in response to a cue can be as long as 400 ms after the cue (Sheth, Nijhawan, & Shimojo, 2000). Conversely, when discrete stimuli such as letters are presented sequentially at the same location, researchers find selection latencies under 25 ms (Goodbourn & Holcombe, 2015). The current work proposes an "attentional drag" theory to account for this discrepancy. This theory, which has been implemented as a computational model, proposes that when attention is deployed in response to a cue, smoothly changing features temporally extend attentional engagement at that location whereas a sudden change causes rapid disengagement. The prolonged duration of attentional engagement in the smooth condition yields longer latencies in selecting feature information. In three experiments participants monitored two changing color disks (changing smoothly or pseudo-randomly). A cue (white circle) flashed around one of the disks. The disks continued to change color for another 800 ms. Participants reported the disk's perceived color at the time of the cue using a continuous scale. Experiment 1 found that when the color changed smoothly there was a larger selection latency than when the disk's color changed randomly (112 vs. 2 ms). Experiment 2 found this lag increased with an increase in smoothness (133 vs. 165 ms). Finally, Experiment 3 found that this later selection latency is seen when the color changes smoothly after the cue but not when the smoothness occurs only before the cue, which is consistent with our theory.

24.25, 3:30 pm **Unlike saccades, quick phases of optokinetic nystagmus (OKN) are not preceded by shifts of attention** Nina M Hanning[1,2](hanning.nina@gmail.com), Heiner Deubel[1]; [1]Allgemeine und Experimentelle Psychologie, Ludwig-Maximilians-Universität München, [2]Graduate School of Systemic Neurosciences, Ludwig-Maximilians-Universität München

Quick phases of optokinetic nystagmus are often equated to saccades. Indeed, their trajectories resemble the saccadic 'main sequence', and both saccade and quick phase control involve the same brainstem circuitry. However, whether and to what extend higher cortical areas associated with saccade programming (e.g. lateral intraparietal area, frontal eye fields) also participate in the control of OKN quick phases remains unknown. One hallmark of saccadic eye movements is the premotor shift of attention towards the saccade goal location, which is assumed to rely on overlapping networks for attention and oculomotor control in these higher cortical areas. Hence, the question arises if quick phases, like saccades, also draw attention towards their endpoint. We measured the spatiotemporal distribution of visual attention during OKN induced by a full-field dynamic pink noise stimulus (which we introduced at VSS 2018), that either moved leftwards or rightwards at a speed of 15°/s. At a random time and position the moving noise stimulus contained a brief orientation signal (50 ms) which participants had to discriminate. Taking visual orientation sensitivity as a proxy of attention, this paradigm allowed us to determine how attention is deployed during quick and slow phases of OKN, without the presence of object-like visual structures. Our results show that, unlike before saccades, visual attention is not enhanced at the endpoint of OKN quick phases. Instead, the data reveal that visual attention during OKN is predominantly allocated to the current gaze position. This suggests that OKN quick phases are reflexive gaze resetting movements controlled by low level, rather than higher, attention-related centers. OKN quick phases are not saccades.

Acknowledgement: This work was supported by grants of the Deutsche Forschungsgemeinschaft (GI964/1-1 and DE336/5-1).

24.26, 3:45 pm **Eye tracking supports active attentional suppression from negative templates** Nancy B Carlisle[1](nancy.carlisle@gmail.com), Ziyao Zhang[1]; [1]Department of Psychology, Lehigh University

Previous research has shown a reaction time benefit when participants are given a 'negative template' indicating the color of distractors in an upcoming array compared to when participants are given an uninformative cue (Arita, Carlisle, & Woodman, 2012). The RT benefits following a negative cue suggested active attentional suppression. However, this research utilized a 12-item display, with two colors separated by hemifield in order to equate

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the information value of a positive and negative template. This experimental design allows for an alternative explanation for the RT results, where participants may wait until the search array appears, and create a positive template for the item that does not match the negative cue (Becker, Hemsteger, & Peltier, 2015). In this study, we examine this positive recoding proposal using eye tracking across three conditions. First, the separated condition where two colors are present and separated by hemifield, where positive recoding is possible. Second, a separated mixed color condition where half the items in the search array match the cued color and are contained within one visual hemifield, while the other half are a mix of color, where positive recoding is not possible but location-based strategy could be possible. And third, a jumbled mixed color condition where half the items match the cued color, the other are mixed color, and locations are randomized. In this final condition, neither positive recoding nor a location strategy would help participants. Across all three conditions, we find evidence that the eye movements avoid items matching the negatively cued distractor on saccades 2-4 (more fixations on targets for negative cues than neutral cues, all p's < .01). Importantly, for the separated mixed color and jumbled mixed color condition, this avoidance could not be caused by the positive recoding account. These results support active attentional suppression.

24.27, 4:00 pm **Tracking the item in focus of attention in working memory through pupillometry** Nahid Zokaei[1, 2](nzokaei@gmail.com), Alexander Board[1,2], Sanjay Manohar[2,3], Anna C Nobre[1,2]; [1]Oxford Centre for Human Brain Activity, Wellcome Centre for Integrative Neuroimaging, Department of Psychiatry, University of Oxford, [2]Department of Experimental Psychology, University of Oxford, [3]Nuffield Department of Clinical Neurosciences, University of Oxford

Studies have shown that pupil responses can reveal the nature of attended information at perception. We, in a series of studies, asked whether pupillary responses also reflect the item in the focus of attention during working memory retention. In each study, participants were asked to keep in mind the orientation of two gratings, one bright and one dark. At the end of the trial, a probe stimulus prompted reproducing the orientation of one of the stimuli. Importantly, there was no difference in the brightness of the anticipated probe. We manipulated the item in the focus of attention using auditory retrospective cues; cueing either the brightness (study 1) or the location (study 2) of one of the stimuli or using internally guided temporal expectations to prioritise individual's items in memory at specific times during the delay interval (study 3). Our findings demonstrated that the pupils reflected the item in focus of the attention during a blank memory delay, with prioritised darker stimuli eliciting a larger pupil response compared to bright stimuli. Importantly, the same pupil response was observed even when brightness was an irrelevant feature of the stimuli and could be ignored (study 2 and 3, as the spatial location of the most relevant item was cued). This suggest, to some extent, preservation of irrelevant features in working memory representations, including brightness which can be tracked via the pupil response. Lastly, our findings from study 3 demonstrate that the pupil response to the memory representations can be dynamically modulated by internally guided temporal expectations.

Acknowledgement: British Academy, Wellcome Trust

Faces: Neural mechanisms

Saturday, May 18, 5:15 - 6:45 pm, Talk Room 1

Moderator: Isabelle Buelthoff

25.11, 5:15 pm **Strong face selectivity in the fusiform can develop in the absence of visual experience** N Apurva Ratan Murty[1,2] (ratan@mit.edu), Santani Teng[3,4], David Beeler[1], Anna Mynick[1], Aude Oliva[3], Nancy Kanwisher[1,2]; [1]McGovern Institute for Brain Research, Massachusetts Institute of Technology, [2]Centre for Brains, Minds and Machines, Massachusetts Institute of Technology, [3]Computer Science and Artificial Intelligence Laboratory (CSAIL), MIT, [4]Smith-Kettlewell Eye Research Institute

How does the FFA arise in development, and why does it develop so systematically in the same location across individuals? Preferential fMRI responses to faces arise early, by around 6 months of age in humans (Deen et al., 2017). Arcaro et al (2017) have further shown that monkeys reared without ever seeing a face show no face-selective patches, and regions that later become face selective are correlated in resting fMRI with foveal retinotopic cortex in newborn monkeys. These findings have been taken to argue that 1) seeing faces is necessary for the development of face-selective patches and 2) face patches arise in previously fovea-biased cortex because early experience with faces is foveally biased. Here we present evidence against both these claims. We scanned congenitally blind subjects (N = 6) with fMRI while they performed a one-back haptic shape discrimination task, sequentially palpating 3D-printed photorealistic models of faces, hands, mazes and chairs in a blocked design. Five out of six participants showed significantly higher responses to faces than other categories in the lateral fusiform gyrus (see Figure 1 A,B). Overall, the face selectivity of fusiform regions for tactile faces in congenitally blind participants was comparable to the face selectivity in sighted subjects (N = 8) for videos of the same stimuli rotating in depth (see Figure1 C,D). Evidently, the development of strongly face-selective responses in the lateral fusiform gyrus does not require a) seeing faces, b) foveating faces, or c) perceptual expertise with faces. We speculate that face selectivity in congenitally blind participants reflects either amodal representations of shape and/or the interpretation of faces as social stimuli (Van den Hurk et al, 2017;Powell et al., 2018).

25.12, 5:30 pm **Differential white matter connections to ventral and lateral occipito-temporal face-selective regions underlie differences in visual field coverage** Dawn Finzi[1](dfinzi@stanford.edu), Jesse Gomez[2,3], Vaidehi Natu[1], Brianna Jeska[1], Michael Barnett[1,4], Kalanit Grill-Spector[1,2,5]; [1]Department of Psychology, Stanford University, Stanford CA, [2]Neurosciences Program, Stanford University, Stanford CA, [3]Department of Psychology, UC Berkeley, CA, [4]Department of Psychology, University of Pennsylvania, PA, [5]Wu Tsai Neurosciences Institute, Stanford University, Stanford CA

The human face-processing network can be divided along two distinct streams: ventral occipito-temporal cortex (VOTC) containing IOG-faces, pFus-faces, and mFus-faces, and lateral occipito-temporal cortex (LOTC) containing pSTS-faces and mSTS-faces. VOTC regions are thought to be involved in processing face identity, while LOTC regions are involved in processing dynamic aspects of faces. Despite these differences in function, the anatomical or computational origins driving these differences remain unknown. As face identification and dynamic perception rely primarily on foveal and peripheral vision, respectively, we hypothesized that white-matter connections from early visual cortex (EVC) to ventral face-selective regions would originate more foveally than connections to lateral regions. To test this, we scanned 23 participants using 3T functional MRI and diffusion MRI. We used a functional localizer to identify face-selective regions in each participant, which were used as seed regions to functionally define white matter tracts. Then we tested to which eccentricities in EVC these tracts connected. We found that lateral regions were connected to more peripheral eccentricities in EVC (pSTS-faces: mean±SE = 7.1°±1.1 °; mSTS-faces: 11.9°±1.2°) than ventral regions (IOG-faces: 2.9±0.4°; pFus-faces: 4.7±0.6°; mFus-faces: 6.0±0.6°, outliers removed), where endpoint distributions all peaked within the central 3° (Figure 1). We next tested if white matter connections contribute to visual field coverage in face-selective regions. We conducted a second experiment (N=13) in which we estimated population receptive fields using a retinotopic mapping experiment. Consistent with the connectivity patterns, visual field coverage in ventral regions was foveally-biased, while visual coverage in LOTC regions extended much further into the periphery (Figure 2). Together, these findings demonstrate that (i) the anatomical and functional segregation of face-selective regions into two streams has a structural foundation and (ii) that differential patterns of white-matter connections from EVC to face-selective regions contribute to the differential visual field coverage across processing streams.

Acknowledgement: This research was funded by the NSF Graduate Research Development Program (grant DGE-114747) and Ruth L. Kirschstein National Research Service Award (grant F31EY027201) to JG, and the NIH (grants 1ROI1EY02231801A1, 1RO1EY02391501A1) to KGS and training grant 5T32EY020485 supporting VN

25.13, 5:45 pm **Decoding the Viewpoint and Identity of Faces and Bodies** Celia Foster[1,2,3,4](celia.foster@tuebingen.mpg.de), Mintao Zhao[1,5], Timo Bolkart[2], Michael J Black[2], Andreas Bartels[1,3,6,7], Isabelle Bülthoff[1]; [1]Max Planck Institute for Biological Cybernetics, Germany, [2]Max Planck Institute for Intelligent Systems, Germany, [3]Centre for Integrative Neuroscience, Germany, [4]Graduate Training Centre of Neuroscience, Tübingen, Germany, [5]School of Psychology, University of East Anglia, UK, [6]Department of Psychology, University of Tübingen, Germany, [7]Bernstein Center for Computational Neuroscience, Tübingen, Germany

Our visual system allows us to recognize familiar individuals across different viewpoints, despite large differences in low-level visual information. Previous neuroimaging research has shown that there is a hierarchical organisation

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across face-responsive brain regions, with lower-level regions representing head viewpoint and higher-level regions representing face identity. In this study, we investigated whether a similar hierarchy is present in body-responsive brain regions, as we also see bodies from many different viewpoints and psychological research has shown we also use information from the body for identification. Furthermore, we investigated whether representations of viewpoint and identity are face and body specific, or generalise to a common representation. We trained participants to recognize three individuals from images of their face and body. We then recorded their brain activity using fMRI while they viewed images of the face and body (shown separately) of the individuals from different viewpoints. Participants responded to the identity or viewpoint, revealing differences in neural representation depending on which feature participants attended to. We found that the occipital face area and extrastriate body area contain representations of face and body viewpoint, and that these viewpoint representations generalize across the face and body (e.g. a classifier trained to distinguish viewpoint of faces could decode viewpoint of bodies). Furthermore, we found that the fusiform body area (FBA) represents body identity in a viewpoint-invariant manner. We decoded face identity in the FBA, and also found a trend in the anterior temporal face area, that has previously been shown to represent face identity. In total, our results show that lower-level face- and body-responsive regions represent viewpoint, and these representations are not driven by low-level visual similarity. We show that the FBA represents body identity, indicating that a similar hierarchy is present for body identity representations in occipitotemporal cortex as has been previously identified for faces.

25.14, 6:00 pm **Distinct spatiotemporal profiles for identity, expression, gender, and gaze information during face perception from intracranial EEG recordings** Brett B Bankson[1,2](brett.bbankson@gmail.com), Michael J Ward[1], R. Mark Richardson[3], Avniel S Ghuman[1]; [1]Laboratory of Cognitive Neurodynamics, Department of Neurological Surgery, University of Pittsburgh, [2]Cognitive Program, Department of Psychology, University of Pittsburgh, [3]Brain Modulation Lab, Department of Neurological Surgery, University of Pittsburgh

When the brain visually detects a face, a well-defined distributed network of brain areas is rapidly engaged to represent the combination of visual, social, and affective information inherent to faces. It has traditionally been difficult to elucidate simultaneously the spatial and temporal dynamics that underlie face representations because of recording technique limitations that cannot adequately measure transient, fine-grained differences in individual face feature dimensions. To rectify this, we recorded intracranial electroencephalography (iEEG) from 29 epilepsy patients (~3300 total electrode contacts) who completed a gender discrimination task with face stimuli from the Radboud Faces Database. Each patient viewed repetitions of 14 unique identities (7 female) displaying each 5 facial expressions and 3 gaze directions. We adopt an elastic net regularized regression approach to perform whole-montage classification of face identity, expression, gaze, and gender over time that allows us to identify precise cortical sources of face information from individual electrode contacts. First, this analysis shows differing latencies by which above-chance classification of exemplar-level information initially emerges for various face dimensions: identity and expression at ~140 ms, and gender at ~190 ms. Second, we quantify the spatial representation of these face dimensions throughout temporal cortex to demonstrate that more medial electrode contacts contribute to identity decoding, more lateral electrode contacts contribute to expression decoding, and a large, diffuse set of contacts contributes to gender decoding. Additionally, we find distinct contributions of ERP and high-frequency broadband signal components to these spatial profiles. Finally, we identify a robust posterior-anterior gradient throughout ventral temporal cortex along which face identity information emerges temporally. The results here highlight the heterogeneity of cortical areas that represent individual face dimensions across time, the unique profiles of iEEG signal components during face processing, and the utility of data-driven investigations over whole-montage human iEEG signal.

25.15, 6:15 pm **Mapping face- and house-selectivity in ventral occipito-temporal cortex with intracerebral potentials.** Simen Hagen[1](simenhagen1@gmail.com), Corentin Jacques[2], Louis Maillard[1,3], Sophie Colnat-Coulbois[4], Bruno Rossion[1,2,3], Jacques Jonas[1,2,3]; [1]Université de Lorraine, CNRS, CRAN, F-54000 Nancy, France, [2]Psychological Sciences Research Institute and Institute of Neuroscience, University of Louvain, B-1348 Louvain-La-Neuve, Belgium, [3]Université de Lorraine, CHRU-Nancy, Service de Neurologie, F-54000 Nancy, France, [4]Université de Lorraine, CHRU-Nancy, Service de Neurochirurgie, F-54000 Nancy, France

Categorization of visual entities is thought to be supported by distinct neuronal populations in the human ventral occipito-temporal cortex (VOTC). Here we report a global mapping of the VOTC for selective responses to faces and houses with intracerebral EEG in a large population of human subjects (N=70). Participants viewed variable objects images presented periodically at 6 Hz with either variable face or house images interleaved as every 5th image (in separate sequences). Face-and house-selective responses were objectively quantified at the face or house stimulation frequency (6Hz/5=1.2 Hz) and harmonics. House- and face-selective contacts were spatially organized along the medial-to-lateral axis, respectively, consistent with neuroimaging studies (Fig.1). Importantly, both types of contacts, with a higher proportion for face- than house-selective sites, were found in the anterior temporal lobe (ATL), a region contaminated by large artifacts in neuroimaging (Fig. 2, top). Moreover, in the ATL we found a substantial portion of face- or house-exclusive contacts that showed no response for other objects at 6 Hz (Fig. 2, bottom). Finally, at "overlap" contacts responding to both faces and houses, the amplitudes to faces and houses correlated weakly (Fig. 3), indicating that these contacts also measure at least partly dissociated face- and house- responses. Thus, overall, the results suggest that both posterior and anterior portions of the VOTC contains distinct and distributed neuronal populations dedicated to recognition of face- and landmark-stimuli.

25.16, 6:30 pm **Seeing (social) relations: human visual specialization for dyadic interactions**Liuba Papeo[1](liuba.papeo@isc.cnrs.fr); [1]CNRS, Institute of Cognitive Sciences

"Social perception" classically indicates the tuning of human vision to certain entities, such as faces and bodies, which turn out to have high social value. But, "social" is primarily a property of a relation that implies at least two entities. We demonstrate that visual perception is tuned to see that relation; namely, it is tuned to process multiple entities in spatial relations that facilitate social interactions. With functional MRI on healthy adults, we identified face-, body-, and place-preferring areas and early visual cortex. We then showed participants images featuring two human bodies facing one other (seemingly interacting), two bodies facing away from each other, and single bodies. Selectively, the body-preferring area in the extrastriate cortex showed stronger activity for facing dyads, than for nonfacing dyads and single bodies. Moreover, the same area showed greater sensitivity (classification accuracy) to differences between facing dyads than between non-facing dyads, suggesting greater involvement in representation of interactive scenarios. These fMRI results are complemented by behavioral studies. Using backward masking during a visual recognition task, we found that the inversion effect, a marker for the special visual sensitivity to faces and bodies, was larger for facing than for non-facing dyads. Finally, a visual search task showed that facing dyads were processed more efficiently than nonfacing dyads. These results demonstrate preparedness of visual perception to process socially relevant spatial configurations, larger and more complex than a single face/body. This mechanism for attaining a fast appraisal of relations in a scene may be critical to channel body perception into social inferences. It contributes to define the perceptual analysis as an integrative structuring of information for higher-level inferential operations, beyond independent shape recognition.

Acknowledgement: European Research Council Starting Grant (Grant Agreement 758473

Development

Saturday, May 18, 5:15 - 6:45 pm, Talk Room 2

Moderator: Laura Emberson

25.21, 5:15 pm **Top-down perception at 6 months of age: Evidence from motion perception** Naiqi G Xiao[1](nx@princeton.edu), Lauren L Emberson[1]; [1]Department of Psychology, Princeton University

Early perceptual development has long been described as a process driven by experiences. However, the underlying mechanisms regarding how experiences shape perception are still unclear. Recent advances in neuroscience suggest that the brain relies primarily on top-down neural networks to adapt perceptual systems based on prediction signals learned from the environment. Recently, this neural capacity has been found available at birth, suggesting that it might be the mechanism that translates experiences into developmental changes in perception. We examined this hypothesis by investigating whether infants' motion perception can be modulated by learned predictive cues. Twenty 6-month-olds first learned two audio-visual associations between musical melodies and motion directions, which were depicted by coherent motion of 720 dots (Fig. 1). Infants' perception of motion directions was demonstrated by smooth pursuing eye movement in motion directions (Fig. 2). We then examined whether they could use the predictive melodies to induce motion perception with motion omission trials, where every dot moved in a random direction without forming any coherent motion pattern. In these omission trials, even no motion pattern was presented, infants still exhibited consistent leftward and rightward eye movement in accord with the predicted motion directions by the melodies in the motion omission trials. A control experiment, which presented static dots after the predictive melodies, failed to show this prediction-based eye movement, suggesting it was motion perception, rather than directional eye movement, induced by the predicting melodies. We further found that the top-down signals were equivalent to 10-20% motion signals in inducing motion perception (Expt3). These findings suggest that the ability to translate predictive cues in the environment into adaptive perceptual changes is already sophisticated at 6 months of age. It further suggests that top-down neural networks via feedback neural connections, play a key role in driving perception development early in life.

25.22, 5:30 pm **Decoding the contents of the developing visual system with fMRI in awake infants** Cameron T Ellis[1](cameron.t.ellis@hotmail.com), Lena J Skalaban[1], Tristan S Yates[1], Vikranth R Bejjanki[2], Javier S Turek[3], Nicholas B Turk-Browne[1]; [1]Department of Psychology, Yale University, [2]Department of Psychology, Hamilton College, [3]Brain Inspired Computing, Intel

The hierarchical organization of the visual system has been supported by studies using convolutional neural networks (CNNs) to decode fMRI data from human adults. Along visual processing streams there is a transition from low-level features such as edges and luminance, represented in earlier model layers, to mid-level invariant features such as shapes and parts, represented in middle model layers, to high-level object identity and category, represented in later model layers. How and when the human visual system comes to be organized this way over development is unclear, partly because of the difficulty of conducting comparable fMRI studies early in development. Here we report our approach for early developmental fMRI based on adult-grade acquisition and analysis methods. Two cohorts of infants/toddlers (N=5 range: 3-8 months; N=8 range: 8-36 months), and an adult comparison group (N=8), watched a short but engaging cartoon during fMRI. Overall, we observed surprising similarity between the brain responses of infants and adults, particularly in visual cortex. To decode the specific contents of the infant brain, we used a CNN to represent the movie in terms of low-, mid-, and high-level content. Converging model-based analyses using univariate regression and representational similarity showed that all levels of content explained similar variance in early visual cortex of infants and adults. However, a developmental difference emerged in later visual areas: in adults, high-level content was better represented than low- and mid-level content and than high-level content in early visual cortex; these differences were not observed in infants, despite the fact that they exhibited reliable visual activity relative to a control auditory region. Additional steps were taken to control for the impact of differences in anatomical alignment and data quality. These findings provide an initial foray into early developmental changes in the large-scale functionality and selectivity of human visual cortex.

25.23, 5:45 pm **Brain damage and early visuospatial problems: a structure-function coupling in very preterm born children**

Maud M van Gils[1](m.m.vangils@erasmusmc.nl), Jeroen Dudink[2], Irwin KM Reiss[3], Johannes van der Steen[1], Johan JM Pel[1], Marlou JG Kooiker[1]; [1]Dept. Neuroscience, Erasmus Medical Center, Rotterdam, the Netherlands, [2]Dept. Neonatology, Wilhelmina Children's Hospital, University Medical Center Utrecht, Utrecht, the Netherlands, [3]Dept. Neonatology, Erasmus Medical Center-Sophia Children's Hospital, Rotterdam, the Netherlands

Background: Preterm born children are at high risk of brain damage, which can adversely affect visuospatial attention and processing development. To clinically validate an adaptation of a standardized magnetic resonance imaging (MRI) scoring system for brain damage [Kidokoro et al.], we assessed its association with visuospatial performance at 1-year and 2-years corrected age (CA) in very preterm born children. Method: 112 children born < 32 weeks postmenstrual age (PMA) underwent an MRI scan at 29-35 weeks PMA. We scored brain damage and growth of cerebral white matter, cortical gray matter, deep gray matter, and cerebellum. Intra- and interrater reproducibility was assessed. At 1y CA, 82 children participated in an eye tracking-based visuospatial attention and motion processing task. At 2y CA, 59 children participated. Visuospatial performance was measured by calculating eye movement reaction times (RT) to visual stimuli. Results: Reproducibility of the adapted MRI scoring system was excellent, with intra- and interrater agreement of 92-100%. 21% of children born preterm had moderate-severe brain damage, whereas 43% had mild and 36% had no brain damage. Preterm children with moderate-severe brain damage had significantly slower RTs to motion stimuli than children with less severe or no brain damage. At 1y CA, slower attentional RTs correlated with more severe cortical gray matter damage (r_s=.32; p=.008) and slower motion RTs with more severe cerebral white matter damage (r_s=.33; p=.005). At 2y CA, no correlations were found. Conclusion: The present results show that very preterm children with moderate-severe perinatal brain damage are at risk of visuospatial attention and motion processing problems early in development. Besides further clinical validation for the MRI scoring system, the findings warrant a combined approach of quantitative structural and functional methods to infer the effects of brain damage and growth on visuospatial performance, and to timely detect and support preterm children at-risk.

Acknowledgement: Funding for this study was provided by NOVUM (stichtingnovum.org)

25.24, 6:00 pm **Is higher susceptibility to attentional deficits in children related to lower susceptibility to Inattentional Blindness in visual search** Beatriz Gil-Gómez de Liaño[1,2](bgil.gomezdelianno@uam.es), Elena Pérez-Hernández[3], María Quirós-Godoy[3], Jeremy M Wolfe[1]; [1]Brigham and Women's Hospital-Harvard Medical School, [2]University of Cambridge, [3]Universidad Autónoma de Madrid

When attention is occupied with one task, an observer may fail to notice a different otherwise salient, unexpected event. This is known as Inattentional Blindness (IB). IB is modulated by individual differences in intelligence, age, or expertise. Here we show, for the first time to our knowledge, that IB is modulated by susceptibility to AD/HD during childhood. A sample of 194 children between 4-10 years old searched for child-friendly, photorealistic images among distractors in a visual search task. An unexpected letter (N) or word (COLOR) appeared in two separate trials during the task. The results show that the IB effect was bigger in younger children, especially for the youngest 4-5 year-olds, who had not been previously tested in an IB task. For the letter condition, there was a marginally significant modulation of IB with AD/HD susceptibility for children between 6-10 years old: Children with moderate to high attentional deficit (AD/HD, n=32) levels, as measured by the Conners & Kiddie Continuous Performance Tests (K-CPT & CPT), showed marginally lower levels of IB (Percentage of IBAD/HDprone=53; Percentage of IBNO_AD/HDprone=70; p=.08). Errors were significantly larger for the AD/HD prone group only when IQ was medium-low (p=.04), while RTs for the IB trials were similar across IQ and AD/HD prone groups. For the word condition the trend was similar, although the effects may have been masked by age, as there is a strong IB decrease from about 7-9 years old. This might be explained by the rapid development of reading skills around those ages; perhaps making words more salient than they are for younger children or adults. Important implications can be derived from these

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results: IB is a potentially valuable paradigm with which to study attentional development in children. Importantly, it could help us to develop new techniques for cognitive interventions with children.

Acknowledgement: Part of this work was supported by the Research Grant Project PSI2015-69358-R (MINECO/FEDER). Also, part of this work was supported by the European Union's Horizon 2020 research and innovation programme, Marie Sklodowska-Curie Actions, under grant 793268 - FORAGEKID (GF)

25.25, 6:15 pm **A Rare Visuospatial Disorder** Aimee K Dollman[1](aimeedollman@gmail.com), Mark L Solms[1]; [1]Department of Psychology, University of Cape Town

Cases with visuospatial abnormalities provide opportunities for understanding the underlying cognitive mechanisms. Three cases of visual mirror-reversal have been reported: AH (McCloskey, 2009), TM (McCloskey, Valtonen, & Sherman, 2006) and PR (Pflugshaupt et al., 2007). We report a fourth case, BS -- with focal occipital cortical dysgenesis -- who displays highly unusual visuospatial abnormalities. She initially produced mirror reversal errors similar to those of AH, who -- like our patient -- showed a selective developmental deficit. On further examination, it became apparent that BS differed from AH in significant respects. A detailed study followed which: (1) comprehensively documented BS's disorder, (2) determined the ways in which it differed from that of AH, and (3) compared it to other similar disorders reported in the literature. Extensive examination of BS revealed the following phenomena: mirror reversal errors (sometimes affecting only parts of the visual fields) in both horizontal and vertical planes; subjective representation of visual objects and words in distinct left and right visual fields; subjective duplication of objects of visual attention (not due to diplopia); uncertainty regarding the canonical upright orientation of everyday objects; mirror reversals during saccadic eye movements on oculomotor tasks; failure to integrate visual with other sensory inputs (e.g., she feels herself moving backwards when visual information shows she is moving forward). Fewer errors are produced under conditions of certain visual variables. These and other findings have led us to conclude that BS draws upon a subjective representation of visual space that is structured phenomenally much as it is anatomically in early visual cortex (i.e., rotated through 180 degrees, split into left and right fields, etc.). Despite this, BS functions remarkably well in her everyday life, apparently due to extensive compensatory mechanisms deployed at higher (executive) processing levels beyond the visual modality.

Acknowledgement: National Research Foundation, UCT Doctoral Research Scholarship, Harry Crossley Postgraduate Scholarship

25.26, 6:30 pm **Quantified visuospatial attention & motion processing in very preterm born children from 1y to 2y corrected age is related to neurodevelopmental outcome** Marlou JG Kooiker[1](m.kooiker@erasmusmc.nl), Maud M van Gils[1], Irwin KM Reiss[2], Johannes van der Steen[1], Johan JM Pel[1]; [1]Dept. Neuroscience, Erasmus Medical Center, Rotterdam, the Netherlands, [2]Dept. Neonatology, Erasmus Medical Center-Sophia Children's Hospital, Rotterdam, the Netherlands

Background: Dysfunctions in dorsal-stream visuospatial attention and motion processing are important mediating factors for adverse visual-sensory and cognitive development in children born preterm. In this longitudinal study, we quantitatively followed visuospatial attention and motion performance from 1-year to 2-years corrected age (CA) in children born very or extremely preterm, and investigated associations with neurodevelopmental outcome at 2y CA. Method: 147 children born < 32 weeks of gestation participated in a nonverbal visuospatial attention and motion processing task at 1y CA. 49 children repeated the task at 2y CA and underwent neurodevelopmental testing (BSID-III). Reflexive orienting behavior to salient cartoons (general attention) and motion stimuli was measured with a 4-AFC paradigm presented on a remote eye tracker (Tobii T60XL or X3). Visuospatial performance was quantified by average reaction times (RT) and RT variability, and classified as normal or delayed based on normative references. Results: From 1y to 2y, visuospatial attention and motion RTs became significantly faster (-39 ms and -152 ms) and less variable. Compared to norm values, delayed RTs were found in 10-23% of preterm children at 1y CA and in 20-35% at 2y CA. Slower attention and motion RTs at 1y CA were significantly associated with lower cognitive BSID scores at 2y ($r=-.53$ and $r=-.49$), and slower motion RTs with lower motor BSID scores ($r=-.31$) at 2y CA. At 2y, slower attention RTs were associated with lower fine motor scores ($r=-.51$). Conclusion: The current longitudinal results suggest that, although overall visuospatial performance from 1y to 2y improved in preterm children, their risk of visuospatial attention and motion processing problems persisted compared to term-born children. The substantial number of children with delayed visuospatial performance at 2y CA, and the association with adverse cognitive and motor developmental outcome at 2y, calls for monitoring and support of visuospatial functions early in life.

Acknowledgement: Funding for this study was provided by NOVUM (stichtingnovum.org)

SATURDAY AFTERNOON POSTERS

Object Recognition: Categories, models, neural mechanisms

Saturday, May 18, 2:45 - 6:45 pm, Banyan Breezeway

26.301 **Distinguishing the effects of object-scene association strength and real-world object size in scene priming** Wei Chen[1](emma.chen.w@nyu.edu), Olivia S. Cheung[1]; [1]Psychology Department, Science Division, New York University Abu Dhabi, Abu Dhabi, UAE

Scenes are complex visual entities and often contain multiple objects. Since specific objects are often expected to be found in particular scenes (e.g., beach chair-beach), such regularities appear to facilitate object and scene perception. Recent findings suggested that object properties, such as real-world size and portability, may modulate scene processing. Specifically, big objects, compared with small objects, are often less portable and are more likely to be found in a specific scene. However, since real-world object size and object-scene association strength are often confounded, it remains unclear which factor may contribute to the facilitation of scene processing. Here we aimed to distinguish the roles of object-scene association strength and real-world object size on scene perception. In a priming task, we used images of big and small objects that are strongly associated with particular scenes (e.g., cheese slicer-kitchen) as primes, and related or unrelated scene images as targets. Participants judged if a scene target was presented upright or inverted. As the association strength between the objects and related scenes were rated high and comparable across big and small object sets, as confirmed in a pilot study, if the facilitation is due to association strength, the magnitude of scene priming should be comparable across big and small object primes. However, if object size is critical, big objects should evoke stronger scene priming than small objects. In two experiments with long (250ms) vs. short (50ms) presentation durations of the primes, participants (n=26 and n=27 in Experiments 1 and 2) showed significant priming with faster judgments for related than unrelated upright scenes (p's<.045) and no interaction between real-world size and priming (p's>.38). These results suggest that although the two factors are often confounded, facilitation of scene perception evoked by objects is unlikely due to object size but depends on the strength of object-scene associations.

26.302 **Does Semantic Activation Affect Human Object Detection in Natural Scenes?** Colin S Flowers[1](cflowers@email.arizona.edu), Rachel M Skocypec[1,2], Mary A Peterson[1,2]; [1]Department of Psychology, University of Arizona, [2]Cognitive Science Program, University of Arizona

We showed (VSS 2018) that human participants can detect whether a flickering colored dot probe near an object's border is located "on" or "off" the object in masked 100-ms exposures of color photographs (mean d' = 0.97); performance was better for central than peripheral locations. The current study paired a subset of those photographs with flickering black/white probes (to improve peripheral probe visibility) and tested whether semantic activation from a word prime shown before the photographs could improve d'. Before each photograph, an unmasked prime was presented for 140 ms. The photograph followed after a 100 ms ISI. Three prime conditions were tested: Neutral ('XXXXXXX'), Match (the basic level name of the object [e.g., 'zebra']), and Mismatch (the name of an object from a different category [natural/artificial; e.g., 'bowl' was the mismatch prime for zebra]). As before, "on" responses for dots located on an object were considered HITs; "on" responses for dots located off the object were considered FAs. Detection sensitivity was again greater for central than peripheral objects (d' = 1.242 vs 0.851; p < 0.001). In addition sensitivity was greater for photographs with natural than artificial objects (d' = 1.374 vs 0.719; p < 0.001), consistent with evidence that natural scenes are processed faster than artificial scenes (Rousselet, et al, 2005). Prime type did not significantly affect d' scores, but did affect criterion, which was more liberal following Match than Mismatch primes (-0.227 vs 0.008; p = 0.036). We take this criterion difference to reflect guesses based on the feasibility of the object in the scene. Thus, semantic priming does not affect object detection in natural images under these conditions. We plan to analyze the photographs individually to assess how object vs. scene-wide characteristics (e.g., object size, amount of crowding in the scene) influence performance in this task.

26.303 **Sexualization leads to the visual processing of bodies as objects** Ruth M Hofrichter[1](hofricrm@mcmaster.ca), M.D. Rutherford[1]; [1]McMaster University, Department of Psychology, Neuroscience & Behaviour

The visual system processes social stimuli such as faces and bodies, differently than other objects (Maurer, Le Grand, & Mondloch, 2002; Peelen & Downing, 2007). While processing of faces (Yin, 1969) and bodies (Reed et al., 2003) is disrupted by inversion, object processing is less disrupted (Stein, Sterzer & Peelen, 2012). Bernard et al.'s Sexualized Body Inversion Hypothesis (SBIH) suggests that female bodies are objectified are therefore processed by the visual system as objects (2012). This hypothesis is supported by evidence of a greater inversion effect for male than female body images in a discrimination task. However, physical differences between the two image sets (male, female) may account for these differences. Using an ideal observer analysis, we quantified discriminability of the male and female images in this set. We then tested whether, after accounting for discriminability, there still was a residual effect supporting the SBIH. Although the discriminability of images predicted participants' performance (F(1,43) = -2.82, p < .001), there was still a reliable residual difference in the inversion effects across the stimulus sets, supporting the SBIH (F(1,43) = 4.99, p = .03). In a second experiment, we tested how varying degrees of sexualization affect objectification of bodies. To manipulate sexualization, each target image was paired with an audio file containing information rated as high or low in sexuality. Audio files were independently rated. Participants' performance was impacted by the model's level of sexuality. Across target sex, less sexualized targets were perceptually processed like social stimuli, while highly sexualized targets were processed as objects, evidenced by the size of the inversion effect (F(1,37) = 3.21, p = .066). Overall, we did find support for the SBIH, and our results suggest that male and female bodies can be perceptually objectified depending on degree of sexualization.

Acknowledgement: National Science and Engineering Research Council (Canada)

26.304 **Adults prefer to look at real objects more than photos** Jody C Culham[1,2](jody.culham@gmail.com), Stephanie M. Schumacher[2], Derek J. Quinlan[1,3], Kevin M. Stubbs[1,2], Judy Basmaji[2], Cosette L. Leblanc[2], Romy E. Segall[2], Valentina Parma[4]; [1]Brain and Mind Institute, Western University, [2]Department of Psychology, Western University, [3]Department of Psychology, Huron College, [4]William James Center for Research, ISPA - Instituto Universitário

Recent research has found that real objects appear to be processed for longer than visually matched photographs, both in terms of brain activation in adults and looking times in infants. Here we asked whether adults, like infants, would prefer to look at real objects over pictures. A head-fixed eye tracker was used to record gaze locations in adult participants while they viewed a pair of stimuli side by side. Half the stimuli were physically real items while the other half were photos, matched for size and viewpoint, presented on a computer monitor. Paired items were visually similar but not identical (e.g., a real orange could be paired with a photo of a peach or vice versa). Participants spent longer looking at the real object compared to the photo (57% vs. 43% of total looking time). These results suggest similar real-object preferences for adults as infants that may account for a variety of other behavioral and neuroimaging differences. More generally, looking preference techniques appear informative in adults as well as infants and provide a new paradigm for the study of real-object preferences and the factors that drive them.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

26.305 **Generating visual stimuli that vary in recognisability** Kevin H Roberts[1](kevin.roberts@psych.ubc.ca), Alan Kingstone[1], Rebecca M Todd[1]; [1]University of British Columbia, Department of Psychology

Researchers may seek to manipulate visual recognition while maintaining the the underlying low-level visual properties of an image.To this end, researchers have used a class of stimuli known as "texforms" that are unrecognisable yet closely match the low-level properties of the original, recognizable stimuli from which they are synthesized.Texforms, however, can require a significant amount of time to generate using parameters specified

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by previous researchers, thereby limiting one's ability to conduct studies that require many exemplars.Furthermore, if a researcher seeks to manipulate the recognisability of texforms to varying degrees, the computational processing time can increase even further.By using different parameters, we show that one can synthesize texforms much more quickly, which permits the generation of many exemplars at different degrees of recognisability.We also compare the low-level visual properties of the texforms generated with different parameters.

26.306 **Here's a novel object: draw variants from the same class.** Henning Tiedemann[1](Henning.Tiedemann@psychol.uni-giessen.de), Yaniv Morgenstern[1], Filipp Schmidt[1], Roland W Fleming[1]; [1]Department of Psychology, Justus-Liebig-University Giessen, Giessen, Germany

When presented with just a single exemplar of an unfamiliar object, we have certain visual intuitions about what other objects from the same class might look like. This is an impressive inference because it is radically under-constrained. Objects can vary along many dimensions, so how do we work out which features of the object are important and which are likely to vary across samples? To investigate this, 17 participants were shown 2D silhouettes of 8 exemplar objects from different classes, which were created to have one or multiple noticeable features (e.g. Sharp corners, distinctive concavities). For each of these, they were asked to draw 12 new objects belonging to the same class, on a tablet computer, resulting in 1632 drawn shapes. The drawings reveal that participants derived very specific inferences about the objects, varying some features substantially, while assiduously preserving others across variants. Despite substantial variations within each class, participants were highly consistent in the features that they chose to include in the variants. Another group of participants viewed the drawings and were asked to rate similarities and assign the variants to the categories. The results reveal high agreement between observers, suggesting robust and consistent inferences. We also analysed the shapes using dozens of image-computable shape metrics (e.g., area, perimeter, curvature statistics, fourier descriptors). Using MDS, the drawn shapes were compared to each other and the exemplars, revealing systematic variations in the features that defined each class. Together, these findings suggest participants infer sophisticated generative models of object appearance from single exemplars. We suggest that when presented with a shape, the visual system parses it, identifies perceptually significant features, and represents the features in a parametric way, providing a means to draw new samples from the internal representation (by varying the parameters of the feature representation).

26.307 **Taking a machine's perspective: Humans can decipher adversarial images** Zhenglong Zhou[1](zzhou34@jhu.edu), Chaz Firestone[1]; [1]Department of Psychological & Brain Sciences, Johns Hopkins University

How similar is the human visual system to the sophisticated machine-learning systems that mirror its performance? Models of object categorization based on convolutional neural networks (CNNs) have achieved human-level benchmarks in labeling novel images. These advances not only support new technologies, but may also serve as candidate models for human vision itself. However, unlike human vision, CNNs can be "fooled" by adversarial examples — carefully crafted images that appear as nonsense patterns to humans but are recognized as familiar objects by machines, or that appear as one object to humans and a different object to machines. This extreme divergence between human and machine classification challenges the promise of these new advances, both as applied image-recognition systems and as models of human vision. Surprisingly, however, little work has empirically investigated human classification of adversarial stimuli; do humans and machines fundamentally diverge? Here, we show that human and machine classification of adversarial stimuli are robustly related. We introduce a "machine-theory-of-mind" task in which observers are shown adversarial images and must anticipate the machine's label from a set of various alternatives. Across eight experiments on five prominent and diverse adversarial imagesets, human subjects reliably identified the machine's preferred labels over relevant foils. We observed this result not only in forced-choice settings between two candidate labels, but also when subjects freely chose among dozens of possible labels. Moreover, this pattern persisted for images with strong antecedent identities (e.g., an orange adversarially perturbed into a "power drill"), and even for images described in the literature as "totally unrecognizable to human eyes" (e.g., unsegmented patterns of colorful pixels that are classified as an "armadillo"). We suggest that human intuition may be a more reliable guide to machine (mis)classification than has typically been imagined, and we explore the consequences of this result for minds and machines alike.

Acknowledgement: JHU Science of Learning Institute

26.308 **Developmental changes in the ability to draw distinctive features of object categories** Bria L Long[1](bria@stanford.edu), Judith E Fan[1], Zixian Chai[1], Michael C Frank[1]; [1]Department of Psychology, Stanford University

Children draw prolifically from an early age, providing a rich source of insight into their emerging understanding of the world. Here, we investigate developmental changes in children's ability to emphasize the relevant visual distinctions between object categories in their drawings. To do so, we developed a tablet-based platform to collect a large number of children's drawings (5368 drawings, 1259 participants aged 2-10 years) via a free-standing drawing station in a science museum. In each session, children could produce drawings of up to 16 different object categories. On each trial, a video verbally cued a particular object category ("Can you draw a dog?"); children then had up to 30 seconds to complete their drawing. We hypothesized that drawings produced by older children would be more recognizable. To evaluate this prediction, we first applied a pretrained deep convolutional neural network model (VGG-19) to extract a high-level feature representation of all drawings. We then trained a 16-way logistic regression model under leave-one-out cross-validation to estimate the recognizability of drawings produced by children in each age group. The model's classification accuracy increased with age, even when controlling for low-level covariates (time spent drawing, ink used, or number of strokes). This pattern replicates results from a smaller, human-rated sample of recognition judgments (N=14 raters, 286 drawings). To investigate the underlying source of these changes in recognizability, we computed the mean feature vector (center) and the mean squared distance of drawings from the category center (dispersion), for each age and category. We found both that the overall distance between category centers increased and that within-category dispersions decreased with age, suggesting that older children may have an increasing ability to include category-diagnostic information in their drawings. Future work will relate these changes in visual production ability to changes in fine motor control and object categorization.

Acknowledgement: NSF SBE Postdoctoral Fellowship 1714726

26.309 **Reliability-based arbitration between noise and event-based component of observers' internal model during perceptual decision making** Jozsef Fiser[1](fiserj@ceu.edu), Adam Koblinger[1], Jozsef Arato[1]; [1]Department of Cognitive Science, CEU

The effects of long-term history on sequentially performed perceptual decision making are typically investigated either under the simplest stationary condition or in the context of changing volatility of the event statistics defined by the generative process. We investigated the rules of human decision making in the more natural situation when changes in the external conditions could be explained away by multiple equally feasible adjustment of the internal model. In each of four experiments, observers performed 500 trials of 2AFC visual discrimination between two arbitrary shapes that could appear with different frequency across trials and were corrupted by various amount of Gaussian noise in each trial. Trials were split to practice and test, where at the transition between the two, the appearance probability of the shapes (AP) changed either abruptly or gradually, their relative noise characteristics (NOISE) were altered, and feedback stopped. Using hierarchical Bayesian modeling, we showed that in this setup, the same perceptual experience can be explained by assuming a change in either AP or NOISE, but the two alternatives induce opposite long-term biases and consequently, different behavior under uncertain conditions. Interestingly, we found that observers strongly preferred one of the two alternatives. However, by manipulating the nature of the AP and the NOISE transition, and the volatility of AP during training, observers' behavioral biases and hence their implicit choice of explaining the situation changed toward the other alternative as predicted by the model based on the newly introduced uncertainty. This suggests that similarly to arbitration between habitual and model-based explicit learning, humans adjust their implicit internal model during perceptual decision making based on the reliability of the various components, which reliability is assessed across detected change points during the sequence of events.

26.310 **Everyday hallucinations?: Strong expectations lead to the misperception of faces in visual noise** Reshanne R Reeder[1,2](reshanne.reeder@ovgu.de), Johannes Salge[1]; [1]Department of Experimental Psychology, Institute of Psychology, Otto-von-Guericke University, [2]Center for Behavioral Brain Sciences

Visual hallucinations are stigmatized as a symptom of extreme psychological disorder, but in reality even healthy people can experience them during sleep or sensory deprivation, or under the influence of psychoactive drugs. It is difficult to study hallucinations in a laboratory setting because the experience often requires an extreme context. One method of researching hallucination-like phenomena requires a combination of ambiguous sensory input and strong sensory expectations. Previous studies have found that inducing a strong expectation to see faces leads to misperceptions in brief presentations of static Gaussian noise patterns, but detection responses were confounded with acquiescence response bias and physical similarities between specific noise patterns and faces. Here we report a replication (Exp1) and 3 variations of the previous paradigm, in which we attempted to induce misperceptions of faces while systematically removing bias (Exp2-3) and weakening temporal, spatial, and feature expectations (Exp4). Our results indicate that controlling for physical similarities between faces and specific noise patterns significantly decreases biased face detections while keeping a reliable proportion of expectation-influenced responses. Weakening expectations leads to very few face detections in most subjects. Together, the results show that an optimal balance between low bias and high expectations can lead to reliable visual misperceptions in healthy subjects.

Acknowledgement: CBBS ScienceCampus funded by the Leibniz Association, SAS-2015-LIN-LWC

26.311 **Learning to generalize like humans using basic-level object labels** Joshua C Peterson[1](peterson.c.joshua@gmail.com), Paul Soulos[1], Aida Nematzadeh[1], Thomas L Griffiths[1]; [1]Department of Psychology, University of California, Berkeley

Convolutional neural networks (CNNs) have become a standard for modeling several aspects of human visual processing, especially natural object classification, where they rival humans in performance. Most recent work on improving the correspondence between CNNs and humans has focused on low-level architectural modifications, and has paid less attention to changes in training supervision. We identify one way in which the training objective of the network differs greatly from that of humans: CNNs are almost exclusively trained on fine-grained, subordinate-level labels (e.g., Dalmatian), while humans also make use of more coarse-grained, basic-level labels (e.g., dog) that unify otherwise perceptually divergent subordinate classes. We show through a series of experiments that the level of abstraction in the labels used to train the network determines to a large extent how it will generalize, and consequently its correspondence with human generalization behavior.

26.312 **Neural Dynamics of Category Representations Across Space and Time in the Ventral Visual Cortex** Yalda Mohsenzadeh[1](yalda@mit.edu), Caitlin Mullin[1], Benjamin Lahner[1], Aude Oliva[1]; [1]Computer Science and Artificial Intelligence Lab, MIT

Previous neuroscience works have established a functional organization across ventral visual stream such that distinct categories are processed in different brain areas; e.g. the parahippocampal cortex (PHC) for places, the object-selective lateral occipital complex (LOC), the fusiform gyrus for faces and animates. However, it is still an open question how categorical representation in these specialized brain regions unfold over time. Here we extended the approach of MEG-fMRI fusion from Cichy et al. (2014,2016) to reveal the category-related spatiotemporal neural dynamics of vision in the human brain. We collected fMRI and MEG data while participants (N=15) viewed 156 natural images in four categories, namely objects, scenes, faces and animates (people and animals). We created theoretical model representational dissimilarity matrices (RDMs) representing category membership—higher similarity within a category. Using representational similarity analysis, per category content, we correlated spatially-resolved fMRI RDMs with temporally-resolved MEG RDMs while partialling out the other three category models. Then we localized the category-related neural activity in fMRI data by conducting a searchlight analysis, comparing each category model RDM with searchlight fMRI RDMs. Finally, we filtered the partial fMRI MEG representational correlations with the spatially localized category contents resulting in a spatiotemporal map per category while controlled for other categories. Scene and Object category processing started at ~80ms in early visual cortex and reached medially to PHC at ~110ms and laterally to LOC at ~100ms, respectively, both with a peak at ~135ms. Body category content emerged in LOC at ~90ms and extended to Fusiform at ~110ms. Fusiform showed significant face category content processing starting at 70ms reaching a peak at ~140ms. Together, our results revealed the spatiotemporal dynamics of category representations in the ventral stream at the millimeter and millisecond resolution.

Acknowledgement: This research was funded by NSF grant number 1532591, in Neural and Cognitive Systems and the Vannevar Bush Faculty Fellowship program funded by the ONR grant number N00014-16-1-3116. The experiments were conducted at the Athinoula A. Martinos Imaging Center at the McGovern Institute for Brain Research, Massachusetts Institute of Technology.

26.313 **The "A Day in the Life" Project: A Preliminary Report** Jenny Hamer[1](jhamer@ucsd.edu), Celene Gonzalez[2], Garrison W Cottrell[1]; [1]University of California San Diego, [2]California State University San Bernardino

The goal of this research project is to create a model the human visual system with anatomical and experiential constraints. The anatomical constraints implemented in the model so far include a foveated retina, the log-polar transform between the retina and V1, and the bifurcation between central and peripheral pathways in the visual system. The experiential constraint consists of a realistic training set that models human visual experience. The dataset most often used for training deep networks is ImageNet, a highly unrealistic dataset of 1.2M images of 1,000 categories. The categories are a rather Borgian set, including (among more common ones) 'abacus', 'lens cap', 'whiptail lizard', 'ptarmigan', 'abaya', 'viaduct', 'maypole', 'monastery', and 120 dog breeds. Any network trained on these categories becomes a dog expert, which is only true of a small subset of the human population. The goal of the "Day in the Life" project is to collect a more realistic dataset of what humans observe and fixate upon in daily life. Through the use of a wearable eye-tracker with an Intel Realsense scene camera that gives depth information, we are recording data from subjects as they go about their day. We then use a deep network to segment and label the objects that are fixated. The goal is to develop a training set that is faithful to the distribution of what individuals actually look at in terms of frequency, dwell time, and distance. Training a visual system model with this data should result in representations that more closely mimic those developed in visual cortex. This data should also be useful in vision science, as frequency, probably the most important variable in psycholinguistics, has not typically been manipulated in human visual processing experiments for lack of norms. Here we report some initial results from this project.

Acknowledgement: NSF grant SMA-1640681

26.314 **Relating category-selective regions in biological and artificial neural networks** Jacob S Prince[1](jacob.prince@yale.edu), Talia Konkle[1]; [1]Department of Psychology, Harvard University

In the occipitotemporal cortex of the human brain, a few focal regions respond relatively selectively to some categories—e.g. faces and houses. However, recent empirical work has shown that the representational geometries of these regions can be quite strongly correlated with each other and with occipitotemporal cortex outside of these regions (Cohen et al., 2017). Here, we leverage deep convolutional neural networks to provide some insight into this unexpected empirical result, defining and probing deepnet category-selective "regions". Data acquisition occurred by extracting artificial neuron activations from a pretrained convolutional neural network (Alexnet) in response to the image set used in Cohen et al. Within each layer, non-overlapping subsets of neurons responding preferentially to faces and places were defined using a selectivity contrast (faces>all other categories; houses>all other categories). Deepnet face- and place-selective regions defined in the last convolutional layer (after pooling) had moderate-to-highly correlated geometries, mirroring the human brain data. For example, face- and place-selective regions of 100 neurons had representational geometries that correlated with human fusiform face area (FFA, r=0.66) and parahippocampal place area (PPA, r=0.81), and with each other (deepnet-FFA to deepnet-PPA r=0.56). Also like the human brain data, these deep net regions were correlated with the geometry of the "non-selective" layer neurons: r=0.61 and r=0.54). Even though these deepnet neurons did not learn features specifically to do place or face recognition, face and place "regions" were present with correlated geometries similar to human FFA and PPA. Given that the features of deepnet neurons are optimized to discriminate all categories from all other categories, our results are consistent with the broad possibility that

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occipitotemporal cortex as a whole participates as one massive discriminative feature bank, where face and place regions reflect a topographic mapping of this feature space onto the cortex.

Acknowledgement: Harvard Brain Science Initiative Collaborative Seed Grant

26.315 **A cognitively-aligned representational space for DNNs**
Kandan Ramakrishnan[1](krama@mit.edu), Yalda Mohsenzadeh[1], Mathew Monfort[1], Aude Oliva[1]; [1]CSAIL, MIT

Deep neural networks (DNNs) have been shown to correlate with object, face and scene recognition neural markers in the human brain. DNNs are typically trained to optimize recognition accuracy on large-scale datasets and learn task-specific internal representations. However, our brain learns to develop high-level representations for categories across multiple recognition tasks (e.g. objects, scenes, actions etc). DNNs might be closely aligned to neural representations in the brain if trained similarly on a diverse set of categories. Here we investigate if DNNs can learn internal units that capture a common representational space for objects, places, faces and actions. To train such neural networks we combine categories from different datasets such as ImageNet, Places, Moments in Time and additionally introduced a novel people (faces in context) dataset. This new aggregated "seed" dataset consists of more than 1200 visual concepts combining objects, places, actions, people's emotions, gender and age. After training state of the art DNNs on this dataset, we analyzed the representation learned by the internal units. Training on the Seed dataset leads to a higher interpretability compared to a DNN trained only for one category (i.e. like object classification). The diversity of the dataset enables internal units of the network to learn not only object and scene-specific units but also units for facial expression and actions. Thus, this gives rise to a representational space in the DNNs that might be more closely aligned to the neural representation learned by human brains. Together, the new Seed dataset and DNN models may establish a benchmark for computational neuroscience experiments dedicated to explore the learning, computation and representation of higher-level visual concepts. Acknowledgement: This research was funded by NSF grant number 1532591, in Neural and Cognitive Systems and the Vannevar Bush Faculty Fellowship program funded by the ONR grant number N00014-16-1-3116.

26.316 **The time course of novel visual object recognition.**
Martin Arguin[1](martin.arguin@umontreal.ca), Justine Massé[1]; [1]Centre de Recherche en Neuropsychologie et Cognition and Département de psychologie, Université de Montréal, Montréal, Canada.

The novel method of random temporal sampling served to investigate the temporal progression of visual encoding/processing effectiveness in novel object recognition. 12 observers first learned to associate each of six novel synthetic 3-D objects displayed from variable viewpoints to a keyboard key serving to signal its recognition. Objects were made by attaching together two elongated blobs with variable widths, curvature, and tapering. For the recognition test, one object overlaid with white visual noise was displayed for 200 ms (1200 trials/participant) and the participant pressed its associated key. The signal-to-noise ratio (SNR) varied randomly throughout exposure duration at a rate of 120 Hz. The SNR temporal profile was generated on each trial by the integration of 5-60 Hz sinewaves (5 Hz steps) of random amplitudes and phases and contrast energy was equated across image frames. Z-scored classification images of the temporal SNR profile and of the SNR frequency content through time supporting correct performance were calculated. The average temporal classification image shows that encoding effectiveness reaches its peak at 17 ms after stimulus onset, to then decline to a minimum at 75 ms. It then increases to reach an intermediate value at the end of exposure. The average time-frequency classification image shows a peak of encoding effectiveness for 15-20 Hz SNR oscillations lasting throughout the 200 ms exposure. A lower peak occurs at 45-50 Hz, centred at 100 ms. Minimum effectiveness occurs at 35-45 Hz frequencies early after stimulus onset. This minimum persists throughout exposure duration while shifting towards lower frequencies, ending at 25-30 Hz at 200 ms. Individual temporal classification images were very variable (average of pairwise correlations: .03) whereas the time-frequency profiles were highly similar across participants (.65). The time-frequency classification images capture fundamental features of novel visual object processing that are largely shared across individuals.

Acknowledgement: This study was supported by grants from the Natural Sciences and Engineering Research Council of Canada and from the Fonds de la Recherche du Québec – Nature et Technologies. We are grateful to Prof. Charles E. Connor for providing us the program that served to generate the objects used in this study.

Binocular Vision: Rivalry, suppression

Saturday, May 18, 2:45 - 6:45 pm, Banyan Breezeway

26.317 **Pupillometry and Microsaccade Responses Reveal Unconscious Processing of Face Information Under Interocular Suppression**
Yung-Hao Yang[1](yunghaoyang@gmail.com), Hsin-I Liao[1], Shimpei Yamagishi[1], Shigeto Furukawa[1]; [1]NTT Communication Science Laboratories, NTT Corporation, Japan

Interocular suppression happens when a monocular stimulus is suppressed by strong competing masks from the other eye. Typically, researchers measure stimuli detection from interocular suppression or aftereffects of suppressed stimuli (e.g., priming and cueing) to reveal the visual processing outside of visual awareness. However, these psychophysical measurements only reveal the end-product of unconscious processing, not the temporal dynamics. In this work, we tested whether pupillary responses and microsaccades could be reliable indicators for revealing the dynamical unconscious processing of visual information. To demonstrate unconscious visual processing, we presented upright and inverted faces under interocular suppression, and participants were asked to press a response key as soon as they detected any part of the face. Meanwhile, their pupillary responses and eye movements were recorded by an infrared eye camera. The detection times showed the typical face inversion effect—upright faces were detected faster than inverted ones. Critically, upright faces evoked stronger pupil constriction than inverted ones roughly one second prior to the behavioral detection. On the other hand, while the microsaccade rate was similar for the upright and inverted faces, it generally decreased 500-ms before face detection. On top of these observations, we speculate that pupil constriction may be associated with a gradual unconscious accumulation of face information, presumably reflecting deeper memory processing and/or emotional arousal. In contrast, the microsaccade rate may reflect a general cognitive effort and/or decision-making process before awareness access, regardless of the content of the visual information. These pupillometry and microsaccade rate measurements represent a methodological improvement for revealing dynamical unconscious processing under interocular suppression.

26.318 **Underlying mechanisms of temporal dynamics in bistable perception**
Yijun Ge[1](geyijun827@gmail.com), Ruanyuan Zhang[2], Chencan Qian[3], Chen Chen[1], Juraj Mesik[1], Stephen Engel[1], Sheng He[1,3]; [1]Department of Psychology, College of Liberal Arts, University of Minnesota, Minnesota, United States of America, [2]Center of Magnetic Resonance Imaging, Department of Neuroscience, University of Minnesota, Minnesota, United States of America, [3]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, Beijing, China

Individuals differ in how fast they process and interpret input information, make choices, and control movements. In order to uncover underlying factors that produce variability in human brain dynamics across individuals, we measured switching dynamics for four relatively independent bistable perceptual phenomena (Necker Cube, Rotating Cylinder, Translating Diamond, and Biological Motion, based on Cao et al, 2018). In each individual, we also acquired data characterizing their attentional abilities (alerting, orienting, executive control), rates of information accumulation in perceptual decision making, levels of internal noise, perceptual grouping ability, and magnitude of sensory adaptation. Results from 90 participants show that different types of bistable perception are differentially influenced by attentional, noise, and perceptual decision factors. Base on robust factor analysis (Tucker-Lewis Index (TLI)>0.97, RMSEA< 0.05) using the Maximum Likelihood method of extraction, fast switching of point-light biological motion (front vs. back view of walker) was associated with stronger attentional orienting effect as well as better perceptual grouping of contours. Higher intrinsic additive noise and poor executive attentional control are associated with longer periods of ungrouped bars instead of the coherent translating diamond. Interestingly, slower rate of information accumulation in perceptual decision regarding a subjective Kanizsa shape predicts longer periods of perceiving the coherent translating diamond and slower switching of the rotating cylinder from structure-from-motion. Participants with stronger effects of attentional alerting showed faster switching when viewing the Necker cube. Our results provide further support that individual differences in brain dynamics arise from independent differences in dynamics of the supporting brain regions. In addition, intrinsic noise, different aspects of attention are differentially important for the switching dynamics of different bistable phenomena.

Acknowledgement: supported by Engdahl Family Research Fund

Saturday PM

26.319 **Bi-stable perception as a bridge between vision and decision making** Jan Brascamp[1](brascamp@msu.edu), Amanda L McGowan[2], Matthew B Pontifex[2]; [1]Department of Psychology, Michigan State University, [2]Department of Kinesiology, Michigan State University

Perception is regularly discussed by analogy with higher-level cognition (e.g. Helmholtz's 'perception as inference'). But rarely do such analogies go beyond the metaphorical to permit an explicit comparison between the ways in which the perceptual brain and the executive brain deal with comparable problems. This study aims to do this. In a comparison between models of decision making and of perceptual bi-stability, we identified formal similarities between, first, how deliberate two-choice decisions are made and, second, how a percept emerges at the appearance of a bi-stable stimulus. We then experimentally evaluated this parallel. Specifically, properties of deliberate decisions are commonly quantified using a variable termed 'response proportion': the proportion of trials in a condition that yield a given choice. When analyzed in these terms, deliberate choices with a high response proportion (e.g. correct choices in an easy condition) involve both shorter response times and weaker decision-related pupil dilations than choices with a lower response proportion (e.g. choices in a harder condition). To test whether the same applies to non-volitional percept choices, we recorded pupils while intermittently presenting an ambiguous structure-from-motion sphere to observers who reported, at each stimulus onset, either leftward or rightward rotation: the perceptual outcome of a non-volitional decision. Because perception at such onsets depends on prior history (priming), we could use prior history to assign each onset a probability that either direction would be perceived: a quantity analogous to response proportion. We found that, indeed, manual responses were fastest, and pupil dilations smallest, for percept reports that were strongly predicted by prior history (i.e. percept choices with a high response proportion). These results show how analytical tools from the decision literature can be applied to a perceptual process, and suggest similarities between the ways in which the perceptual brain and the executive brain arbitrate between options.

26.320 **Pre-stimulus connectivity patterns predict perception at binocular rivalry onset** Elie Rassi[1](elie.elrassi@sbg.ac.at), Andreas Wutz[1,3], Nicholas Peatfield[4,2], Nathan Weisz[1,2]; [1]Centre for Cognitive Neuroscience, University of Salzburg, [2]Center for Mind/Brain Sciences, University of Trento, [3]The Picower Institute for Learning and Memory, MIT, [4]CTF MEG, Canada

Binocular rivalry is a powerful tool for studying the neural correlates of visual attention and perception. When two stimuli are presented dichoptically in a controlled setting, people report seeing one dominant percept at a time rather than a combination of the two stimuli. In a MEG study, I show that pre-stimulus connectivity patterns in category-sensitive brain regions, as seen by frequency-resolved graph theoretic measures and source-reconstruction, could predict participants' percept of a face or a house at the onset of binocular rivalry. Additionally the percept can be very reliably decoded from post-stimulus evoked responses.

26.321 **Lateralized occipitotemporal tDCS modulates dynamics of binocular rivalry between faces and words** Linan Shi[1](shiii@ibp.ac.cn), Zhouyuan Sun[1], Geoffrey F. Woodman[3], Peng Zhang[1], Sheng He[1,2]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, [2]Department of Psychology, University of Minnesota, [3]Department of Psychology, Center for Integrative and Cognitive Neuroscience, Vanderbilt Vision Research Center, Vanderbilt University

During binocular rivalry, the relative dominance times of the two competing images are influenced by both low level image factors as well as high level object properties. In a previous study (He & Liu, VSS 2010), we demonstrated that for rivalry between faces and words, there was a face advantage for left visual field presentation and a word advantage for right visual field presentation. This is due to the fact that face and word representations are biased towards the right hemisphere and left occipitotemporal cortex respectively. In the current study, we went beyond the previous correlational observation and investigated potential causal effects from lateralized tDCS stimulations. While observers viewed centrally presented streams of faces and words engaged in binocular rivalry, tDCS (anodal or cathodal) was applied to the left or right occipitotemporal cortex. Results from 11 participants show that, compared to the sham condition, right occipitotemporal anodal tDCS significantly increased the relative dominance durations of faces over words, while cathodal tDCS significantly reduced the relative face dominance. However, left occipitotemporal tDCS had little effect on their relative dominance durations. In addition to the effect on relative dominance, Anodal, but not cathodal, tDCS of either left or right occipitotemporal sites led to more rapid rivalry switching. Together, our results suggest that tDCS could selectively strengthen or weaken high level representations of visual inputs, and causally modulate rivalry competition at an earlier stage through recurrent processing. Additionally, anodal tDCS likely increased neuronal excitability and noise levels, leading to more frequent rivalry switching.

26.322 **Parameter dependence of first and subsequent percepts in visual tri-stability** Thomas G.G. Wegner[1,2](thomas.wegner@physik.tu-chemnitz.de), Jan Grenzebach[1,2], Alexandra Bendixen[2], Wolfgang Einhäuser[1]; [1]Chemnitz University of Technology, Institute of Physics, Physics of Cognition Group, [2]Chemnitz University of Technology, Institute of Physics, Cognitive Systems Lab

Multistability refers to alternations in perception caused by a physically constant stimulus. It has been a matter of debate whether the first perceptual interpretation after stimulus onset is fundamentally different from subsequent perceptual interpretations. Here we study this question by systematically varying stimulus parameters and by assessing the resulting proportion of different percepts at onset and during continuous viewing. We used two overlaid colored drifting gratings, which can be perceived as individual gratings passing in front of each other ("segregated percept") or as an integrated plaid ("integrated percept"). In this configuration of the plaid stimulus, either grating can be perceived as dominant during segregated perception, resulting in tri-stability (one integrated, two segregated percepts). We asked 18 participants to view ten versions of the plaid stimulus that differed in the enclosed angle between the gratings. Each version was presented ten times for 30s each. To mimic a real onset (rather than just a blank interval), observers performed a fixation task on three points between presentations of different stimulus versions. Unlike most previous studies that used two response options, we asked observers to report either of the three percepts by holding one of three buttons. To verify the responses, we measured the direction of the optokinetic nystagmus induced by the stimulus. We compared predominance of the integrated percept during prolonged viewing to the probability to perceive the integrated percept after stimulus onset. In both measures, integration dominated for shallow angles, segregation for acute angles. For medium angles, the integrated percept still dominated at onset, but segregation became more dominant during subsequent viewing phases. Our results underline the distinct role of the first percept, which shows a different dependence on stimulus parameters than percepts during prolonged viewing.

Acknowledgement: German Research Foundation (DFG grant-no.: BE 4284/4-1, EI 852/8-1)

26.323 **Natural-scene-based SSVEPs revealed effects of short-term monocular deprivation**Lili Lu[1](lvll@psych.ac.cn), Sheng He[2], Yi Jiang[1], Stephen A Engel[2], Min Bao[1]; [1]CAS Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing 100101, China, [2]Department of Psychology, University of Minnesota

It is known that short-term monocular deprivation (MD) via patching enhances the deprived eye's dominance in binocular rivalry. Recently, we reported that scrambling the phase without changing the amplitude spectra of images input to one eye induced a similar shift of perceptual eye dominance. An interesting question is whether the increase in eye dominance also applies during perception of natural scene stimuli without conspicuous interocular competition. Moreover, to our knowledge, all the past work on short-term MD has focused on testing the eye dominance before and after the MD. It thereby remains largely unknown whether and how the eye dominance changes during the MD. Here we used the steady-state visual evoked potential (SSVEP) technique to measure the neural effects of MD with natural scene tests. Images to the two eyes were tagged with different frequencies. Two kinds of tests were used. One was an unfiltered test with both eyes receiving the original video images. The other was a MD test with an intact image presented to the non-deprived eye and mean luminance or pink noise presented to the deprived eye. The unfiltered test was conducted before and after 120 min of MD, and the four MD tests was conducted at 4 points during the deprivation. The results from the unfiltered tests showed that 120 min of MD boosted the SSVEP amplitudes elicited by the inputs from the deprived eye relative to the non-deprived eye (occipital electrodes, $t(19) > 3.08$, $p < 0.01$), indicating increased neural gain for the deprived eye. However, for the MD test during deprivation, the ratio of SSVEP amplitudes for the deprived vs. non-deprived eye did not change significantly over time; this puzzling result requires further exploration. Our findings suggest that the effects of short-term MD can be evident with natural scene stimulation without strong interocular competition.

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26.324 **Homeostatic control of interocular balance revealed with contrast mismatch** Daniel Y Tso[1](tsod@upstate.edu), Ronald A Miller[1]; [1]Dept. Neurosurgery, SUNY Upstate Medical University

Short-term monocular deprivation (STMD), wherein one eye is deprived of input for 1-3 hours, induces a temporary (30-60mins) shift in interocular balance. Surprisingly the deprived eye (DE) gets relatively stronger post-deprivation in comparison to the non-deprived eye. STMD may be viewed as presenting an interocular contrast mismatch where one eye (DE) receives a lower contrast than the other. What if the contrast imbalance is in the opposite direction, a contrast increment relative to baseline? Is the STMD effect symmetrical? Primate V1 was optically imaged for ocular dominance columns (ODCs) starting with a baseline of 40% contrast sine gratings of four orientation to each eye. Then the left (manipulated) eye (ME) was switched to 80% contrast, back to 40%, then to 20%, then back to 40% while the right eye was constantly stimulated with 40% (each period lasted for 1-2 hours). Line profiles across the ODCs show DC offset shifts indicative of the relative strength of each eye's response. The result is that the response to the ME stimuli at first is commensurate with the contrast change, but later begins to shift to match the fellow eye. Whenever the ME returns to baseline (40%), the response "overshoots" or "undershoots" DC zero implying a relative gain change that opposes the previous contrast imbalance. This behavior indicates a binocularly-regulated interocular balancing mechanism, with a time constant of ~30mins. An additional analysis that examines the peak-peak amplitude of the ODC signal shows a companion result, supporting the notion of a binocular homeostatic mechanism regulating interocular balance. Although this STMD gain shift effect was approximately symmetrical, there was an asymmetry such that the 40-80 increment yielded a larger gain shift than the 40-20 decrement. A variant of the DSKL model for binocular combination replicates key features of these interocular contrast imbalance responses.

26.325 **Re-balancing the eyes using monocularly-directed attention** Sandy Wong[1](sandy.wong@mail.mcgill.ca), Alex Baldwin[1], Kathy Mullen[1], Robert Hess[1]; [1]Department of Ophthalmology, McGill Vision Research, McGill University

The strength of each eye's contribution to the visual percept, or ocular dominance, can be measured using binocular rivalry, which in turn can be modulated by attention. Interestingly, eye-specific voluntary attention can be modulated by monocular cueing (Zhang et al., doi: 10.1177/0956797611424289). Here we investigate whether directed attention to one eye using a monocular cueing task can modulate ocular dominance, as measured by binocular rivalry. We collected data from ten adults with normal vision over five sessions, each with four conditions: monocular cueing to the left eye, monocular cueing to the right eye, binocular cueing, and random cueing. Incompatible grating stimuli were presented to the participants' two eyes. Throughout the task, participants used a joystick to continuously report which stimulus they saw, while making judgements about the cueing stimuli to direct attention to the cued eyes. The amount of time an eye's rivalry stimulus is perceived throughout the duration of the task reflects the strength of that eye's contribution to the visual percept. After averaging across conditions within each participant, the change in ocular dominance throughout the task was calculated. To ensure that the changes in ocular dominance were due to attention rather than the task, some participants did five sessions of two control conditions: no cueing and cueing without the task. No significant change in ocular dominance was found in these conditions. It appears that monocular cueing shifts ocular dominance the most toward becoming more balanced, and this effect is greatest when the weaker eye is cued. The effect was greatest in those who had large eye imbalances to begin with. This result suggests that directed attention to one eye using a monocular cueing task has the potential to correct binocular imbalances.

26.326 **Unconscious meridional rivalry in oblique astigmatism** Gad Serero[1](gadserero29@gmail.com), Maria Lev[1], Uri Polat[1]; [1]School of Optometry and Vision Sciences, Faculty of Life Sciences, Bar-Ilan University, Ramat-Gan, Israel

Introduction: Binocular vision is not a simple summation of the monocular inputs. Binocular summation (BS) is sub-linear, where stimulating both eyes only improves sensitivity by a factor of ~1.4 compared to the linear sum (factor ~2), effect that is usually attributed to interocular suppression. Binocular rivalry (BR) occurs when conflicting images are presented to the eyes, producing alternating periods of monocular dominance. In astigmatism, the image falling on the retina is blurred in one meridian. In oblique astigmatism (OA), the blur meridian is opposite, 45º in one eye and 135º in the other, resulting in two conflicting images. Here we explored the influence of astigmatism on BS and BR. Methods: Fully corrected subjects (n=21) divided to OA (n=8) and normal controls (n=13) were tested on contrast detection and collinear facilitation (CF) in different orientations and eyes (monocular, binocular), as well as on subjective report of the sharpness of oriented lines. BS was measured using contrast detection of Gabor patches. In BR, the 2 monocular images available for processing by the visual system were identical due to the optical correction. Results: BS of single target was better by 1.4 than the monocular thresholds. The difference in BS between meridians and groups was not significant. However, the monocular CF was significantly better in the clear than the blurred meridian in the oblique astigmatic group, reminiscent of the lateral facilitation of meridional amblyopia. Monitoring binocularly static oriented lines, OA subjects reported alternating sharpness, similar to the classical BR. Conclusions: Our results show that subjects with normal vision may have abnormal lateral interactions similar to meridional amblyopic subjects. This effect may lead to competition for dominance between the eyes for the strongest visual input, leading to bi-stable natural perception, and to a binocular unconscious meridional rivalry affecting BS in OA people.

Acknowledgement: ISF (1825/16)

26.327 **Novel Procedure for Generating Continuous Flash Suppression: Seurat Meets Mondrian** Randolph Blake[1](randolph.blake@vanderbilt.edu), Oakyoon Cha[1,2], Gaeun Son[1,2], Sang Chul Chong[2]; [1]Psychology, Vanderbilt University, [2]Graduate Program in Cognitive Science, Yonsei University

Continuous flash suppression (CSF), used in hundreds of studies to manipulate visual awareness, entails presentation of a stationary image (the 'target') to one eye and an animated sequence of arrays of geometric figures (the 'mask') to the other eye. The prototypical CFS sequence comprises different-sized rectangles of various colors, dubbed 'Mondrians' after the Dutch painter Piet Mondrian whose abstract compositional style used simple forms and colors devoid of figurative quality. When presented as a rapid, changing sequence to one eye, Mondrians - or other, similarly constructed textured arrays - can abolish awareness of a target viewed by the other eye for many seconds at a time, producing target suppression durations much longer than those associated with conventional binocular rivalry. We have devised a novel visual animation technique that replaces meaningless Mondrian figures with recognizable visual objects and scenes as inducers of CFS, allowing explicit manipulation of the visual semantic content of those masks. By converting each image of these CFS sequences into successively presented objects or scenes each comprised of many small, circular patches of color, we can create 'pointillist' (cf. Seurat) CFS sequences closely matched in terms of their spatio-temporal power spectra. Moreover, randomly rearranging the positions of the pointillist patches yields scrambled versions of these images, thus destroying their recognizability. Using pointillist CFS sequences, we have discovered that CSF sequences comprising a stream of different objects produces more robust interocular suppression than do sequences comprising a stream of different scenes, even though the two categories of CSF are matched in low-level feature strength. Color is not critical for creating this superiority of objects over scenes, as demonstrated by CFS sequences made from achromatic object- and scene-images. Pointillist CFS provides a useful means for examining the impact of high-level image meaning in the modulation of visual awareness.

Acknowledgement: Centennial Research Fund (Vanderbilt Univ.) and NRF-2017M3C7A1029658 (National Research Foundation of Korea)

26.328 **A Signal Detection Analysis of Nonconscious Perception of Orientation with Continuous Flash Suppression** Ali Pournaghdali[1](Apour005@fiu.edu), Bennett L. Schwartz[1]; [1]Department of Psychology, Florida International University

Bias-free measures can evaluate perceptual sensitivity of participants in the conscious and nonconscious tasks. The aim of this study is to use signal detection theory measures to evaluate nonconscious perception of orientation during continuous flash suppression (CFS) for different levels of target contrast. Using CFS, we rendered a left or right-oriented Gabor patch (+45 or -45 degrees from the vertical line) for 300 milliseconds for six participants with normal to corrected-to-normal vision. In each trial, we randomly presented a Gabor patch with one of nine previously selected contrasts, using the method of constant stimuli. In each trial, we asked participants to judge the orientation of the targets using a 2-alternative forced-choice (2AFC) discrimination task and to judge the presence/absence of the targets with a yes/no detection task. After acquiring data, we calculated participants' perceptual sensitivity (d') for 2AFC and detection task for every level of target contrast and tested for significant difference between two measures in each level of contrast using one tailed Z-test (Marascuilo, 1970). Out of 54 participants/contrasts comparisons, 9 showed signs of nonconscious perception by having significantly higher d' in the 2AFC task as compared to the detection task. The significant differences between two tasks were evident only in two participants. According to these results, we could not find conclusive evidence for the dissociation between conscious and nonconscious perception of orientation with CFS. These results point to the importance of bias-free measures for evaluating conscious and nonconscious perception.

26.329 V1 Laminar Activation during Binocular Rivalry Flash Suppression

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When observers continuously view a stimulus in one eye and then an incompatible second stimulus appears in the other eye, their perception invariably switches from the initial stimulus to the second stimulus. Curiously, reversing the presentation order of the two stimuli in this phenomenon (termed binocular rivalry flash suppression) reliably causes an entirely different perceptual state, despite identical retinal stimulation. fMRI studies have found large congruence between primary visual cortex (V1) responses and perceptual state. In contrast, neurophysiology studies have found only a small fraction of V1 neurons that correlate with the perceptual outcome of flash suppression. This apparent discrepancy could be explained if flash suppression evokes a dissociation between neuronal inputs (synaptic activity) and neuronal outputs (spiking). To test this hypothesis, we recorded laminar neuronal responses in V1 of two awake behaving macaques that we exposed to stimulus sequences evoking binocular rivalry flash suppression. We specifically focused on estimating the laminar build-up and decay of synaptic activity using Current Source Density (CSD), a quantitative measurement of localized net depolarization. We found that binocular rivalry flash suppression profoundly affects the laminar profile of CSD. This modulation included the initial volley of activation in the granular layers, which receive the bulk of geniculate inputs. Both matching binocular stimuli, which do not elicit binocular rivalry flash suppression, and incongruent binocular stimuli, which can evoke flash suppression, evoked larger activity than monocular stimulation. However, binocularly incongruent stimuli yielded a larger magnitude of CSD response compared to binocularly congruent stimuli, suggesting that stimulus conflict between the two eyes increases V1 synaptic activation. We show that V1's laminar profile of synaptic activity is significantly altered during flash suppression, providing important clues as to the underlying mechanisms that lead to perceptual effect during flash suppression.

Acknowledgement: R01EY027402-02,5T32 EY007135-23, P30-EY008126

26.330 Using pattern classification and EEG to reveal the temporal characteristics of categorical processing during interocular suppression

Dustin Cox[1](dcox2013@fau.edu), Edward Ester[1], Sang Wook Hong[1], Yosun Yoon[1]; [1]Department of Psychology, College of Science, Florida Atlantic University

Continuous flash suppression (CFS) is an interocular suppression paradigm used to examine the extent that visual information is processed without visual awareness. Neuroimaging evidence demonstrates that neural signals associated with categorical processing are attenuated during CFS, but with the sensitivity of multivariate pattern analysis (MVPA), signatures of categorical processing in high-level cortex can be detected during interocular suppression (Sterzer, Haynes, & Rees, 2008). By applying MVPA to EEG, there is potential to elucidate the temporal characteristics of categorical processing during interocular suppression. However, results from a previous EEG study reveal that a pattern classifier could not decode the category of object images viewed during CFS (Kaunitz et al., 2011). The present study was conducted to further investigate whether temporal characteristics of categorical processing during interocular suppression can be revealed in the EEG time series using MVPA. In a first experiment, EEG data was recorded while participants viewed flickered object images during normal viewing or during CFS. The images were flickered to implement a frequency-tagging approach in an attempt to increase the signal-to-noise ratio for detecting neural signatures of categorical processing during CFS. Similar to previous findings, the performance of a pattern classifier was attenuated when decoding the category of the images viewed during CFS compared to that achieved for normally-viewed images. In another experiment, participants viewed a visible prime image that belonged to the same or a different category as a subsequently viewed target image that was temporarily suppressed from visual awareness by CFS. The participants indicated the moment the target image broke suppression (i.e., a semantic-priming/breaking-CFS (bCFS) paradigm). Using the same frequency-tagging approach implemented in the first experiment, the results reveal the evolution of decoding performance over time with respect to the behavioral report of bCFS as a function of the categorical relationship of the prime and target images.

26.331 Multi-center mapping of human ocular dominance columns with BOLD fMRI

Gilles de Hollander[1](gilles.de.hollander@gmail.com), Wietske van der Zwaag[2], Chencan Qiang[3], Peng Zhang[3], Tomas Knapen[1,2]; [1] Department of Experimental and Applied Psychology, Vrije Universiteit, Amsterdam, the Netherlands, [2]Spinoza Centre for Neuroimaging, Royal Academy of Sciences, Amsterdam, the Netherlands, [3]Institute for Biophysics, Chinese Academy of Sciences, Beijing, China

The two eyes' input into primate V1 is topographically organized into ocular dominance columns (ODCs). A few fMRI studies have shown the existence of ocular dominance maps in human V1, but only in a small subset of subjects with a flat V1 and using highly anisotropic 'pencil' voxels (Cheng et al., 2001 and Yacoub et al., 2007). Here, we report robust detection of ocular dominance columns using isotropic submillimeter voxels in the same subject, at two different 7 Tesla MRI sites separated by 7,815 km. We used gradient echo EPI (0.7mm 3dEPI and 0.8mm 2dEPI) on a Philips Achieva 7T scanner at the Spinoza Centre in Amsterdam and a Siemens 7T Magnetom at the Institute of Biophysics of the Chinese Academy of Sciences in Beijing. Using custom-built projection screens inside the transmit coil and prism glasses for dichoptic stimulus presentation, the subject was presented monocular counterphase flickering checkerboards for 8–24 seconds, in alternation between the left and right eyes. Using a highly automated segmentation, registration and preprocessing pipeline, we aligned the functional data to anatomical volumes and estimated percent signal change for left and right eye stimulation. In the Amsterdam dataset, the correlation between the left>right-contrast for the first 5 runs and the last 5 runs was $r=.45$. Between the datasets from Amsterdam and Beijing, there was a correlation between "left > right" contrasts $r=.37$ for all 'signal' voxels thresholded at $p< 0.01$ (uncorrected) in V1 in the Amsterdam dataset. These results show that ODCs from the same human subject can be reliably detected from two remote 7T machines with very different setups, using BOLD fMRI at submillimeter isotropic resolution. These approaches pave the way for future study of fine-grained functional architecture of the human brain.

26.332 Depth Estimates in Half Occlusions in Natural Scenes

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Binocular disparity is a primary cue for depth perception. However, not all visible regions of natural scenes create binocularly paired retinal projections. Monocularly visible (half-occluded) regions occur at depth edges where foreground surfaces occlude backgrounds. Previous research has shown that, with simple stimuli, half-occluded targets are perceived as near as possible, given the constraints imposed by stereo-geometry. Here, we asked how depth is perceived in half-occluded regions of natural scenes. We sampled hundreds of stereoscopic image patches (3x1°) from a natural image database with co-registered distance measurements. Each patch had an extended half-occluded region that was ~10-30 arcmin wide; the set of patches contained a range of different depths. On a haploscope, human observers viewed patches through a stereoscopic window and estimated the depth of the depicted half-occluded surfaces; a monocular image probe indicated the target surface location. Observers reported depth estimates by adjusting the disparity of a binocular response probe in a neutral field, viewed through an adjacent window; the task was easy and responses were repeatable. In condition one, all image cues were available. Humans reported depth estimates that matched the actual surface depths. In the minority of patches that produced inaccurate estimates, we measured the perceived shape of half-occluded surfaces by systematically changing the location of the image probe. In condition two, the image probe stereo-geometry was identical, but all image cues were removed. Now, human observers underestimated the depth, as predicted by classic findings. Thus, natural images contain cues that increase the accuracy of depth estimates near depth edges. Finally, we manipulated image cues (e.g. contrast) in different regions (e.g. the binocular background), to determine which cues and regions are critical for accurate depth perception near depth edges. Together, our findings show how stereo-geometry and image cues determine depth percepts in half-occluded regions of natural scenes.

Acknowledgement: R01-EY028571, 5T32EY007035-40

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Spatial Vision: Crowding, eccentricity

Saturday, May 18, 2:45 - 6:45 pm, Banyan Breezeway

26.333 **Pre-saccadic isotropization of crowding zones** Mehmet N Agaoglu[1](mna@berkeley.edu), Drew J Wodecki[1], Susana T L Chung[1]; [1]School of Optometry, University of California, Berkeley

A key feature of visual crowding (impaired recognition in clutter) is its radial-tangential anisotropy in the periphery. Impending saccades are known to cause spatiotemporal mislocalizations to briefly flashed stimuli. We investigated whether and how crowding zones are affected before saccades that are targeted to a different location than the crowded stimuli.In Experiment-1a, seven observers performed a peripheral (10deg to the right) orientation discrimination task (2-AFC, ~24500 trials). In saccade trials (80% of all), a fixation spot jumped 10deg vertically, cueing the observer to make a saccade. Target stimulus (a tilted Gabor, 4cpd, tilt adjusted for each observer for 80% correct) was presented, with or without horizontally or vertically flanking vertical Gabors. The target-flanker spacing was adjusted using the method of single stimuli. We found large individual differences in both the strength and extent of crowding. The effect of saccades was also idiosyncratic. Interestingly, we found nearly isotropic crowding zones both in fixation and saccade conditions. In Experiment-1b, only the fixation trials (~2100 trials) were run to determine whether the isotropy was due to additional attentional load of the saccade task. However, the results were similar. To determine whether the lack of anisotropy was due to the stimuli/task, we used a letter recognition task (10-AFC) in Experiment-1c (~2100 trials, only fixation). Six observers showed strong anisotropy. In Experiment 2, we repeated Experiment-1a using this letter recognition task with five observers (15000 trials). Consistently, we found weaker and near perfect isotropy in the fixation and saccade conditions, respectively. For four observers, this was due to enlarged tangential zones. Our results suggest that impending saccades as well as stimuli-task combinations, which necessitate larger spatial integration reduce the anisotropy of crowding zones. The locus of spatial attention might be a common denominator for all these factors.

Acknowledgement: NIH R01-EY012810 and a UC Berkeley URAP Summer Fellowship

26.334 **Offline transcranial direct current stimulation (tDCS) can improve the ability to perceive crowded targets** Guanpeng Chen[1,2,3,4](naonaocgp@pku.edu.cn), Ziyun Zhu[1,2,3,4], Fang Fang[1,2,3,4]; [1]School of Psychological and Cognitive Sciences and Beijing Key Laboratory of Behavior and Mental Health, [2]Peking-Tsinghua Center for Life Sciences, [3]Key Laboratory of Machine Perception (Ministry of Education), [4]PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing, China

The deleterious influence of nearby flankers on target identification in the periphery is often referred to as visual crowding. Studying visual crowding can advance our understanding of the mechanisms of visual awareness and object recognition. Alleviating visual crowding (e.g., through perceptual learning) is one of the major ways to improve peripheral vision. Although there is a rapidly growing interest in using tDCS to modulate visual perception in humans, it remains unknown whether tDCS can alleviate visual crowding effects. We performed three experiments to investigate this issue. In Experiment 1, subjects were asked to perform an orientation discrimination task with the isolated and crowded targets in the periphery, before and after applying 20 minutes of 2 mA anodal tDCS to early visual cortex (P1 or P2) of the hemisphere contralateral or ipsilateral to the visual stimuli. We found that, electrical stimulation of the hemisphere contralateral to the visual stimuli could significantly reduce the crowding effect. This reduction was absent after the sham stimulation and could not be explained by the performance improvement with the isolated target. In Experiment 2, using the same behavioral task and the same tDCS protocol, we found that the contralateral DC stimulation remained effective in alleviating crowding at a smaller eccentricity. In Experiment 3, we adopted a letter recognition task and found that the alleviation of the letter crowding effect still existed after tDCS. In all the three experiments, no reduction was observed when tDCS was applied to the hemisphere ipsilateral to the visual stimuli. Taken together, we conclude that offline tDCS is effective in alleviating visual crowding across different visual eccentricities and perceptual tasks, which sheds new light on the mechanisms of visual crowding and possible practical applications.

26.335 **Spatio-Temporal Dependencies of Letter Feature Processing** Susana T.L. Chung[1](s.chung@berkeley.edu), Daniel R Coates[2]; [1]School of Optometry, University of California, Berkeley, [2]College of Optometry, University of Houston

It is widely accepted that we recognize letters by first detecting the presence of letter features, followed by integrating the available features to form an overall percept of the letter.Does the processing of letter features depend on spatial and temporal factors? Here, we used a data-driven approach to investigate how letter features are processed amongst letters that are in close proximity to one another, when their spatial content is restricted, and for two stimulus durations.We presented trigrams (sequences of three lowercase letters) to five observers whose task was to identify all three letters on each trial.Trigrams were presented for 50 or 200 ms at 10° in the lower visual field. Letters were rendered in lowercase Arial font (x-height=1.2°, center-to-center separation=1.3°), and were band-pass filtered with a center frequency of 1.35 or 5 c/letter.Each observer completed 5200 trials for each combination of conditions.Letter features for each response and stimulus letter were classified as round, descenders, ascenders, oblique and arch (Bouma, 1971).In general, letter recognition error rates were higher for the middle than the two outer letter positions, for the 50- than the 200-ms condition, and for filtered than unfiltered letters (although the error rates were similar for the 1.35 and 5 c/letter conditions).For the error trials, letter mislocations occurred only sparingly (averaging ~5%).Instead, we observed significant rates of occurrences of feature interactions amongst neighboring letters, such as mislocations, gains, losses, doubling, and sometimes masking of one another.The rates of occurrences of these feature interactions differed for the two durations, and exhibited a dependence on the filter condition.Our findings provide strong evidence for the contingent nature of spatio-temporal processing of letter information when letters are presented in close proximity to one another, and will help constrain models of visual crowding.

Acknowledgement: NIH Research Grant R01-EY012810

26.336 **Visual crowding disrupts the cortical representation of letters in early visual areas** Hojin Jang[1, 2](hojin.jang@vanderbilt.edu), Frank Tong[1, 2]; [1]Department of Psychology, Vanderbilt University, [2]Vanderbilt Vision Research Center

Real-world environments are often highly cluttered, presenting a challenge to our visual system. In particular, our ability to recognize an object in the periphery can be severely impaired by the presence of neighboring distractors, especially when those distractors share similar visual features with the target. Although crowding has been found to suppress the amplitude of responses in the early visual cortex, it is less clear as to whether crowding might impair the quality of information represented in these early areas. In this study, we relied on high-field, high-resolution fMRI at 7 Tesla to investigate the cortical representation of letters and digits in crowded and uncrowded viewing conditions. A digital-clock format with seven possible line segments was used to present numbers ('3', '4', '7', and '9' in this study) and letters ('E', 'h', 'J', and 'P'). In the crowded condition, the target letter/digit presented was presented with flanking stimuli that shared the same luminance polarity, whereas in the uncrowded flanker condition, the flankers were presented with the opposite luminance polarity. Results from 3 participants showed suppressed fMRI responses for crowded as compared to uncrowded targets, consistent with previous fMRI studies. To examine the quality of cortical representations, we applied pattern classification to letter/digit responses in individual visual areas and evaluated decoding accuracy using leave-one-run-out cross-validation. We found that decoding accuracy was significantly impaired on crowding runs, in comparison to uncrowded flanker runs and single-target runs. Moreover, we observed reduced functional connectivity between visual areas in the crowding condition, consistent with a previous report of crowding affecting functional connectivity (Freeman et al., 2011). Our results provide new evidence suggesting that when a target item is presented with visually similar flankers, the early visual representation of the target is disrupted and becomes less distinct due to mechanisms of crowding.

Acknowledgement: This research was supported by NIH grant R01EY029278 to F.T.

26.337 **Two eyes are not better than one with crowded targets**
Maria Lev[1,2](mariale2post@gmail.com), Jian Ding[1], Uri Polat[2], Dennis Levi[1]; [1]School of Optometry and Helen Wills Neuroscience Institute, UC Berkeley, Berkeley, CA 94720, USA, [2]School of Optometry and Vision Science, Faculty of Life Sciences, Bar-Ilan University, Ramat Gan, Israel

Introduction: For a broad range of near threshold stimuli and tasks, two eye are better than one. Binocular summation (BS) is ubiquitous, resulting in improved sensitivity by a factor of ~1.4. However, we note that most experiments and models of BS have focused on local targets. Here we explored the effect of flankers on BS. Methods: We measured both letter identification and contrast detection in healthy young adult observers with fully corrected vision. Letter identification was measured with low contrast (30%) E targets flanked by an array of E flankers presented for 40 ms at the fovea. Target-flanker separation was either one or 0.4 linter-letter-spacing ("crowded"). Contrast detection was measured for a Gabor patch, either in isolation or flanked by two high contrast flankers, positioned either in collinear or orthogonal configurations. Target-flanker separation was varied to measure the effect of spatial interactions, both in the fovea and at an eccentricity of 4 degrees. For both experiments, monocular (each eye) and binocular stimuli were randomly interleaved using shutter goggles (NVIDIA 3D Vision, 120 Hz, background luminance for non-stimulated eye was 40 cd/m2)Results: for single targets (letter or Gabor) and orthogonal configurations, binocular performance was ≈ 25 - 30% better than monocular performance. Similar summation was found for the collinear configuration at large target-flanker separations. However, there was no binocular advantage for letter identification in the crowded condition, or for contrast detection in the collinear configuration for short target-flanker separation of 3 lambda (non-overlapping). Interestingly, for orthogonal flankers, BS is found for all target-flanker separations.Conclusions: Our results show that nearby flankers completely eliminate binocular summation for letter identification and contrast detection, but only when the configuration is collinear. Current models of binocular combination need to be updated to explain the effects of spatial interactions on binocular summation.

Acknowledgement: ISF(1825/16)

26.338 **The occurrence of illusory conjunctions correlates with the spatial noise in peripheral vision**
Yuri A. Markov[1](yuamarkov@gmail.com), Lilit G. Dulyan[1], Ruth Rosenholtz[2], Igor S. Utochkin[1]; [1]National Research University Higher School of Economics, [2]Brain & Cognitive Sciences/CSAIL, MIT

Illusory conjunctions (IC) refer to errors in which an observer correctly reports features present in the display, but incorrectly pairs features or parts from multiple objects. There is a long-standing debate in the literature about the nature of ICs; for example, whether they arise from the lack of focused attention (Treisman & Schmidt, 1982) or from lossy peripheral representations (Rosenholtz et al., 2012). Here, we test the hypothesis that the occurrence of ICs relates to spatial uncertainty of features falling within the same noisy "window". According to this idea, ICs occur when the spatial uncertainty is large compared to the distance between items, causing confusion over which features belong to which item. In Experiment 1, we directly measured the spatial noise at 3°, 6°, 9°, 12° from fixation. A compact "crowd" of four dots briefly appeared, followed by the presentation of a probe circle at various distances from the "crowd". Observers had to respond whether any dot had fallen within the probed region. The probability of perceiving the dots as outside the probe as a function of distance provides a measure of spatial noise as a function of eccentricity. In Experiment 2, we presented four differently colored and oriented bars, located on an invisible circle with a diameter varying from 1° to 3.5° (the "separation"), and centered at one of three eccentricities (4°, 8°, 12°). Participants had to report the color, orientation, and location of any of the bars. The number of correct answers, guesses (reporting non-presented features), and ICs were estimated. The number of IC increased with eccentricity and decreased with separation. There is good resemblance between the spatial noise and the IC pattern. We conclude that there can be an overlap between the mechanisms of spatial localization and IC in peripheral vision.

26.339 **Direct capture of peripheral appearance reveals what is lost and retained in peripheral vision**
Natalia Melnik[1](natalia.melnik@psy.unibe.ch), Daniel R. Coates[1,2], Bilge Sayim[1,3]; [1]Institute of Psychology, University of Bern, Bern, Switzerland, [2]College of Optometry, University of Houston, Houston, TX, USA, [3]SCALab - Sciences Cognitives et Sciences Affectives, CNRS, UMR 9193, University of Lille, Lille, France

Objects viewed in the visual periphery lack the fine detail available in foveal vision. This is partly due to a reduction in visual resolution and stronger susceptibility to clutter (i.e., 'crowding') with increasing eccentricity. However, what exactly is lost and what is retained in peripheral vision remains elusive. For example, in forced choice paradigms, which restrict responses into coarse categories such as letters, target appearance can strongly diverge from the provided categorical alternatives and still yield correct responses. To address this shortcoming, we introduce Geometrically Restricted Image Descriptors (GRIDs) to capture the appearance of shape. In this paradigm, stimuli are constructed solely from segments on a 3x3 grid. We created letters and letter-like shapes (matched in perimetric complexity) to investigate the influence of familiarity on peripheral shape perception. Stimuli were presented at 10° eccentricity in the right visual field, using a gaze-contingent display to prevent foveation. The task was to capture target appearance by connecting points on printed grids placed in front of the participants. Observers viewed the display as long as necessary and were allowed to look back and forth between the screen and the printed grid. GRIDs treat each segment of the presented shapes as distinct targets. Responses were analyzed in terms of character and segment accuracy. Performance depended strongly on familiarity: 94% of the letters and only 53% of the non-letters were depicted correctly. The segment errors in the non-letters, including omissions and truncations, revealed the exact origins of the observed character degradations. We propose that GRIDs are an effective tool to investigate object and shape perception, permitting the capture of fundamental characteristics of visual appearance.

Acknowledgement: This research was supported by the Swiss National Science Foundation (SNF PP00P1_163723 awarded to Bilge Sayim).

26.340 **The cost of using several crowding units to recognize a complex object**
Denis G Pelli[1](denis.pelli@nyu.edu), Darshan Thapa[2]; [1]Psychology Dept, NYU, [2]Computer Science, NYU

Crowding is the failure to recognize a simple target because it is too closely surrounded by clutter. It is characterized by a crowding distance beyond which clutter has no effect.We take this oval area to be the receptive field of a crowding "unit".Thus, a word seen peripherally can be recognized only if neighboring letters are at least a crowding distance apart, i.e. seen by distinct crowding units. Some objects, e.g. faces, are substantially more complicated than a roman letter and seem to be analyzed more like a word than a letter. At a given eccentricity such objects can only be successfully identified if the object is large enough that crowding units isolate key parts, like the letters in a word or the features of a face. Efficiency for identifying a roman letter in noise is respectable, roughly 15% (Pelli et al., 2006). The efficiency for a word is much worse, reduced by the reciprocal of the number of letters (Pelli & Farell, 2003).We suppose that each crowding unit has a respectable efficiency, but that the visual system combines them inefficiently, requiring the same energy per unit, regardless of the number of units.This predicts that efficiency for a complicated object will be inversely proportional to the number of crowding units required to see it.We tested the prediction by measuring n and efficiency. For n, we measure the threshold size at 10 deg eccentricity, and divide the threshold area by the known crowding area.We measure efficiency from human and ideal threshold contrasts for identification on a white noise background.We tested eight fonts: Hiragino, Songti, Checkers, Kuenstler, Sabbath, San Forgetica, and Sloan. Plotting log efficiency vs. log n, we get a linear regression slope of -0.84 with r=0.82.This supports the hypothesis that recognition of complex objects inefficiently combines the contributions of multiple crowding units.

Acknowledgement: 1R01EY027964

26.341 **When detrimental crowding becomes beneficial uniformity in peripheral letter recognition**
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A target letter is usually more difficult to identify when flanked by other letters. This phenomenon, known as crowding, strongly depends on the similarity of the target and the flankers: reducing target-flanker similarity normally benefits target identification ('uncrowding'). For example, when reporting the central letter of a trigram, performance is superior when the trigram alternates in contrast polarity (e.g., black, white, black) compared to a trigram with uniform letters (e.g., white, white, white). Here, we show that alternating contrast polarity is detrimental when reporting all letters of a trigram. Stimuli consisted of uniform and alternating trigrams, presented for 150 ms at 10 degrees eccentricity. Participants reported either a single letter or all three letters. In the single report, performance on the central letter was superior in the alternating compared to the uniform condition, replicating the well-known advantage of 'uncrowding' by opposite contrast polarity. On average, the accuracy of all three letters did not differ between alternating and uniform trigrams in the single report. By contrast, when reporting all letters, average performance was superior in the uniform compared to the alternating condition, reversing the usual pattern of results when only reporting the central target. There was no advantage for the central letter in alternating compared to uniform trigrams when all letters were reported. Our results show that the benefit of low target-flanker similarity observed in standard crowding paradigms can be reversed by changing the task requirements. We suggest that benefits of uniformity outweigh the deleterious effect of crowding when all letters are targets.

Acknowledgement: Swiss National Science Foundation (SNF grant PP00P1_163723).

26.342 **Differences and similarities between temporal crowding, spatial crowding and masking** Yaffa Yeshurun[1](yeshurun@research.haifa.ac.il), Shira Tkacz-Domb[1]; [1]Psychology department, University of Haifa

Temporal crowding, classical masking and spatial crowding are 3 phenomena with which target identification is impaired by the presence of other irrelevant stimuli (distractors). With temporal crowding and masking the distractors appear before and/or after the target at the same location, but with masking, the inter-items SOAs are considerably shorter. With spatial crowding, the distractors surround the target in space rather than in time. Here, we examined whether the processes mediating these 3 phenomena are similar or different. We used a continuous orientation report task in a temporal crowding paradigm. Critically, a similar continuous report task was previously employed with both classical masking and spatial crowding, allowing us to compare these previous outcomes with those observed in this study. Our observers viewed a sequence of 3 randomly oriented items separated by varying SOAs (170-475 ms), and had to reproduce the target's (middle item) orientation. On some trials (baseline trials) only the target appeared. The target and distractors were either similar (Experiments 1 & 2) or dissimilar (Experiment 3). Orientation error distributions were analysed with a mixture model analysis. In all 3 experiments, SOA (target-distractor distance in time) and distractors presence affected the standard deviation of the Gaussian distribution and substitution rate, but not guessing rate. This pattern of results is very different from that found for classical masking or spatial crowding. With masking, SOA mainly affected guessing rate, and with spatial crowding target-distractor spacing mainly affected guessing and substitution rate. Such different results suggest that these 3 phenomena involve different processes: reduction of signal-to-noise ratio mediates masking and spatial crowding, while impairment of encoding precision occurs only with temporal crowding. Still, the 2 types of crowding share some commonalities because with both, manipulating target-distractor distance (in time or space) and target-distractor similarity affected substitution rate.

26.343 **Humans trust central vision more in the light and the dark** Alejandro H. Gloriani[1](alejandro.gloriani@staff.uni-marburg.de), Alexander C. Schütz[1]; [1]Experimental & Biological Psychology, University of Marburg

To make optimal perceptual decisions, the visual system requires knowledge about its own properties and the relative reliability of signals arriving from different parts of the visual field. In the human retina, these signals come from two types of photoreceptors: cones, active under bright daylight illumination (photopic viewing) and highly concentrated in the fovea; and rods, active under dim illumination at night (scotopic viewing) and absent from the fovea (scotopic foveal scotoma). It is unclear if the scotopic foveal scotoma is filled-in and if humans can take into account the differences between scotopic and photopic vision when making perceptual decisions. We investigated the preference for central and peripheral vision under scotopic and photopic viewing. Stimuli consisted of a striped center (smaller than the foveal scotoma) and surround, which could have the same (continuous) or the orthogonal (discontinuous) orientation. In each trial two stimuli were presented. In Experiment 1, observers had to indicate which stimulus appeared continuous or discontinuous (half of the observers each). In Experiment 2, observers had to make two decisions: first they had to select which of the two stimuli they want to judge and then they had to report if this selected stimulus was continuous or discontinuous. We found that a stimulus with a discontinuity in the scotopic foveal scotoma appeared as continuous, providing evidence for perceptual filling-in. We also found that observers preferred information from central vision under photopic viewing and even when it was not veridical and only inferred under scotopic viewing. This general preference for central vision indicates that humans are not aware of their scotopic foveal scotoma and that it is not taken into account for perceptual decision making. This suggests that filling-in precedes the estimation of confidence, thereby shielding awareness from the foveal scotoma with respect to its contents and its properties.

Acknowledgement: This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 676786).

26.344 **Radial-tangential anisotropy of bisection thresholds in the normal periphery** Robert J Green[1](robert.green@berkeley.edu), Susana T L Chung[1]; [1]School of Optometry, UC Berkeley

It is well known that the spatial interaction zone exhibits a radial-tangential anisotropy in the normal periphery, such that the zone is larger along the radial than the tangential meridian. Several reports provide evidence that bisection thresholds (judging whether an object divides a spatial interval into two equal halves) also demonstrate such a radial-tangential anisotropy in the normal periphery. However, most of these data were obtained only along two meridians (radial and tangential), which are insufficient to fully quantify the characteristics of the two-dimensional shape of the bisection zone. Here, we measured thresholds for a three-dot bisection task along four meridians to map out the two-dimensional shape of the bisection zone. Three collinear dots, with the two outer dots separated by 1°, were presented with the center of the ensemble located at 5° eccentricity in the right, lower-right or lower visual field. The three dots were presented along four meridians (radial, tangential and ±45° from the radial). We presented the middle dot at five displacements from the center of the spatial interval (0, ±1, ±2, steps). Observers judged whether the middle dot was closer to either of the two outer dots. A psychometric function was fit to each set of data. The displacement that corresponded to 75% response toward the direction of one of the two outer dots was used to represent the bisection threshold. Consistent across four observers, bisection thresholds were higher along the radial than the tangential meridian, demonstrating a radial-tangential anisotropy, but only in the right and lower visual fields. In the lower-right field, bisection thresholds were similar along all four tested meridians. Our results provide a more complete picture of the two-dimensional shape of the spatial fidelity zone for bisection in the normal periphery and allow us to model small rotations of the zones.

Acknowledgement: Grant support: NIH Research Grant R01-EY012810

26.345 **Under-confidence in peripheral vision** Matteo Toscani[1](Matteo.Toscani@psychol.uni-giessen.de), Karl R Gegenfurtner[1], Pascal Mamassian[2], Matteo Valsecchi[1]; [1]Justus-Liebig-Universität Gießen, [2]Ecole Normale Supérieure, Paris

Vision is damaged by uncertainty: to make sense of the physical properties of the world the visual system needs to deal with missing information and noisy sensory mechanisms. Although we have some sensitivity to our level of uncertainty, these judgements can be systematically biased yielding over or under-confidence. Here we investigated whether observers can correctly estimate the loss of perceptual precision that characterizes peripheral vision. Fifteen naïve observers were presented with one oriented Gabor stimulus at 30 dva eccentricity and one in the centre, in random order. Observers had to categorise whether the Gabor was rotated clockwise or counter-clockwise with respect to a fixed reference, separately for the stimulus in the periphery and the one in the centre. Then, they had to choose which of the two perceptual judgments they were more confident to be correct. The rotation was fixed at 5 degrees, but the contrast of the Gabor was adaptively varied to keep both peripheral and central performance within a similar range.
In order to compare peripheral and foveal confidence independently of performance, we first computed the difference in performance between the peripheral and the central judgements as a function of central and peripheral contrast. Then, we computed an index of confidence based on the agreement between the difference in performance and confidence judgements, for a given central and peripheral contrast. All the participants but one exhibited under-confidence in the periphery: their performance was higher than they thought (p=0.021 -Wilcoxon signed rank test). Although observers' judgements were biased, they still reflected some knowledge about the level of perceptual uncertainty. In fact, when observers were more confident in either

the central or the peripheral judgments, the corresponding accuracies were higher (t(14)= 2.7327,p=0.016; t(14)=7.7, p < 0.001; for central and peripheral judgments, respectively).

26.346 **Vision in the extreme-periphery (1b): perception of rotation rate** Daw-An Wu[1](daw-an@caltech.edu), Takashi Suegami[2,1], Shinsuke Shimojo[1]; [1]California Institute of Technology, [2]Yamaha Motor Corporation U. S. A.

Peripheral vision (20-40º eccentricity) has been characterized extensively, but there is limited research extending to the 95+º limits of the human visual field. Flickering stimuli appear to flicker more rapidly when viewed in the extreme periphery than when they are foveated (Shimojo, VSS'19).Here, we find that this effect generalizes to another form of dynamic perception:Rotating stimuli in the extreme periphery are perceived as rotating faster than identical stimuli presented at the fovea (bars, crosses, cartoon icons, 2-4º visual angle). When the peripheral stimulus was enlarged (2-3x), speed mismatch was increased, suggesting that the effect is not based simply on cortical projection sizes.Comparisons of speed mismatches with bar-shaped and cross-shaped stimuli suggested that the effect may be driven by raw motion energy. When a long row of rotating stimuli is presented, the last stimulus in the periphery is perceived as rotating faster, while the rest appear more or less uniform.Removing the last stimulus causes the next in line to appear uniquely fast.In addition, when stimuli are shown in a large array, stimuli on the corners of the array appear to rotate faster than the rest (demonstrated at VSS 2018 Demo Night).This suggests involvement of a surround-suppression mechanism, as found in basic motion processing. The perception of rotation rate is likely to involve a combination of object-based tracking of rotation angles, and the processing of raw motion energy. Differences in visual acuity may cause foveal vision to rely more on object tracking and peripheral vision to rely more on motion energy. Perceptual mismatches may arise when attempting to comparing across such different process outputs.

Acknowledgement: Yamaha Motor Corporation U.S.A., JST-CREST

26.347 **Exploring the effects of gaze-contingent rendering on reading performance** Angelica Godinez[1](angelica_godinez@berkeley.edu), Rachel Albert[2], David Leubke[2]; [1]School of Optometry, University of California, Berkeley, [2]NVIDIA Research

Peripheral vision exhibits different information processing properties compared to foveal vision (e.g., acuity, crowding, flicker sensitivity, color perception). Gaze-contingent rendering (also called foveated rendering) is designed to exploit the limitations of the peripheral visual system in order to decrease bandwidth, reduce power consumption, and speed up rendering (Guenter et al., 2012). This technique is already being explored in industry (Google & LG's 1443 PPI display, Fove, and Varjo) as a solution to meet increasing display demands. Previous evaluations of gaze-contingent rendering techniques have focused on detecting artifacts in natural images (Patney et al., 2016; Albert et al., 2017), but it is unknown what kind of effect this type of image degradation may have on observer behavior and performance in other contexts such as reading. Text poses a particularly difficult challenge for gaze-contingent rendering since it contains both high contrast and high spatial frequencies, causing visible flicker and aliasing artifacts when down-sampled in the periphery. Peripheral vision is also known to play an important role in saccade planning while reading (Yang & McConkie, 2001). We measured subject performance under gaze-contingent rendering using a reading task. On each trial, observers were instructed to read a passage and answer whether a particular word appeared in the text. We conducted multiple experiments varying the amount of peripheral degradation across several peripheral rendering techniques, including subsampling and Gaussian blur. We recorded reading speed, eye movements, and performance on the task. Results suggest that both the rendering technique and the amount of peripheral degradation influence reading behavior. We demonstrate that performance-based metrics such as reading behavior are an important tool for evaluating peripheral rendering techniques. Furthermore, we advocate for developing new rendering methods to improve the effectiveness of gaze-contingent rendering for text-based imagery.

26.348 **Perceptual factors in mental maze solving** Dian Yu[1](dianyu2017@u.northwestern.edu), Qianqian Wan[2], Benjamin Balas[3], Ruth Rosenholtz[1,4]; [1]Computer Science and Artificial Intelligence Lab, MIT, [2]Department of Psychology, Hong Kong University, [3]Department of Psychology, North Dakota State University, [4]Brain & Cognitive Sciences, MIT

Mentally solving visual mazes can be difficult cognitively, e.g. when each intersection has many branches. But sometimes, due to perceptual factors, even tracing the one and only path can be difficult in a compact and complex maze. Perceptual aspects of maze solving have been largely overlooked in previous research. We hypothesize that the perceptual difficulty of mental maze solving is related to visual crowding, which adds ambiguity about the shape of the path. In the current study, participants solved mazes by judging whether a continuous path connected the start and end points of each maze. We altered the level of crowding for each maze by changing its visual features and examined how this influences maze-solving time. In Experiment 1, we varied wall thickness in each maze, a manipulation previously shown to affect crowding (Chang & Rosenholtz, 2016). As walls get thicker, adjacent paths become more separated (less crowded). Indeed, observers solved the mazes faster with increasing wall thickness (F(2,44) = 28.86, p< .001). In Experiment 2, we again varied wall thickness, and also added visual complexity to the mazes by replacing straight walls with wavy lines. Observers solved mazes with four different wall types: thin-straight, thick-straight, thin-wavy, thick-wavy. We replicated results from Experiment 1 that observers were faster solving mazes with thick compared to thin walls (F(1,23) = 35.50, p< .001). Observers were also consistently faster with straight compared to wavy walls for both thickness (F(1,23) = 16.13, p=.001). Together, we show mental maze solving is affected by features that influence visual crowding. Tracing paths in more crowded mazes may require more and smaller saccades due to a smaller "uncrowded window" (Pelli & Tillman, 2008), leading to slower performance. Crowding may also interfere with figure-ground segmentation – more crowded mazes make it harder to perceive the path as figure and recognize its shape.

Acknowledgement: NSF CRCNS:Neurocomputation in the Visual Periphery

Color and Light: Psychophysics, neural mechanisms

Saturday, May 18, 2:45 - 6:45 pm, Banyan Breezeway

26.349 **A Quadratic Model of the fMRI BOLD Response to Chromatic Modulations in V1** Michael A Barnett[1](micalan@sas.upenn.edu), Geoffrey K Aguirre[2], David H Brainard[1]; [1]Department of Psychology, University of Pennsylvania, [2]Department of Neurology, University of Pennsylvania

Purpose. Prior functional brain imaging studies have measured the location and amplitude of cortical responses to chromatic contrast. We aim to develop a model of cortical response that captures the effects of color direction and contrast. We build on the observation that psychophysical chromatic sensitivity is well-described by ellipsoidal isodetection contours. Specifically, we ask whether a model employing ellipsoidal isoresponse contours describes the BOLD response in human V1. Methods. We scanned 3 subjects while they viewed 12 Hz flickering full field symmetric chromatic modulations, restricted to the LM cone-contrast plane around a common background. We studied 8 color directions at 5 contrast levels, with responses for each direction/contrast pair measured in ten separate acquisitions. An anatomical template was used to restrict analysis to voxels in V1 corresponding to 0 to 20 degrees eccentricity. We fit the data with two models: i) a general linear model (GLM) in which each direction/contrast was modeled by its own regressor ii) a quadratic color model (QCM) in which the isoresponse contours were elliptical and the effect of overall contrast was modeled by a single sigmoid. Quality of fit was evaluated using cross-validation, with one acquisition left out in each cross-validation iteration. Results. Cross-validated RMSE, evaluated with respect to the time course of the BOLD response, was essentially the same for the full GLM and more restricted QCM. The isoresponse contours obtained from the QCM showed that more chromatic contrast is required for a modulation in the L+M contrast direction to produce the same response as a modulation in the L-M contrast direction, matching prior work. Conclusions. The QCM provides a good account of the BOLD fMRI response across LM color direction and contrast. This account in turn provides a quantitative description of the BOLD response to modulations of any direction/contrast within the LM plane.

Acknowledgement: NIH RO1 EY10016

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26.350 **fMRI responses to foveal versus peripheral chromatic and achromatic stimuli** Erin Goddard[1](erin.goddard@mail.mcgill.ca), Kathy T Mullen[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University, Canada

The fovea is a specialized region of the primate retina whose high density of photoreceptors underlies the high acuity and color sensitivity of our central vision. Despite this, much fMRI research into the basic responses of early visual cortex has used peripherally presented stimuli, often accompanied by an irrelevant task at fixation. Here we test the extent to which fMRI responses of a range of visual areas were dominated by the foveal part of the stimulus. We used radial sinusoidal gratings of four types, designed to target different mechanisms that vary in their distribution across the retina: L-M isolating (red-green), S-cone isolating (blue-yellow), achromatic P-type (high SF, low TF), and achromatic M-type (low SF, high TF). In Experiment 1, these stimuli were presented at each of 3 sizes: 1.4, 4.1 and 15.0 degrees. In Experiment 2, each stimulus was composed of different stimulus types in the center (1.4 degrees) and annular surround (1.4-15.0 degrees). Across runs, participants attended to either the center or the surround stimulus. We used a series of classification analyses to measure how well each region's pattern of activity could be used to decode the type of stimulus and its size (Experiment 1) or the type of stimulus in the center and surround (Experiment 2). Early visual areas (V1, V2, V3) had relatively more information about stimulus size than stimulus type, whereas for later visual areas (V3A/B, LO, hMT, hV4, VO1 and VO2) this was reduced or reversed. Across stimulus types, there was no evidence for different patterns of spatial summation across stimuli targeting mechanisms with differing retinal distributions. In Experiment 2, decoding of the of the surround stimulus increased when attended across all cortical areas. Decoding of the center stimulus only increased with attention in VO1/VO2, suggesting a foveal/peripheral asymmetry in attentional enhancement

Acknowledgement: CIHR grants 153277 and 10819 to Kathy T. Mullen

26.351 **Cortically-stimulating gratings reveal non-cardinal colors better than do LGN-stimulating spots** Karen L Gunther[1](guntherk@wabash.edu), Colby Dunigan[1], Carson Powell[1], Jorge Rodriguez[1]; [1]Psychology, Wabash College

We are examining the ability of spots versus gratings to reveal non-cardinal colors.Neurons in the LGN respond better to spots, while cortical neurons respond better to gratings (DeValois, Cottaris, Elfar, Mahon, & Wilson, 2000). In addition, non-cardinal mechanisms are known to not emerge until the cortex (Gegenfurtner, 2003).Thus, non-cardinal mechanisms should be more likely to be revealed with cortically-stimulating gratings than LGN-stimulating spots.This has been shown in the isoluminant color plane in macaque monkeys (Stoughton, Lafer-Sousa, Gagin, & Conway, 2012) and in the RG/LUM color plane in humans (Gegenfurtner & Kiper, 1992).Recent reviews of non-cardinal mechanisms (Eskew, 2009) and S-cone vision (Smithson, 2014) do not report that this has yet been examined in the TRIT/LUM color plane. We are filling in this gap by testing all three color planes, using both spots and gratings, in the same study and in the same species (human).Thresholds to detect spot or grating stimuli are measured in aligned or orthogonal speckled noise.For example, an orange/turquoise grating may be presented in orange/turquoise or purple/lime noise.Evidence for separate underlying neural mechanisms is seen when the threshold to detect the stimulus in aligned noise is greater than in orthogonal noise.All stimuli in the isoluminant plane are individually isoluminant via heterochromatic flicker photometry. Non-cardinal colors are created in equal threshold space.We aim to test 10 subjects in each color plane; preliminary results are largely following predictions.

Acknowledgement: National Science Foundation Grant No. BCS-1753808

26.352 **Hue selective masking: an SSVEP study** Sae Kaneko[1,2](sakaneko@riec.tohoku.ac.jp), Ichiro Kuriki[2], Søren K Andersen[3]; [1]Frontier Research Institute for Interdisciplinary Sciences, Tohoku University, [2]Research Institute of Electrical Communications, Tohoku University, [3]School of Psychology, University of Aberdeen

Are the intermediate hues (hues off the cardinal axes in the cone-opponent color space) represented as the summation of the cone-opponent mechanisms in human early visual areas? We addressed this question by smoothly scanning visual cortex responses to different hues (Experiment 1) and masking by a different hue (Experiment 2) using steady-state visual evoked potentials (SSVEPs). All colors were chosen from a hue circle on the equiluminant plane in a cone-opponent color space, whose origin was equal energy white (EEW). The stimulus was a check pattern (6 x 6 deg) on a uniform background (EEW at 30 cd/m2). In Experiment 1, half of the tiles were filled with the test hue and the other half with EEW. The tiling pattern alternated at 5 Hz, while the test hue changed smoothly at 24 s/cycle rate. Cone contrast of the test was standard (ΔL/Lbkgnd= 8 %, ΔS/Sbkgnd= 80 %), half (4, 40 %), or a quarter (2, 20 %). Participants observed the stimulus while conducting an easy detection task. In Experiment 2, half of the tiles' hue was the test hue (flickered on/off at 5 Hz) at half contrast, while the other tiles' was one of the four intermediate hues at the standard contrast, which flickered at 6 Hz (masker). In Experiment 1, the SSVEP amplitudes showed asymmetric patterns around the hue circle, which is consistent with the hue-selectivity study by fMRI. Data from Experiment 2 showed weakened responses to the hues around the masker hue, and the affected range spans approximately to a quadrant of the hue circle. The estimated bandwidths of hue-selective channels in previous psychophysical studies ranged 60-90 deg and our result could be a physiological support. These results suggest that the SSVEP results elucidate the characteristics of mechanisms at early cortical site selectively tuned to the intermediate hues.

Acknowledgement: JSPS KAKENHI Grant-in-Aid for Young Scientists (18K13365)

26.353 **The effect of emotion on neural representations of color.** Yelim Lee[1,2](lchoa92@gmail.com), Daehyun Kim[3], Won Mok Shim[1,2]; [1]Center for Neuroscience Imaging Research, Institute for Basic Science, [2]Department of Biomedical Engineering, Sungkyunkwan University, [3]Korea Army Academy at Young-Cheon

Previous work suggested that emotion affect both basic perceptions and high-level cognition. At the perceptual level, positive mood has been shown to enhance broad, holistic, and inclusive processes, whereas negative mood has been associated with narrow and sharpened perceptual selection (Derryberry & Tucker, 1994; Fredrickson & Branigan, 2005; Uddenberg & Shim, 2015). However, it remains unclear whether and how the broadening or narrowing effect of emotion can affect the neural representations of visual features. Here, we examined whether positive and negative affective states modulate feature-selective responses in early and high-level visual areas. Participants first listened to music clips to elicit positive (happy), negative (sad), or neutral emotions. After mood induction, using fMRI and an inverted encoding model (Brouwer & Heeger, 2009), population-level color-selective responses were examined in the primary visual cortex (V1) and extrastriate areas (V2, V3, V4v, and VO) while participants performed a color categorization task on a spiral with one of the 12 colors chosen from the DKL color space. Consistent with previous findings (Isen & Daubman, 1984), the number of categories into which participants grouped the colors was lower in the happy condition compared to the sad and neutral conditions, reflecting inclusive processes induced by the positive affect. While the influence of the positive affect was identified behaviorally, the color-selective responses in V4 were degraded in the sad condition compared to the neutral condition, indicating that the negative affect can have an influence on the selectivity of color responses. This result suggests that emotion can affect neural representations of basic visual features and that the negative affect in particular may modulate feature selectivity.

Acknowledgement: IBS-R015-D1

26.354 **Similarities in response non-linearities in macaque lateral prefrontal cortex visual neurons during in vivo and in vitro experiments. Implications for normalization models.** Julio C Martinez-Trujillo[1,2,3](julio.martinez@robarts.ca), Eric S Kuebler[1,2,3], Michelle Jimenez[1,2,3], Jackson Blonde[1,2,3], Kelly Bullock[1,2,3], Megan Roussy[1,2,3], Benjamin Corrigan[1,2,3], Roberto Gulli[1,2,3], Diego Mendoza-Halliday[5], Santiago Gomez-Torres[4], Stefan Everling[1,2,3], Julia Sunstrum[1,2,3], Meagan Wiederman[1,2,3], Michelle Everest[1,2,3], Wataru Inoue[1,2,3], Michael Poulter[1,2,3]; [1]Schulich School of Medicine and Dentistry, Department of Physiology and Pharmacology, Western University, Canada, [2]Robarts Research Institute, Western University, Canada, [3]Brain and Mind Institute, Western University, Canada, [4]Department of Physiology, McGill University, Canada, [5]McGovern Institute for Brain Research at M.I.T., USA

Visual neurons in many brain areas show non-linear response profiles as a function of the stimulus shown inside their receptive fields. These can be fit with different non-linear functions to obtain the tuning curve of the neuron for a particular feature. One example is the contrast response function, e.g., increases in the contrast of a stimulus inside a neuron's receptive field produce changes in its response profile that can be fitted by a sigmoid function. Such properties have been attributed to lateral inhibition and normalization within a network of interconnected neurons. Here we test the hypothesis that non-linearities in response functions of single neurons during in vivorecordings can be at least in part attributed to their intrinsic (not network

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dependent) response properties. To address this issue, we first obtained response functions from single neuron recordings in the lateral prefrontal cortex (LPFC areas 8A/9/46) of two macaques to gratings of varying contrast inside their receptive fields. We then conducted patch clamp in vitrorecordings in slices extracted from the same LPFC area of 4 macaques using square current pulses of varying intensities that attempted to simulate increases in input strength when increasing contrast. In both datasets we convert spikes trains to firing rates over 250ms of stimulus presentation (in vivo) or pulse duration (in vitro) and fit the data with a sigmoid and a linear function. From 27 in vivo neurons, 52% were best fitted by the sigmoid and 48% were best fitted by a line. From 31 in vitro neurons 45% were best fitted by the sigmoid and 55% by a line. The proportions of neurons fitted with either function was not significantly different between areas (p>0.1, Chi-Square test) suggesting that non-linearities in the responses of visual neurons can be explained to a large degree by intrinsic cell properties.

Acknowledgement: CIHR, NSERC, BrainSCAN

26.355 **Decoding chromaticity and luminance information with multivariate EEG** David W Sutterer[1](david.w.sutterer@vanderbilt.edu), Andrew Coia[2,3], Vincent Sun[5], Steven Shevell[2,3,4], Edward Awh[2,3]; [1]Vanderbilt University, [2]Institute for Mind and Biology, University of Chicago, [3]Department of Psychology, University of Chicago, [4]Department of Ophthalmology & Visual Science, The University of Chicago, [5]Chinese Culture University

Recent work suggested that it is possible to decode which chromaticity an observer is viewing from the multi-electrode pattern of low frequency EEG activity on the scalp (Bocincova and Johnson, 2018). However, chromatic stimuli may vary also in luminance, and there has been debate about whether differences in the visual evoked potentials (VEPs) from stimuli of different chromaticities are driven by differences in the luminance or the chromaticity of the stimuli (Skiba et al., 2014). Thus, an open question is whether the chromaticity of a stimulus can be decoded even when differences in luminance do not inform the classification. To answer this question, we conducted two experiments in which we systematically varied both the luminance and the chromaticity of a centrally presented disk. In experiment one, we presented two chromaticities (appearing red and green) at three luminance levels (6.5, 10.8, and 17.4 cd/m2, on a 5 cd/m2 background) on separate trials. In experiment 2 we presented 4 chromaticities (appearing red, orange, yellow, and green) at two luminance levels (6.5 and 10.8 cd/m2, on a 5 cd/m2 background). For each observer, we first performed heterochromatic flicker photometry to equate each chromaticity at each luminance level. Next, observers monitored centrally presented chromatic discs (150ms stimulus duration) while EEG was recorded. Using a pattern classifier and the multivariate topography of scalp EEG activity we were able to accurately decode the chromaticity of observed stimuli. We could also decode the luminance level of each stimulus. Critically, we were able to decode the chromaticity of the stimuli when we trained the classifier on the chromaticities presented at one luminance level and tested at a different luminance level. Thus, the multivariate topography of EEG activity can be used to decode which chromaticity is being viewed, even when chromaticity is decoupled from variation in luminance.

26.356 **Dynamic of ON and OFF chromatic adaptation** Clemente Paz-Filgueira[1](cpaz@uic.edu), Michael R. Tan[1,2], Dingcai Cao[1]; [1]Department of Ophthalmology and Visual Sciences, University of Illinois at Chicago, Chicago, IL, USA, [2]Department of Bioengineering, University of Illinois at Chicago, Chicago, IL, USA

Introduction: Zaidi et al (Current Biology, 2012) devised a time varying chromatic adaptation paradigm that used two hemifields modulating in opposite (ON and OFF) directions in cardinal axes. The present study assessed the dynamics of ON and OFF chromatic adaptation separately under different background chromaticities and identified which process determined the dynamics of adaptation with simultaneous ON and OFF modulations. Methods: Two stimulus types were used: one consisted of two hemifields (subtending 3.6°) complementarily modulated to opposite ends of a cardinal axis (simultaneous ON/OFF) and the other was only one of the two hemifields modulated along one end (either ON or OFF) of a given cardinal axis (L+M-, l=L/(L+M)- and s=S/(L+M)-axis). Modulation was half a cycle of a sinusoid (1/32Hz), starting and finishing on the mean background chromaticity. Nine backgrounds (20cd/m2) were set: one achromatic (EEW), 2 reddish (+l), 2 greenish (-l), 2 bluish (+s) and 2 yellowish (-s). The task was to report the time to reach the identity point, that is, when the stimulus had the same color as the background. Results: Compared with the ON stimuli, the time at the identity point occurrence for the OFF stimuli was shorter in the L+M and s directions, particularly with the EEW, bluish and yellowish backgrounds. Relative to the EEW background, the identity times with complementary modulations in the s-axis was decreased by the yellowish backgrounds and increased by the bluish backgrounds. Finally, the identity times with complementary modulations were equal or larger than the slower mechanism tested separately for the ON and OFF stimuli for all backgrounds. Conclusions: The ON and OFF adaptations in the L+M and s directions have different dynamics and the slower mechanism determined adaptation with simultaneous ON and OFF modulations.

Acknowledgement: UIC core grant for vision research P30- EY01792.

26.357 **Luminance and chromatic contrast sensitivity at high light levels** Sophie Wuerger[1](s.m.wuerger@liverpool.ac.uk), Rafal Mantiuk [2], Maria Perez-Ortiz[2], Jasna Martinovic[3]; [1]Department of Psychological Sciences, University of Liverpool, [2]Department of Computer Science and Technology, University of Cambridge, [3]School of Psychology, University of Aberdeen

Contrast sensitivity functions (CSF) are commonly used to characterise the sensitivity of the human visual system at different spatial scales, but little is known how the CSF changes from the mesopic range to a highly photopic range reflecting outdoor illumination levels.The purpose of our study was to further characterise the CSF by measuring the luminance and the chromatic sensitivity for background luminance levels from 0.2 cd/m2 to 7000 cd/m2.Stimuli consisted of Gabor patches of different spatial frequencies, generated using MatLab, varying from 0.5 cpd to 6 cpd andwere displayed on an HDR display generating luminance levels of up to 15000 cd/m^2. Contrast sensitivity functions were measured in three directions in colour space, reflecting early post-receptoral processing stages: an achromatic (L+M) direction, a 'red-green' (L/(L-M)) direction, and a 'lime-violet' direction (S/(L+M). Thresholds are defined as the distance in cone contrast space at which 84% correct performance was achieved. Within each session, observers were fully adapted to the fixed background luminance (0.2, 2, 20, 200, 2000 or 7000 cd/m2) and on each trial a stimulus of a different frequency (0.5, 1, 2, 4, 6 cpd) and colour (achromatic, red/green, lime/violet) was presented.Our main finding is that the background luminance has a differential effect on luminance compared to chromatic contrast sensitivity. Contrast sensitivity is increasing with background luminance up to around 200 cd/m^2, in particular for medium and high frequencies. Even higher luminance levels (2000 cd/m^2) yield a decrease in luminance contrast sensitivity which is not observed in the chromatic sensitivity curves, or occurs at higher light levels. The differential effect of background luminance on luminance and chromatic contrast sensitivity implies that a local cone contrast adaptation model is not sufficient to account for the observed sensitivity changes.

Acknowledgement: EPSRC EP/P007503

26.358 **Comparison of three methods for determining equiluminance** Jingyi He[1](he.jing@husky.neu.edu), Yesenia Taveras Cruz[1], Rhea T Eskew[1]; [1]Department of Psychology, Northeastern University, Boston MA 02115

Several methods have been used to determine the relative modulation of the L and M cones that minimizes luminance modulation, including the minimally-distinct border (MDB; Boynton, 1978), heterochromatic flicker photometry (HFP; Ives, 1912), and minimum motion (MM; Anstis & Cavanagh, 1983) techniques. When performed on a modern computer-driven display, MDB is the simplest to set up (code, calibrate, and run), MM is likely to be the easiest for naive observers to learn and perform, and HFP is intermediate on both of these dimensions. We compared the three techniques in terms of their variability across measurements, their agreement with one another, and their test-retest reliability. In all techniques, the ~2 deg stimuli were presented at the center of a uniform grey background (59 cd/m2). Observers used buttons to vary the stimulus angle in the (L, M) plane of cone contrast space – S cones were not modulated -- either at 25% or 50% of the maximum contrast available at each angle, to find the equiluminant angle. In HFP, observers minimized apparent flicker of a square at 10.75 Hz. In MM, observers minimized the motion of a 2.5 cpd counterphase grating at 2 Hz. In MDB, observers attempted to minimize the distinctness of an 'isolated edge' (a horizontal step multiplied by a Gaussian; McLellan et al., 1994) in two variants: 500 ms flashes (MDB1), or steady presentation (MDB2). A second session was done at least a week after the first session. At all mean equiluminant settings, L and M contrasts were of opposite sign, as expected. Across observers, HFP produced the lowest |L/M| ratio (smallest equiluminant angle) while MDB1 and MDB2 gave somewhat larger |L/M|

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ratios. Inter-method correlation coefficients showed only moderate consistency across methods. MM and HFP showed high test-retest reliability while MDB1 did not. Additional comparisons will be discussed.

Acknowledgement: NIH Grant R01 EY023281

26.359 **Spectral Luminance Filtration's Effect on Color Contrast Sensitivity in Color Normal and Color Deficient Observers** Johnathan W Hoopes[1](jhoopes@sco.edu), Patricia M Cisarik[1]; [1]Optometry Department, Southern College of Optometry

Spectrally-selective luminance filters (SSLFs) can be designed to enhance color perception by creating greater separation between medium and long wavelengths. Whether SSLFs normalize color contrast sensitivity (CCS) for red and green stimuli in inherited red-green color deficient (CD) observers is unknown.We assessed change in CCS for red and for green stimuli in 80 healthy adult eyes (69 color normal, CN; 11 CD). Using a clinical instrument (ColorDx, Konan Medical), subjects identified the gap in an isoluminant Landolt C via a 4-alternative forced choice procedure.The psi-marginal adaptive method was used to determine CCS threshold.Eight blocks were used to test 2 stimulus sizes, 2 colors, and 2 filter conditions, all constant within a block and viewed at 60 cm.The mean change in CCS from no filter to SSLF condition was significantly different for CN compared to CD observers (Red, logMAR =1.04:p < .001; Green, logMAR = 1.04: p = .008).Multiple linear regression of change in CCS on age, gender, visual acuity, color vision status, history and number of mild traumatic brain injuries was significant only for color vision status for both colors (p < .001).For logMAR = 1.22 size stimuli, the distributions of change in CCS were significantly different for CN vs CD observers (red: p < .0001; green: p = .018).Comparison of CCS without filter for CN and CCS with filter for CD showed no significant difference in the distributions for the logMAR = 1.04 stimuli (p = 0.12) nor for the logMAR = 1.22 red stimulus (p = 0.08), but a significant difference emerged for CN vs CD observers for the logMAR = 1.22 green stimulus (p = 0.04). Change in CCS produced by SSLFs normalizes CCS for CD observers.Whether CCS can predict subjective success with SSLFs remains to be explored.

26.360 **Blue light effects on the gap effect** Hsing-Hao Lee[1](hsinghaolee@gmail.com), Su-Ling Yeh[1,2,3,4]; [1]Department of Psychology, National Taiwan University, [2]Graduate Institute of Brain and Mind Sciences, National Taiwan University, [3]Neurobiology and Cognitive Neuroscience Center, National Taiwan University, [4]Center for Artificial Intelligence and Advanced Robotics, National Taiwan University

It has been shown that exposure to blue light affects our executive functions, alertness, and circadian rhythm. Recent studies also showed that brain regions related to eye movements such as frontal eye field (Hung et al., 2017) were activated by intrinsically photosensitive retinal ganglion cells (ipRGCs), which contain photoreceptors that are especially sensitive to blue light. We used the saccadic and manual gap paradigm to investigate whether blue light affects the gap effect, a facilitated saccadic or manual response to a peripherally presented target by extinguishing the fixation shortly before the target onset. Participants were exposed to blue and orange light in two consecutive days, and they were instructed to respond to peripherally presented targets in one of four directions (left, right, up, and down) either through saccade or manual response as quickly and accurately as possible. Robust gap effects were found in both saccadic and manual response under both light exposures, and downward direction led to the slowest response. In addition, the saccade latency was significantly shorter under blue light compared to orange light; however, the manual response times were not different between the two light conditions. A significant interaction between gap/overlap condition and colors of light was found in saccade latency: saccade latency in the overlap condition under orange light was significantly longer than the one under blue light. This indicated that the larger gap effect under orange light was mainly driven by the delay in the overlap condition. Among the three explanations of the gap effect (general warning, attentional disengagement, and oculomotor systems), attentional release and oculomotor response were affected under blue light, which resulted in a smaller saccadic gap effect. This study has bridged up the connection between neuroimaging and behavioral studies, showing how blue light affects our attention and eye movements.

Acknowledgement: Taiwan's Ministry of Science and Technology, MOST 104-2410-H-002 -061 -MY3

26.361 **Minimum (motion) measurements of human color matching functions** Alex J Richardson[1](aj.richardson518@gmail.com), Kassandra R Lee[1], Eric Walowit[2], Michael A Crognale[1], Michael A Webster[1]; [1]Department of Psychology, University of Nevada, Reno, [2]Color Savvy Systems

Human color vision differs widely among individuals. This variability is problematic when trying to accurately reproduce colors across normal observers on different devices such as monitors or printers, especially with the advent of systems with more narrowband primaries. Thus there is increasing interest in measuring and correcting for the color profile of individual observers. Factors responsible for this variability are well known and include differences in lens and macular pigment density, LM cone ratios, photopigment peak sensitivities and optical density. Variability in these factors is reflected to various degrees in color matching and isoluminant settings. Color matching functions, though informative, are time-consuming, difficult to measure, and insensitive to cone ratios. In contrast, isoluminant settings are relatively easy to acquire, and are affected by LM cone spectra and ratios as well as preretinal screening, though largely insensitive to S cones. Here we model how well variations measured only in isoluminant settings – e.g. in a minimum motion task (Anstis and Cavanagh, 1983) - can recover the different sources of physiological variation and thereby predict an individuals' color matches. Only two stimulus comparisons are required to define the isoluminant plane. We show that variations in lens and macular density (among the largest sources of variance in color matching), and LM ratios tilt the plane in distinct ways, and evaluate the extent to which these tilts can be used to estimate the values for these factors. We also evaluate the number of conditions (e.g. foveal vs. peripheral) and the stimulus spectra that are best for parceling out the different functions, and then compare how well these estimates can predict simulations of complete color matching functions. Our results help guide a determination of the smallest and most practical set of measurements that may suffice to characterize an individual's color experience for reasonably accurate color reproduction.

Acknowledgement: supported by EY-10834 and P20-GM103650

26.362 **Vision in the extreme-periphery (3a): color perception is induced by foveal input** Mohammad Shehata[1,2](shehata@caltech.edu), Takashi Suegami[1,3], Yusuke Shirai[2], Daw-An Wu[1], Shigeki Nakauchi[2], Shinsuke Shimojo[1,2]; [1]California Institute of Technology, [2]Toyohashi University of Technology, [3]Yamaha Motor Corporation U.S.A.

(Shehata, M. and Suegami, T. equally contributed to this work) Peripheral vision (20-40° eccentricity) has been characterized as categorically different from foveal, in color and spatial/temporal resolution. Extreme-periphery (40° up) has been neglected, although this is subject to greatest ambiguity, thus the most heavily modulated by attention, inference, and signals from the fovea. We conducted a series of psychophysics, to test our "compensation hypothesis" which proposes that the brain compensates for the sparse, ambiguous visual input in the extreme-periphery, by utilizing inferences from sources such as unambiguous signals from the fovea. Here we examine if the color in fovea affects color perception in the extreme-periphery. Methods:In Experiment 1, each trial consisted of a sequence of three 50 ms flashes of light (500 ms SOA), two pre-target flashes at fixation, followed by a target flash at one of the 4 locations (left/right × near-/extreme-periphery). Near = 39° and far = 70-90°, set by observer's 50% threshold for flash detection. Initial flashes could be white/red/green, while target could be red/green (perceptually equalized brightness). Observers rated the target's color on a 7-point scale from Clearly Red to Clearly Green. Experiment 2 was identical, except the second flash was presented at a location halfway between the fixation and target, and SOAs were reduced to 100ms, producing apparent motion. Results:Observers reported the target's color correctly at 39°, regardless of the pre-target color. In the extreme-periphery, however, the perception of target's color was affected by the fixation's color, and vivid illusory color was sometimes perceived (e.g. green target reported as clearly red when preceding flashes were red). Such effects were enhanced in Experiment 2, where the target was bound to the other flashes by apparent motion. Ambiguous chromatic signals in the extreme-periphery may be compensated (even if erroneously) by unambiguous color input to the fovea.

Acknowledgement: Yamaha Motor Corporation U.S.A.

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26.363 **Vision in the extreme-periphery (3b): effects of eccentricity and foveal input on color perception** Yusuke Shirai[1](shirai17@vpac.cs.tut.ac.jp), Takashi Suegami[2,3], Mohammad Shehata[1,2], Shinsuke Shimojo[1,2], Shigeki Nakauchi[1]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, [2]Biology & Biological Engineering, California Institute of Technology, [3]Yamaha Motor Corporation U.S.A.

Color vision declines in the periphery (20-40˚ eccentricity) and has been thought to be less functioning. Therefore there have been relatively few studies on color vision in the extreme-periphery (>40˚). This area, however, is subject to greatest ambiguity, thus the most heavily modulated by attention and other sensory modalities. In a series of psychophysics, we tested our "compensation hypothesis" which proposes that the brain compensates for the sparse, ambiguous visual input in the extreme-periphery, by unambiguous signals from the fovea or another sensory modality. Here, we examine the effect of eccentricity and foveal color on color perception in the extreme-periphery. In Experiment1, a brief central fixation (white, 50ms) was presented twice with 450ms interval. After the interval, a target (red/green, 50ms) was presented at one of the 16 locations between 65˚ to 95˚ (on left/right). The observers named target's color (red/green/not-seen) and then reported its confidence by 5-point scale (5:very sure~1:very unsure). In Experiment2, observers performed the same task except fixation's color (red/green/white). Target was presented in the extreme-periphery (left/right) where the average confidence for the correct naming in Experiment1 met 2. Colors used in both experiments were individually adjusted so as to have perceptually-equal brightness. Fixation's and target's color, and location of the target were randomized. In Experiment1, as expected, correct naming responses (e.g., "red" to red target) decreased, and wrong naming responses (e.g., "green" to red target) increased with increasing eccentricity of target location. Surprisingly, however, confidence for the wrong naming was increased and reached to plateau at around 85˚ eccentricity. Experiment2 showed that incongruent fixation's color induced wrong naming (e.g., green fixation induced "green" response to red target) with high confidence. Thus, observers actually perceived illusory color, implying that ambiguous input in the extreme-periphery is compensated by unambiguous foveal color signal.

Acknowledgement: JSPS KAKENHI (No.18KK0280)

26.364 **McCollough world: A novel induction method for orientation-contingent color aftereffects** Katherine E.M. Tregillus[1](ktregillus@ski.org), Yanjun Li[1], Stephen A Engel[1]; [1]Department of Psychology, University of Minnesota, Twin Cities

The McCollough Effect (ME) is a well-known visual illusion characterized by long-lasting color afterimages following adaptation to two color/orientation pairings. For example, viewing a red and black vertical grating alternating with a green and black horizontal grating causes achromatic vertical and horizontal patterns to appear greenish and reddish, respectively. Though the ME can be induced with only a few minutes of exposure, adapting to gratings for longer durations is challenging. Here we propose a method that allows participants to adapt for hours, resulting in very strong, long-lasting afterimages. To create this "McCollough world," participants viewed videos through a head-mounted display (HMD) with an attached camera. Frames from the camera were filtered in the Fourier domain to limit energy to a narrowband of orientations and then were binarized. Vertical and horizontal filters were paired with red and green, and the color/orientation pairs alternated every 2 sec. The images appeared as tiger-stripe like representations of the world. Content was difficult to recognize, but illusory contours and motion allowed recognition of the gist of many scenes. Participants lived in this McCollough world for two hours. We measured the magnitude of afterimages by having observers view physically achromatic gratings and adjust the color of the whitish stripes to the opposite color, nulling the aftereffect. The nulling task was performed immediately after adaptation, again 15 minutes later, and again 1 hour after adaptation. In all 3 participants tested, aftereffects were substantially larger (mean = ~50%) than those produced by a 10 min "classic" ME induction. This was the case at all three timepoints tested. All participants also reported afterimages after removing the HMD, where vertical and horizontal edges viewed in the real world appeared colorful. Our method allows participants to adapt for many hours at a time, producing strong aftereffects amenable to study with neuroimaging.

Acknowledgement: NSF grant BCS1558308

26.365 **White Illusion: Effects of Inducer Contrast, Test-Bar Location, and Test-Bar Contrast** Bruno Breitmeyer[1](brunob@uh.edu), Richard W. Plummer[2], Ralph Hale[3], James M. Brown[2]; [1]Department of Psychology, University of Houston, [2]Department of Psychology, University of Georgia, [3]Department of Psychological Science, University of North Georgia - Gainesville Campus

In the White illusion, test bars colinear with an inducing grating's darker bars appear lighter than when the same test bars are flanked by the inducing grating's darker bars. We previously reported that the function relating illusion magnitude to the contrast of the illusion inducers changes from nearly linear to clearly nonlinear as one progresses from low-level sensory to high-level perceptual illusions. Here we investigate additionally how the White illusion depends on 1) the inducer grating's contrast (0.00 – 0.96), 2) the contrast of the test bar (0.12, 0.26) and 3) location of the test bar (colinear, flanked). Observers were required to adjust the luminance of a comparison bar until it matched the test bar's perceived lightness. We define the contrast-dependent changes of the illusion magnitude as the inducer's contrast-response function (CRF). Based on prior findings pointing to the important roles of high-level perceptual effects (e.g., grouping, surface transparency) in modulating the White effect, we expected 1) that the CRF is nonlinear for both test-bar contrasts and for both test-bar locations, and 2) that the CRF shifts toward a higher inducer contrast when the test-bar contrast increased from 0.12 to 0.26. Additionally, variation of test bar location allowed us to see if the contribution of the colinear and flanked test bars to the White illusion were equal or not. Results confirmed our predictions and support prior findings indicating that the White illusion is not produced by low-level (e.g. lateral inhibitory, simultaneous-contrast) effects but instead relies on higher-level perceptual effects, thus implicating correspondingly higher-level cortical processing. Our results also showed that the colinear test bars contributed more strongly to the White illusion than the flanked test bars did.

26.366 **Adaptation to melanopic stimulation does not affect cone-mediated flicker sensitivity** Joris Vincent[1](joris.vincent@pennmedicine.upenn.edu), Geoffrey K Aguirre[1], David H Brainard[2]; [1]Department of Neurology, Perelman School of Medicine, University of Pennsylvania, [2]Department of Psychology, School of Arts and Sciences, University of Pennsylvania

Melanopsin-containing retinal ganglion cells (ipRGCs) are known to contribute to reflexive visual functions (e.g., pupil constriction). Histological and ERG studies in rodents indicate that the ipRGCs modulate cone signals via recurrent axon collaterals, a mechanism by which melanopsin stimulation could alter visual perception. Here we test if changes in the melanopsin stimulation level of a steady background affect thresholds for detecting flicker seen only by the cones. Threshold sensitivity for 5 Hz LMS cone-directed flicker was measured on 2 pairs of adapting fields that differed only in their melanopsin stimulation or only in their LMS cone stimulation; each pair differed by a 350% isochromatic contrast step. Stimuli were generated using a digital light synthesis engine with 56 effective primaries and presented as a 27.5° diameter field, of which the central 5° was occluded. The three authors served as participants and viewed the stimuli monocularly with a pharmacologically dilated pupil. During each of four separate sessions the participant adapted to each background for 5 minutes prior to collection of 120 trials of a two-interval forced-choice paradigm. Flicker threshold expressed as differences in LMS cone excitation did not differ between the high- and low-melanopic backgrounds for any of the three participants (thresholds for the three participants on the high-melanopic background were 0.89x, 1.02x, 1.03x the thresholds on the low-melanopic background). Thresholds on the high-LMS background were higher (by 3.81x, 4.14x, 4.50x) than on the low-LMS background. The elevations in response to LMS background change serve as a positive control and are consistent with the 4.5x increase expected from Weber's law. A substantial increase in the melanopic content of a steady adaptation field does not affect sensitivity to LMS cone-directed flicker. This finding speaks against the possibility that cone sensitivity is regulated by signals arising from tonic melanopsin stimulation.

Acknowledgement: National Institutes of Health Grant R01 EY024681 (to G.K.A. and D.H.B.) Core Grant for Vision Research P30 EY001583, and Department of Defense Grant W81XWH-15-1-0447 (to G.K.A.)

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26.367 **The Potential Contribution of Melanopsin to Steady-State Electroretinogram and VEP Responses**

Michael R Tan[1,2](mtan30@uic.edu), Clemente Paz-Filgueira[1], Dingcai Cao[1]; [1]Department of Ophthalmology and Visual Sciences, University of Illinois at Chicago, Chicago, IL USA, [2]Department of Bioengineering, University of Illinois at Chicago, Chicago, IL USA

Introduction: Anatomical studies have indicated that melanopsin-expressing intrinsically photosensitive retinal ganglion cells (ipRGCs) provide feedback signals to dopaminergic amacrine cells to restructure retinal function and also directly project to the lateral geniculate nucleus (LGN). Our previous psychophysical measurements indicated that a higher background melanopsin activation level reduces cone-mediated contrast sensitivity (Tan et al. VSS 2018). To assess whether melanopsin's modulatory effect is mediated by ipRGC intraretinal signaling or ipRGC-to-LGN transmission, we measured electroretinograms (ERG) and visually evoked potentials (VEP) simultaneously. Methods: Stimuli were presented as a 30° annulus with central 10° blocked in a five-primary Maxwellian-view photostimulator, which can control rod, cone and melanopsin stimulation independently. ERG and VEP were recorded simultaneously for the sinusoidal modulations of irradiance (100% Michelson contrast, temporal frequency at 1, 8 or 16 Hz) and cone luminance (L+M+S, 26% Michelson contrast, temporal frequency at 1, 8 or 16 Hz) under two background melanopsin activation levels, with the "Mel-HIGH" condition having 33% higher melanopsin activation than the "Mel-LOW" condition. The mean luminance was 2,000 Td or 20,000 Td. Results: Consistent with psychophysical findings, the ERG and VEP amplitudes were lower with the "Mel-HIGH" condition than those with the "Mel-LOW" condition for both luminance levels. Conclusions: These results suggest that both intraretinal signaling and ipRGC-to-LGN transmission are likely to contribute to the modulatory effect on cone-mediated contrast sensitivity.

Acknowledgement: Illinois Society for the Prevention of Blindness, UIC core grant for vision research P30- EY01792 and Research to Prevent Blindness

26.368 **Differential Effects of Low-Dose Alcohol versus Acute Sleep Deprivation on Light-Evoked Pupil Response Dynamics**

Terence L. Tyson[1](terence.l.tyson@nasa.gov), Nathan H. Feick[2], Patrick F. Cravalho[2], Erin E. Flynn-Evans[1], Leland S. Stone[1]; [1]Human Systems Integration Division, NASA Ames Research Center, [2]San José State University

The pupillary light reflex (PLR) has been used as a biomarker to detect and monitor sleep and circadian disruption (McGlashan et al., 2018) and altered neural status (Hall & Chilcott, 2018). Previous studies have found changes in PLR dynamics from alcohol, but only at high blood alcohol concentrations (e.g., BAC = ~0.1%; Reichelt et al., 2003). Sleep loss was also found to perturb PLR dynamics (Goldich et al., 2010). We investigated and compared the effects of low-dose alcohol (< 0.08% BAC) and of acute sleep deprivation (24 hours) in a separate constant routine (CR) protocol. Twelve participants completed a CR acute sleep deprivation study, which included 2-5 daytime (baseline) and 7-9 nighttime pupil measurements up to 25 hours after awakening. Sixteen participants received a single low-dose alcohol (producing < 0.08% peak BAC) preceded by 3 baseline and followed by at least 5-9 post-dosing pupil measurements. Five performance metrics of the PLR dynamics were computed: latency and time constant for both constriction and dilation, and mean pupil size (MPS). Sleep study. The dilation time constant and MPS showed significant ($p < 0.01$) linear decreases as a function of time awake (mean slope +/- SEM: -0.50 +/- 0.15%Δ/hr and -0.47 +/- 0.14%Δ/hr, respectively). In addition, the constriction time constant and MPS showed significant sinusoidal modulation as a function of circadian phase (mean r2 = 0.59, $p < 0.05$). Alcohol study. None of the PLR metrics showed a significant linear trend as a function of BAC up to 0.08%. Conclusion. Although 24-hours of sleep loss and 0.08% BAC have been shown to produce similar impairment in psychomotor performance (Dawson & Reid, 1997), the PLR appears well-able to distinguish between these two scenarios, given that PLR dynamics exhibit significant changes associated with sleep loss and/or circadian misalignment, yet appears unperturbed at BACs below 0.08%.

Acknowledgement: Supported by the Force Health Protection Program of the Office of Naval Research (SAA 402925)

Visual Memory: Working memory, individual differences

Saturday, May 18, 2:45 - 6:45 pm, Pavilion

26.401 **Detrimental Effects of Effortful Physical Action on Cognitive Control in Younger and Older Adults**

Lilian Azer[1](lazer001@ucr.edu), Weizhen Xie[1], Hyung-Bum Park[1], Weiwei Zhang[1]; [1]Department of Psychology, University of California, Riverside

Physical action and cognition are often entangled as one directs their oculomotor system to events deemed important. Particularly, incorporating mental representations and processes with eye movement relies on working memory. In an attempt to understand the impact of effortful physical action on cognition that extends beyond the oculomotor system, we have previously demonstrated that increased physical load impairs cognitive control and its manifestation in visual attention and working memory (Marcus et al., 2016, VSS). Given the growing literature indicating the decline in executive functions with aging, it is thus important to further examine whether older age magnifies the detrimental effects of physical load on cognitive control. In the present study, 16 older and 16 younger adults participated in a working memory color Change Detection task under a concurrent physical load. Physical load was operationalized asdifferent levels (5% versus 30%) of the maximal voluntary contraction exerted on an isometric dynamometer by individual participants. For both groups, working memory performance was comparable between the two physical load conditions. However, working memory performance decreased from low physical load to high physical load when five irrelevant colors were presented along with the to-be-remembered colors, suggesting reduced cognitive control of access to working memory under high physical load. Moreover, this reduction was greater in older participants than younger participants. Together these results suggest that age modulates the interactions between physical and cognitive efforts.

26.402 **The association between visual working and long-term memory across normal ageing**

Giedre Cepukaityte[1,2](giedre.cepukaityte@psy.ox.ac.uk), Nahid Zokaei[1,2], Anna C. Nobre[1,2]; [1]Wellcome Centre for Integrative Neuroimaging, Oxford Centre for Human Brain Activity, Department of Psychiatry, University of Oxford, [2]Wellcome Centre for Integrative Neuroimaging, Department of Experimental Psychology, University of Oxford

The extent to which mechanisms are shared between visual working memory (WM) and long-term memory (LTM) for the same type of information is unclear. To date WM and LTM performance has been measured using highly distinct tasks. Therefore, we developed a novel delayed-report contextual spatial memory task which allows to probe the quality of remembered objects within scenes in an analogous way in both WM and LTM.We applied the task to healthy young, middle-aged, and older adults (n=60) in order to chart whether similar patterns of age-related changes occur for WM and LTM. In each trial participants viewed either one or three everyday objects embedded in a photographic scene followed by a memory delay. They were then either probed to report the location of one of the objects (WM trials) or asked to tap a centrally-presented fixation cross (learning trials) on a touchscreen. The LTM stage followed 20 minutes later and involved an analogous memory probe on stimuli from learning trials only, in addition to confidence ratings (LTM trials). We obtained various measures of memory performance, such as response times, memory accuracy and error, quantified as the Euclidian distance between the true location of the object and the response location, that could be compared across memory domains. We found that, as expected, memory errors were larger when three objects had to be remembered as compared to one object and that errors for LTM were larger than for WM. In addition, older adults performed significantly worse than both the young and middle-aged groups. However, a preliminary analysis showed that although young and middle-aged adults had a similar increment in error from WM to LTM, the increment in older adults was smaller, suggesting an altered relationship between these two memory functions in this group.

Acknowledgement: MRC (UK), Wellcome Trust, British Academy, NIHR BRC.

26.403 **What and where: The influence of attention on visual short-term memory for item and spatial location information, and the relationship to autism traits.**

Dana A Hayward[1](dana.hayward@ualberta.ca), Jelena Ristic[2]; [1]Psychology, University of Alberta, [2]Psychology, McGill University

Top-down attentional control can bias visual short-term memory (VSTM), such that "retro-cues", cues presented after a stimulus array, improve memory for cued items. Less is known, however, about whether memory for different aspects of a stimulus, such as its identity or spatial location, are also affected by top-down attention. Here we investigated the effect of top-down attention on VSTM for object type and spatial location. Further, and based on prior research suggesting a link between subthreshold autism traits and working memory impairments, we administered a questionnaire to measure autism traits. Ninety-four typical individuals varying in the number of autism traits performed a visual search task in which they were asked to detect the presence or absence of a target. To measure the top-down attention effect on VSTM, on a subset of trials, participants were probed about the target's identity (what it was) and its location (where it was). For target-present trials, we found a dissociation in VSTM for what and where memory, as participants were less accurate for what (37%) as compared to where (86%) target information. Further, VSTM performance varied with participants' number of autism-like traits, whereby those with fewer autism traits were more accurate for what probes and less accurate for where probes as compared to those with greater numbers of autism traits. Finally, we found that accuracy for the attention task correlated with VSTM for spatial location, but not item type. On the whole then, while participants were overall more accurate at remembering the spatial location of the target as compare to its identity, an individual's social competence modulated this effect. In addition, top-down attention modulated VSTM for spatial information only.

26.404 **Memory capacity meets expertise: increased capacity for abnormal images in expert radiologists** Hayden Schill[1](h-schill@ucsd.edu), Jeremy M Wolfe[2], Timothy F Brady[1]; [1]Department of Psychology, University of California, San Diego, [2]Department of Ophthalmology and Radiology, Harvard Medical School, Brigham & Women's Hospital

Memory capacity depends on prior knowledge, both in working memory and long-term memory. Furthermore, abnormal or surprising items tend to be better remembered, in large part because they attract additional attention (Friedman, 1979). Radiologists have greater long-term memory for medical images compared to novices (Evans et al., 2010), and they do not need to see a physical lesion to know that an image is abnormal: an image of the breast contralateral to the actual lesion ("contra-abnormal"), can be sufficient for radiologists to label a case as abnormal (Evans et al., 2016). We investigated whether expert radiologists (N=32) show an increased capacity in working memory for abnormal images, and to what extent an image must have a focal abnormality for such additional processing to be engaged. Stimuli were single-breast mammograms with 80 abnormal cases and 40 normal (non-cancerous) cases. Half of the abnormal images were of the breast containing a visible abnormality, and the other half were from the breast contralateral to the visible abnormality. Images were presented for 3 seconds each, followed by two questions. (1) Was the image normal or abnormal? (2) Have you seen this image before? Confidence was rated on a six-point scale. Images were either new or a repeat from 3 items or 30 items back. Detecting 3-backs indexed working memory, and detecting 30-backs indexed long-term memory. Expert radiologists have a d' of 1.6 for detecting 3-backs and a d' of 1.0 for detecting 30-backs. We found a d' of 0.2 benefit for focally abnormal images at 3-back, and d' of 0.3 at 30-back, which suggests experts have better memory for abnormal images. Overall, radiologists showed no memory benefit for the contralateral abnormal images. Interestingly, however, high expertise observers were more likely to rate these images as abnormal.

Acknowledgement: NSF BCS-1829434 to TFB

26.405 **The importance of distinguishing between subjective and objective guessing in visual working memory** Timothy F Brady[1](timbrady@ucsd.edu), Mark W Schurgin[1], John T Wixted[1]; [1]Department of Psychology, University of California, San Diego

Imagine you are shown 8 colors, and then probed on your memory. You perform poorly and subjectively feel like you are "guessing". This intuition is common and is part of the appeal of "slot" models, since it is consistent with discrete limits on how many items are represented. Is such a subjective feeling of guessing incompatible with signal detection and other resource-like accounts that propose you have information about all items? Here we show that *subjective* guessing is naturally and clearly predicted by signal detection accounts. However, subjective guessing is not the same as *objective* guessing (d'=0). We provide strong evidence against objective guessing even at the highest set sizes, including (1) a meta-analysis of previous data used to argue for slots, as well as (2) new continuous report data (N=30) with subjective confidence reports. We also show that signal detection accounts of these data (Schurgin, Wixted, & Brady, 2018) perfectly predict the phenomena of subjective guessing, since confidence in signal detection is derived from a single sample of underlying memory strength, which varies item-to-item. What does it mean to have some information about all items in working memory? Typical models and intuitions rely on the idea that each item has a single representation at any given moment (I think the item is green, but it was yellow). Signal detection models instead conceptualize memory in terms consistent with population codes (eg., Bays 2014) or a probability distribution over colors. That is, having some information about an item simply means having (probabilistically) ever-so-slightly higher activity in sensory channels related to colors that were previously seen, compared to colors that were not previously seen at a given location. Altogether, our results demonstrate how subjective guessing is predicted by signal detection models and can falsely lead to intuitions that favor slot models.

Acknowledgement: NSF CAREER BCS-1653457 to TFB

26.406 **Capacity Limits on Visual Imagination** Cristina R Ceja[1](crceja@u.northwestern.edu), Steven L Franconeri[1]; [1]Psychology Department, Northwestern University

When memorizing a static set of objects with different features (e.g., red, yellow, and blue circles), or tracking a moving set of objects with identical features (e.g., purple circles), accuracy-based capacity estimates are typically 3-4 objects (Zhang & Luck, 2008). When these tasks merge, requiring a viewer to bind different features of multiple moving objects, capacity drops to 1-2 objects (Xu & Franconeri, 2015). These tasks focus the viewer on an external display, in which object features are readily available to the viewer for access and bindings can be more readily upheld. But the visual system can also represent and transform information that is generated endogenously. Might these same patterns of success and failure occur for sets of object features generated from a viewer's own imagination, such that subjective reports of performance mirror these objective capacity measures? We showed participants sets of simple colored objects (1-4 items; either the same or different colors), followed by a blank screen, where we asked them to imagine the objects moving in a variety of ways (linear translation or rotation, as a group). They then reported the level of difficulty for each transformation (1-5 scale). Although these participants (N=30) were naïve to previously established capacity limits, their subjective reports mirrored past results. Difficulty ratings rose with increases in set size (1.1 unit increase from 1 to 4 items), and while this was true for objects of identical color (0.7 unit increase from 1 to 4 items), the rise in reported difficulty was accelerated for displays in which objects were different colors (1.5 unit increase from 1 to 4 items). We propose it is time to integrate new research themes (capacity, ensemble processing, etc) with the classic, but relatively dormant, research topic of mental imagery.

26.407 **Did I guess that? Event-related potentials reveal no differences in error-monitoring following correct responses and forced guesses in a visual working memory task.** Elizabeth M Clancy[1](clancye@uoguelph.ca), Naseem Al-Aidroos[1]; [1]Psychology Department, University of Guelph

Much has been learned about the architecture of visual working memory, and its capacity limit, by measuring and modelling the errors that participants make on visual working memory tasks. Yet, debates persist over fundamental aspects of this memory system. In the present study, we investigated whether event-related potentials (ERPs) could clarify what happens when participants make errors on these tasks, and in particular the role of guessing. Participants were asked to remember colors for a brief delay, and memory was probed by having participants report the location of a probed colour. Unbeknownst to participants, on some trials the memory probe was a novel color not from the memory array, forcing participants to guess their answer. Thus, participants' responses could be classified as correct, incorrect, or forced guesses. Response-locked ERPs on forced-guess trials revealed a negative going potential followed by a positivity with scalp topographies characteristic of the ERN and Pe error-related potentials. The same ERN and Pe were observed when participants responded correctly, suggesting no difference in error monitoring for these two trial types. Incorrect trials were associated with the same ERN, and a larger amplitude Pe; coupled with a larger amplitude P3a time-locked to the memory probe. We conclude this increased error-monitoring reflects awareness of errors due to inattentiveness, rather than failures of memory. These findings suggest that error monitoring was unrelated to task performance; the same ERN and Pe were observed when participants correctly recalled by the probed item and when recall was impossible. While this finding might seem counterintuitive from the perspective of the conventional discrete-capacity memory architecture, it is consistent with other architectures, such as the target confusability model, which posit that all response options are polled at retrieval, potentially producing equivalent response conflict on all trials even when the correct response is made.

Acknowledgement: NSERC

 See page 3 for Abstract Numbering System

26.408 **The content of visual working memory regulates the priority to access visual awareness, including bound memoranda with multiple features**
Yun Ding[1](y.ding1@uu.nl), Andre Sahakian[1], Chris L. E. Paffen[1], Marnix Naber[1], Stefan Van der Stigchel[1]; [1]Experimental Psychology, Utrecht University

Previous studies suggest that 1) pre-activating a visual representation of an item in visual working memory (VWM) prioritizes access to visual awareness for this item and that 2) VWM can contain representations of bound items instead of separate features. It is currently unclear whether VWM affects access to visual awareness at a feature level, a bound conjunction level, or both. To investigate this question, we conducted a series of experiments in which we combined a delayed match to sample task with a breaking Continuous Flash Suppression (b-CFS) task. In each trial, subjects memorized an object consisting of a disk with two halves with different colors for the later recall test and, between them, had to detect the location of a target presented under suppression. We varied the congruence in colors between the memory representation and to-be-detected target. Our results show that memory congruent objects (consisting of a conjunction of features) break CFS faster than memory incongruent objects. Interestingly, we also observed this congruence effect when we presented the memorized object in a horizontally-mirrored configuration of colors. There was no difference between breakthrough RTs when only a single feature in the target was congruent with the memory representations. Our results suggest that VWM prioritizes bound objects for access to visual awareness. We are currently investigating the reason for the similarity of RTs between the memory congruent conjunction and mirrored memory congruent conjunction conditions in additional experiments.

26.409 **Probing The Functional Relationship Between Visual Working Memory and Conflict Resolution Processes**
Melissa E Moss[1](mmoss2@uoregon.edu), Atsushi Kikumoto[1], Jena Z Kunimune[1], Ulrich Mayr[1]; [1]Psychology Department, University of Oregon

Working memory (WM) capacity and conflict resolution (CR) are often regarded as overlapping functions. By one prominent account (e.g., Engle, 2002), working memory is necessary to maintain the current task goals, which in turn provide top-down control over conflicting response tendencies. Consistent with this account, some individual differences research has indicated WM and CR are correlated. Yet, the extent to which WM and CR share common cognitive resources within individuals is unknown. To study how overcoming conflict influences the maintenance of visual WM representations and vice versa, we ran three dual-task experiments in which both CR demand and WM load were manipulated. Participants performed an auditory Stroop task ("High" or "Low" spoken in high/low pitch), during a visual change detection task. The inter-stimulus interval (ISI) between WM array and auditory Stroop onset was either 0ms (stimuli for both tasks presented simultaneously), or 500ms (auditory onset during the WM delay period). In the first experiment, both Stroop task congruency and ISI varied trial-wise. In the second experiment, congruency varied trial-wise, but ISI was manipulated across blocks (varied by block). In the third experiment, both congruency and ISI were manipulated across block. Across the three experiments, we found no significant interaction between CR demand and WM load on performance in either task. Bayes factor analyses indicate strong confidence in favor of accepting the null hypothesis that there is no relationship between CR demand and WM load. Combined with recent individual differences research indicating difficulties with identifying a robust conflict resolution factor (e.g., Unsworth, 2015), these findings suggest that the relationship between working memory functioning and conflict regulation during response selection needs to be reconsidered.

26.410 **Unconscious working memory outside the focus of attention**
Marjan Persuh[1](mpersuh@bmcc.cuny.edu), Alexander Rue[1]; [1]Department of Social Sciences, Human Services and Criminal Justice, BMCC, CUNY

According to state models, working memory consists of a limited capacity state, called the focus of attention, and the activated long term memory. It is unclear whether objects outside the focus of attention are represented consciously or unconsciously. In two experiments we asked participants to remember images of four objects or animals. A simple distraction task followed. In a free recall task, that immediately followed the distraction task, most participants were able to name three to four items. These results demonstrate that for some participants at least one item was not consciously represented. We then presented participants with color or contextual cues, associated with the remaining item. Across both experiments several participants were able to report the memorized item. These results demonstrate that the item was stored in working memory. Our results show that objects that move outside the focus of attention can be represented in working memory unconsciously.

26.411 **Does Lying Require More or Less Visual Working Memory and What Does It Mean for the Legal System?**
Christopher S Sundby[1](christopher.s.sundby@vanderbilt.edu), Geoffrey F Woodman[2]; [1]Neuroscience Program, Vanderbilt University, [2]Department of Psychology, Vanderbilt Vision Research Center, Vanderbilt University

This study uses subjects' electroencephalogram (EEG) and behavior to test an assumption underlying the Federal Rules of Evidence (FRE), the rules that determine what evidence juries hear. Although the rules are intended to promote accuracy, they are premised on untested psychological assumptions. One example of such an untested assumption is an exception to the ban against hearsay, the requirement that the person who actually observed the event must testify under oath. The Present Sense Impression admits hearsay testimony about contemporaneously viewed events based on the assumption that people cannot lie about something they are currently viewing. Here we used a behavioral paradigm and EEG recordings to assess the validity of the assumption that lying about something you are viewing is more difficult. Our measurements of brain activity suggest that individuals hold less information in visual working memory when lying compared to truth telling, possibly by dropping the truthful representation from visual working memory. However, consistent with the Present Sense Impression exception, we found that this strategy took additional time to implement. Thus, scientifically testing the assumptions that our legal system is based on can benefit both the law and the application of vision science to our lives.

Acknowledgement: This research was supported by the National Eye Institute (R01-EY019882, R01-EY025275, P30-EY08126, and T32-EY007135) and National Institute of Justice (2017-IJ-CX-0007).

Visual Memory: Contents, capacity

Saturday, May 18, 2:45 - 6:45 pm, Pavilion

26.412 **Neural evidence reveals two types of rotations in visual working memory during a mental rotation task**
Maya Ankaoua[1](mayaankaoua@mail.tau.ac.il), Roy Luria[1,2]; [1]The School of Psychological Sciences, Tel-Aviv University, [2]The Sagol School of Neuroscience, Tel-Aviv University

In many everyday situations, we perform mental rotation on different objects. While it is clear that visual working memory (VWM) participates in mental rotations, we argue that the exact role of VWM in this process is yet to be determined. One reason is that classic mental rotation tasks usually involve judging whether a stimulus is presented in its mirrored form or in its regular form. Stimuli are rotated in the page plane, or both in the page plane and mirrored. Thus, the task actually involves two different processes of rotation. We separated them by developing a unique task for each rotation type. We collected EEG data and used the Contralateral Delay Activity (CDA) as an indicator of VWM involvement. In Experiment 1 we used a task involving both rotation in the page plane (degrees-rotation) and mirror-rotation. In Experiment 2 we isolated mirror-rotation and in Experiment 3 we isolated degrees-rotation. Experiment 1 results suggested different VWM involvement according to the degrees of rotations when the item was not mirrored, while the mirror-rotation's trials were all at ceiling in terms of VWM, regardless of their rotation degree. Experiment 2 results showed an indication for VWM involvement uniquely related to mirror rotation. Experiment 3 results showed different VWM involvement that is specifically related to the degree of rotation. Our results suggest that there is a difference in VWM involvement while performing different rotation processes, even though there is just one object that is being held in VWM.

26.413 **Spatial working memory representations are resistant to an intervening stimulus and behavioral task**
Grace E. Hallenbeck[1](geh261@nyu.edu), Thomas C. Sprague[1,2], Masih Rahmati[1], Kartik K. Sreenivasan[3], Clayton E. Curtis[1,4]; [1]Psychology Department, New York University, [2]Department of Psychological and Brain Sciences, University of California, Santa Barbara, [3]Division of Science and Mathematics, New York University, Abu Dhabi, [4]Center for Neural Science, New York University

A robust working memory (WM) system requires the maintenance of past but relevant information in memory against a continuous flow of newly incoming but irrelevant information. Recent reports conflict on how WM representations encoded in visual and parietal cortex are susceptible to

Saturday PM

interference (e.g., Bettencourt & Xu, 2016; van Moorselaar et al, 2017; Lorenc et al., 2018; Rademaker et al, pp2018). Here, we test how WM representations are affected by an intervening task by leveraging the robust ability to decode spatial WM representations from retinotopically organized visual field maps in human cortex. We measured brain activity with high-speed fMRI (1.33 Hz) while participants performed a memory-guided saccade task. On 30% of trials the delay was blank. The remaining 70% were dual-task trials where participants performed a challenging motion discrimination task within a small aperture appearing at counterbalanced locations with respect to the WM target while remaining fixated. We used an inverted encoding model (Sprague & Serences, 2013) to reconstruct spatial WM representations across the delay interval in visual field maps defined in occipital, parietal, and frontal cortex. Performing the intervening task slightly reduced memory-guided saccade precision, indicating that the task was effective. In all visual field maps and with high fidelity, we could reconstruct the remembered location on trials with blank delays and in the epoch prior to the intervening stimulus on dual-task trials. However, the intervening task caused a temporary reduction in, but not loss of, reconstruction fidelity in all maps, accompanied by the ability to temporarily reconstruct the location of the intervening aperture. Therefore, WM may be distractor-resistant because it is supported by a widely-distributed network of brain areas.

Acknowledgement: NIH F32-EY028438 (TCS) NVidia Hardware Grant (TCS)

26.414 **Representing the spatiotemporal structure of visual events: Spatial and temporal frames of reference in working memory** Anna Heuer[1](anna.heuer@hu-berlin.de), Martin Rolfs[1]; [1]Department of Psychology, Humboldt-Universität zu Berlin, Germany

All natural visual events exhibit a spatiotemporal structure, but our understanding of how temporal aspects are represented lags far behind our understanding of the role of space. Here, we present data indicating that a combination of both the spatial and the temporal structure of visual events provides frames of reference for storage in working memory. In a series of experiments, participants performed a change detection task, for which they memorized colours presented sequentially at different locations and with different stimulus onset asynchronies. Each item could be uniquely identified by its spatial or temporal coordinates, but neither spatial nor temporal information was task-relevant. The key manipulation was that of retrieval context: The test array was identical to the memory array in terms of either its entire spatiotemporal structure, or only its spatial or temporal components. Removing either spatial or temporal information at retrieval impaired performance, indicating that memory relied, at least to some degree, on the spatiotemporal structure in which items were initially perceived. Overall, more weight appeared to be assigned to the spatial structure, but there were pronounced individual differences in the relative weighting of spatial and temporal information, which were fairly consistent throughout and across sessions. Conceivably, these are indicative of stable individual preferences for coding in the spatial or temporal domain. We observed no substantial differences between a randomly interleaved and a blocked variation of retrieval context, suggesting that encoding in a spatiotemporal frame of reference was not strategically adjusted to task demands. However, the inter-item spacing of spatial and temporal structures influenced the relative weighting of spatial and temporal information. Favouring the frame of reference that is more widely spaced presumably facilitates item individuation and thereby access to representations. We propose that time may serve a similar function as space in the architecture of visual working memory.

Acknowledgement: This work was supported by the Deutsche Forschungsgemeinschaft (DFG Research grant HE 8207/1-1 and RO 3579/11-1).

26.415 **A Big Data Approach to Revealing the Nature of Carryover Effects** Michelle R Kramer[1](kramerm@gwu.edu), Patrick H Cox[1], Stephen R Mitroff[1], Dwight J Kravitz[1]; [1]Department of Psychology, George Washington University

Behavior does not occur in isolation—every cognitive act is influenced by prior experiences and can influence behavior that follows. In experimental design, this manifests as a "carryover effect" (i.e., the influence that a trial has on those that follow). Carryover is challenging to study as each trial must be considered individually. Given the power limitations, most studies focus on effects derived from averaging across trials, and randomize and counterbalance trial order to avoid any systematic effect of carryover. However, this does not change the fact that each individual still experiences an effect of carryover, creating a source of noise, particularly for individual difference experiments. Here, we leverage big data to investigate the nature of carryover, showing that performance is drastically influenced by both the absolute number and relative proportion of prior trials that match or do not match the current trial type, even across an interfering task. The optimization of behavior is proportional to the binomial z-test (R2 = 0.950, p = 1.02*10-23) and is domain-general, with the same pattern found across more than one task and dimension. This precise, scale-free mechanism suggests the implicit optimization of behavior likely occurs in local circuits and involves the striatum and/or local synaptic weight changes. Furthermore, using a novel touch-and-swipe response time measure, we can disentangle the influence of trial history on pre-potent motor responses versus actual task-relevant decisions, with each component showing unique and separable effects. The motor response component is speeded with repetition of any condition regardless of whether or not it matches the current trial condition, whereas the decision component follows a linear pattern, with efficiency defined by the degree to which the accumulated evidence is consistent with the current trial condition. These results reveal the striking and systematic mechanisms by which behavior is optimized to the current context.

Acknowledgement: Army Research Office #W911NF-16-1-0274

26.416 **High-fidelity visual features form complex objects in memory** Aedan Y Li[1](aedanyue.li@mail.utoronto.ca), Keisuke Fukuda[2], Morgan D Barense[1,3]; [1]Department of Psychology, University of Toronto, [2]University of Toronto Mississauga, [3]Rotman Research Institute, Baycrest

Though neuroanatomical and computational models predict feature integration, behavioral evidence for object representations in memory have been mixed. Here, we introduce a novel "conjunction" task to simultaneously measure the fidelity of shape and color memory, building on a recently described perceptually uniform shape space (VCS space: available on the Open Science Framework at https://osf.io/d9gyf/). In a first experiment, we extend a classic object-based memory study by Luck and Vogel (1997) using our conjunction task. Memory fidelity was reduced only slightly as the number of features within an object increased. In contrast, memory fidelity was drastically reduced when the number of objects increased, regardless of the number of features within each object. These results suggest that visual representations can be both object- and feature-based, though features tend to be stored as bound objects. In a second experiment, an interference paradigm examined whether object-based memory was driven by direct integration between shape and color, or driven by indirect integration through spatial location. This second experiment found an interaction between spatial location and the type of interference on memory fidelity, suggesting that shapes and colors can be bound together as well as bound to spatial location. Across two experiments, we show that although objects rather than features are preferentially stored in memory, trial-by-trial memory can flexibly contain both object- and feature-based representations. Moreover, we establish at least two levels of integration for complex objects: direct shape and color binding as well as indirect binding through shared spatial location.

26.417 **What can half a million change detection trials tell us about visual working memory?** Roy Luria[1](royluria@tau.ac.il), Keisuke Fukuda[2], Halely Balaban[1]; [1]Psychology Departement, Tel-Aviv University, [2]Department of Psychology, University of Toronto

Visual working memory (VWM) represents the surrounding world in an active and accessible state, but its capacity is severely limited. To better understand VWM and its limits, we collected data from over 3,800 participants in the canonical change detection task. This unique population-level data-set sheds new light on classic debates regarding VWM capacity. First, individual differences in capacity were found to reflect not only differences in storage-size, but differences in the efficiency of using a similarly-limited storage, supporting the view of VWM as an active process. Second, when information load exceeds capacity limits, we found evidence that certain items are fully stored while others remain completely outside of VWM (instead of all items being represented in lower resolution), in line with the predictions of a slot-like model. Moreover, comparing performance between the first and last trials demonstrated no evidence for proactive interference as the driving factor of capacity limitations. We provide further details regarding the distribution of individual capacity, the relations between capacity and demographic variables, and the spatial prioritization of the items.

26.418 **Working memory distraction resistance depends on prioritization** Remington Mallett[1](remym@utexas.edu), Jarrod A Lewis-Peacock[1]; [1]Department of Psychology, University of Texas at Austin

Working memory is susceptible to disruption from an intervening task, yet it is unclear how this disruption is influenced by the representational state of the memories. Recent behavioral evidence suggests that distraction might differentially impact information stored in high- vs. low-priority states in working memory. For example, Makovski & Pertzov (2015) showed that high-prioritized representations receive a protective benefit, while more recently others have suggested that such representations are preferentially

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susceptible to distraction (e.g., Allen & Ueno, 2018). Here, we sought to leverage neuroimaging to bring new insight into this debate. We trained category-level pattern classifiers with fMRI data and decoded visual working memory representations during a memory delay both before and after a 5-sec distractor task. After encoding two visual stimuli, a retro-cue selected one of the items to be tested by a recognition probe at the end of the trial. Participants knew that this cue could later get reversed, thus they couldn't completely forget the uncued item, but rather should de-prioritize that item (e.g., Lewis-Peacock et al., 2012). Before distraction, classifier evidence was higher for the cued item. After the 5-sec distraction, a second retro-cue indicated whether the participant should "stay" with the cued item, or "switch" to the previously uncued item for the upcoming memory test. Classifier evidence for both memories dropped during distraction, but recovered afterwards. On switch trials, participants cleanly recovered the previously unprioritized memory, with classifier evidence for the now-relevant category showing separation from the irrelevant category. However, when participants attempted to recover a prioritized memory on stay trials, both the prioritized item and the unprioritized item reemerged, with no separation between classifier evidence for the relevant and irrelevant categories. These preliminary (N=9) results suggest that the neural representation of a high-priority visual working memory is preferentially susceptible to interference from a secondary task.

Acknowledgement: R01 EY028746 (JLP)

26.419 **Flexible reprioritization of information in visual working memory** Paige Pytel[1](ppytel2015@fau.edu), Edward F Ester[1]; [1]Department of Psychology, Florida Atlantic University

Working memory (WM) performance can be facilitated by an informative cue presented during storage. This effect – termed a retrocue benefit – is contingent on the reliability of the cue, with larger retrocue benefits observed for highly reliable cues (e.g., 80%) relative to less reliable cues (e.g., 50%). In principle, these differences could reflect cue-driven changes in the strength of a cued memory representation, changes in the strengths of uncued memory representations, or a mixture of both. Here we report two experiments designed to test these possibilities. We recorded EEG while participants performed variants of a retrospectively cued spatial WM task. On each trial, participants were asked to remember the spatial positions of two discs over a short delay. On critical trials a retrospective cue indicated which of the two discs was most likely to be probed at the end of the trial, and across blocks we varied the reliability of the retrospective cue between 50%, 75% and 100%. Next, we reconstructed and quantified time-resolved representations of the cued and uncued disc locations by applying an inverted encoding model to patterns of induced alpha band (8-12 Hz) activity measured over occipitoparietal electrode sites during WM storage. This allowed us to examine whether changes in retrocue benefits with cue validity are better explained by changes in the strength of the cued memory representation, changes in the strength of the uncued memory representation, or both. In both experiments, reconstructed representations of the cued disc were unaffected by retrocue reliability, while reconstructed representations of the uncued disc were reliably stronger when retrospective cues were less reliable. Our findings suggest that changing the reliability of a retrospective cue influences memory performance primarily by modulating the strength of uncued memory representations.

26.420 **Relational Interactions between Visual Memory Representations Increase with Maintenance Duration** Paul S Scotti[1](scotti.5@osu.edu), Yoolim Hong[1], Andrew B Leber[1], Julie D Golomb[1]; [1]Psychology Department, The Ohio State University

Visual working memory representations interact with each other during maintenance. For instance, it has been repeatedly demonstrated that memory reports may be repulsed by (biased away from) a competing memory item nearby in feature space (Bae & Luck, 2017; Golomb 2015). Repulsion effects are thought to emerge because two similarly represented memory items may be more easily remembered via a mechanism that distinguishes the representations away from each other. However, a number of questions remain regarding the dynamics of these relational interactions. Here we asked: Are relational interactions rapidly computed during encoding and/or early maintenance and remain static, or do competing memory items continuously interact throughout maintenance until retrieval? In two experiments, participants studied the colors of two, simultaneously presented, real-world objects for one second. The colors of the two objects were randomly sampled either 45° or 90° apart in color space. After a delay of one second (Expt 1) or three seconds (Expt 2), participants were shown one memory item in grayscale at the center of the screen and asked to select the original color on a color wheel. Our reasoning was that, if relational interactions emerge due to continuous competition during maintenance, then a longer delay between study and test phases should increase repulsion effects. Alternatively, if similar repulsion effects are observed regardless of delay duration, this could suggest memory items are not continuously interacting during maintenance. Using probabilistic mixture modeling, we observed subtle yet robust repulsion effects in Expt 2, with color reports for the tested memory item biased away from the color of the untested memory item. Importantly, this effect was seen for a delay of three seconds but not for a delay of one second. These findings offer preliminary evidence that memory representations are sustained by dynamic interactions, continuously competing with each other during maintenance.

Acknowledgement: NIH R01-EY025648 (JG), Alfred P. Sloan (JG), NSF BCS-1632296 (AL)

26.421 **Clustering based on multiple features in visual working memory** Gaeun Son[1](sohngaeun@gmail.com), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

When a group of single-feature stimuli is stored in visual working memory (VWM), stimuli with similar features form clusters. Based on this result, the present study investigated how stimuli with multiple features form clusters in VWM. In two experiments, participants remembered the orientations of five colored isosceles triangles and then estimated the orientation of a triangle cued to be recalled. Cluster structures of these triangles were independently manipulated on the color and orientation dimensions. Specifically, we made two clusters on the orientation dimension by forming a large cluster of four similar orientations and leaving dissimilar one alone as a single-item cluster. The triangles' colors also formed two clusters (of four similar colors and a single dissimilar color) but made different junctions with the orientation-based clusters. In a congruent-junction condition, the color-based clusters corresponded to the orientation-based clusters such that four similar orientations had similar colors. In an incongruent-junction condition, however, one item from the large color cluster formed the single-item cluster on the orientation dimension while one item from the large orientation cluster formed the single-item cluster on the color dimension. We found that regardless of junction conditions, representations of the triangles formed clusters based on the orientation dimension, indexed by comparable orientation bias patterns between the two conditions. This indicated clustering of multi-feature stimuli based on a task-relevant feature dimension. However, in the incongruent-junction condition, the orientation of the single-item orientation cluster was falsely recalled as the orientations of the large color cluster whose colors were similar to its color. These swapping errors occurred more frequently when colors became more relevant to the task, by designating to-be-recalled item using colors (Experiment 2). These results suggest that stimuli with multiple features form clusters mostly based on a task-relevant feature dimension, but that an irrelevant dimension can interfere with the clustering.

Acknowledgement: This research was supported by the Brain Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (NRF-2017M3C7A1029658).

26.422 **Working memory resources can be efficiently deallocated from items that become obsolete** Robert Taylor[1](taylor.rt17@gmail.com), Paul M Bays[1]; [1]Department of Psychology, University of Cambridge

Visual working memory (VWM) is a limited resource that places constraints on how precisely encoded information can be recalled. The immense processing demands placed on VWM imply that information can quickly become outdated, thereby requiring updating mechanisms that ensure the contents of memory remain relevant to current task goals. Successful deallocation of resources from items that become obsolete is likely to be critical for maintaining the precision of those representations still in memory. Our experimental paradigm involved presenting two memory arrays of colored disks in sequence. The presentation of the second array was a cue to replace either one, or all, of the items from the first array previously encoded into memory. When compared to a condition that was matched in the total number of items presented, we predicted that successful updating would result in fewer actively maintained items, owing to the removal of pre-replacement features. Comparison of precision estimates between these two conditions should therefore provide a test of successful updating. A direct comparison between precision estimates was made difficult by a very small proportion of trials (~4%) on which participants incorrectly reported a pre-replacement feature, which we interpret as a failure to incorporate the information from the second display into memory. Once these trials were removed from analysis, precision estimates were consistent with deallocation of resources from pre-replacement features. We conclude that working memory can be efficiently updated when previous information becomes obsolete, but that this is a demanding active process that occasionally fails.

Acknowledgement: Wellcome Trust

26.423 **Evidence for the world as an external memory: A trade-off between internal and external visual memory storage** Stefan Van der Stigchel[1](s.vanderstigchel@uu.nl), Martijn Schut[1], Rosyl Somai[1]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University

Contrary to the experience of a complete representation of our surroundings, representations of our visual surroundings are limited and constrained by the capacity limits of visual working memory (VWM). However, as long as visual information is readily available in the external visual world, there is no need for a complete internal representation of the outside world, as the world can act as an external memory source. Previous studies have therefore proposed a trade-off between storing information in VWM and making saccades. Here we directly tested this trade-off by using a copying task in which participants were instructed to remember, and copy a model consisting of an arrangement of many elements. If there is an adaptive trade-off between using the external visual world and VWM, the trade-off should be influenced by increasing the cost associated with using external information. We therefore increased the cost of a saccade by increasing the amount of time between saccade offset and external availability of visual information. Results show that participants made numerous eye movements between the workspace, model and blocks, often making one saccade per action performed. Increasing saccade costs resulted in more saccades towards the model and an increased dwell time on the model, suggesting a shift from making eye movements towards taxing internal VWM. Our study provides strong behavioral evidence for a trade-off between using the external world as a memory buffer, versus building complex internal representations. Prior research has shown that VWM and eye movements are directly linked and our results provide evidence that that the link between executing eye-movements and building an internal representation of our world is based on an adaptive mechanism governed by cost-efficiency. Lastly, these results indicate that the default mode of executing many eye-movements is more cost-efficient than storing information in memory.

Spatial Vision: Models

Saturday, May 18, 2:45 - 6:45 pm, Pavilion

26.424 **The spatiotemporal dynamic of attention in normal reading** Augustin Achouline[1](augustin.achouline@umontreal.ca); [1]Psychologie, Université de Montréal

Past decades have seen multiplicate many studies examining the cognitive and neurobiological aspects of reading. However, the strategy underlying expert word identification and the way visuospatial attention is deployed across time and space is still unknown. The study from Blais and al. (2009) represent a significant advance in the knowledge of these process. This article pursues their investigation by using a protocol able to precise how visual words information extraction process across time on neurotypicals readers. 16 students were tested using « Bubble » technique. They read five letters french words sampled in space-time within a 200 ms windows on a computer's screen. First, a signal/noise ratio modulation phase of 150 words was executed to maintain 51% of accuracy. Then, 4 blocs of 150 words each were completed followed by another 75 words modulation bloc. Finally, a block of 150 words was proposed. Data analyses examine how the temporally varying signal/noise ratio determine the response accuracy of participants. Classification images in the temporal domain were constructed for average and each individual by subtracting the weighted sum of the temporal profiles of signal/noise ratios of incorrect trials from those associated with the correct answer. We also constructed classification images in the time-frequency domain which indicate the magnitude of particular frequencies as a function of time. All these classification images were transformed into Z scores to put the images of all participants on the same scale. Statistical significance was determined by the application of the Pixel test. Results tend to reveal a serial processing of letter extraction information in which the order of letter is a function of the diagnostic value of that letter for word identification. These observations are opposed to the parallel processing that is generally accepted as an interpretation of the invariance of latency in expert word reading.

Acknowledgement: Martin Arguin

26.425 **Spatial memory biases reflect encoding precision and not categorical perception** Thomas A Langlois[1](thomas.langlois@berkeley.edu), Nori Jacoby[2], Jordan W Suchow[3], Thomas L Griffiths[1]; [1]Princeton University, [2]Max Planck Institute for Empirical Aesthetics, [3]University of California at Berkeley

The visual memory system encodes information selectively due to limited resources, resulting in systematic distortions and biases. Decades of previous work explains these biases in terms of categorical effects, whereby spatial memory is pulled towards perceptual attractors. Instead, we show that these biases can be accounted for by a rational process that retrieves information from representations with variable precision. Using a novel paradigm based on transmission chains, we explore these representations with an unprecedented degree of resolution. We show that internal memory representations are biased towards "semantic corners," located near the boundaries between semantically meaningful regions within images. We show that these focal points are both diagnostic of image identity and associated with increased discrimination acuity. Our approach allows us to elucidate the nature of internal memory representations, providing a lens for understanding visual memory systems by revealing the latent internal geometry of their perceptual representations.

26.426 **Sensitivity to global form in the presence of noise is stimuli dependent** Mahesh Raj Joshi[1](Mahesh.Joshi@plymouth.ac.uk), Anita J Simmers[2], Seong T Jeon[2]; [1]Eye and Vision Sciences Research Group, School of Health Professions, University of Plymouth, [2]Vision Sciences, School of Health and Life Sciences, Glasgow Caledonian University

Glass patterns composed of varying elements or line segments have been employed previously to investigate global form processing. However, whether or not these different stimuli target similar local or global mechanisms is not known. A total of 5 visually normal participants discriminated the orientation of Glass patterns composed of different component elements (2 elements, dipole; 3 elements, tripole; 4 elements, tetrapole) and line segments (Line2 and Line 4 equivalent to dipole and tetrapole) in the presence of various noise levels. At no noise, the thresholds for Line4 ($\alpha L4 = 1.52° \pm 0.42°$) were the lowest followed by tetrapole ($\alpha qd = 1.65° \pm 1.30°$), tripole ($\alpha ti = 2.24° \pm 1.06°$), dipole ($\alpha di = 3.68° \pm 1.31°$) and Line2 ($\alpha L2 = 3.48° \pm 1.36°$). The thresholds for all stimuli were similar towards higher noise ($\alpha L4 = 18.18° \pm 10.37°$, $\alpha qd = 20.17° \pm 12.79°$, $\alpha ti = 22.37° \pm 16.17°$, $\alpha L2 = 22.89° \pm 12.26°$, $\alpha di = 19.99° \pm 9.89°$ at external noise of 45°). The nested models used to differentiate the performance in terms of local (internal noise) vs. global (sampling efficiency) parameters showed that the model with a difference in internal noise best described the performance between different Glass patterns ($p > 0.1$) and dipole Glass pattern vs. line segments ($p > 0.1$). Our findings suggest that the processing of line segments and Glass patterns with more than two elements may be more influenced by local processing mechanisms than global processing.

26.427 **Lateral modulation of orientation discrimination of center-surround sinusoidal stimuli in peripheral vision** Yih-Shiuan Lin[1](yihshiuan.lin@gmail.com), Chien-Chung Chen[2,3], Mark W. Greenlee[1]; [1]Institute of Psychology, University of Regensburg, Regensburg, Germany, [2]Department of Psychology, National Taiwan University, Taipei, Taiwan, [3]Neurobiology and Cognitive Science Center, National Taiwan University, Taipei, Taiwan

Mounting evidence shows that the center-surround modulation is subject to a normalization process influenced by the surround contrast and orientation. We investigated such orientation specific surround modulation by measuring the adaptation effect of different surrounds on target orientation discrimination. The sinusoidal adaptor consisted of two parts: a central patch and a surround annulus, with orientations assigned independently from one of the five levels between 90° (vertical) and 180° (horizontal), yielding 25 different orientation combinations. The target was a Gabor the same size as the central patch, with orientation ranging from 82° (clockwise tilt, CW) to 98° (counter-clockwise tilt from vertical, CCW). In a two-alternative forced-choice task, observers were asked to judge the orientation of the target (i.e. tilted CW or CCW from vertical) after adaptation to either the annulus or the central patch. We estimated the target thresholds for CW and CCW directions independently using two adaptive staircases. We presented stimuli in the upper right visual field 10° from the central fixation point. Results showed that when the center adapting orientation was at 101.25° CCW threshold was the highest while CW threshold was the lowest. CCW threshold first decreased then increased with adapting surround orientation. The opposite was true for CW threshold: discrimination threshold first increased than

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decreased with surround orientation. The maxima and minima of these threshold curves were close to when the center and surround were of the same orientation. Our results suggest an orientation-selective lateral modulation is involved, in which the surround inhibited the adaptation effect (release from suppression) for CCW stimuli, while enhancing the adaptation effect for CW stimuli. The results can be explained by a version of divisive inhibition model, in which the response of the target mechanisms are their linear excitations divided by a normalization signal plus a constant and modulated by the adaptor.

26.428 **The Alignment of Systemic Low Frequency Oscillations with V1 Retinotopic Organization** Ezgi I Yucel[1,2,3](yucel@uw.edu), Noah C Benson[4], Yunjie Tong[5], Blaise Frederick[6,7], Ione Fine[1,2], Ariel Rokem[2,3]; [1]Department of Psychology, University of Washington, Seattle, WA, [2]UW Institute of Neuroengineering, Seattle, WA, [3]The University of Washington eScience Institute, Seattle, WA, [4] Department of Psychology, New York University, New York, NY, [5]Weldon School of Biomedical Engineering, Purdue University, West Lafayette, IN, [6]McLean Hospital Brain Imaging Center, Belmont, MA, [7]Department of Psychiatry, Harvard Medical School, Boston, MA

It is now well established that the BOLD signal contains systemic low frequency fluctuations (sLFOs, below 0.2 Hz) that are due to global blood-borne signals propagating through the vasculature (Tong et al., 2013). These sLFO signals are particularly noticeable in primary sensorimotor, auditory and visual networks due to their high blood capillary density and/or vascular density (Harrison et al., 2002). Our goal was to examine the effect of these sLFOs on estimated population receptive field (pRF) maps within early visual areas. We used standard techniques (Dumoulin and Wandell, 2008) to estimate pRFs (the Gaussian in visual space that best predicts each voxel's time course) for 8 participants from the Human Connectome Project 7T Retinotopy dataset (using minimally processed 2mm-32k retinotopy data; the stimuli were moving bars, rotating wedges, contracting/expanding rings) both before and after removing estimated sLFOs. SLFOs were estimated by selecting highly vascularized regions as initial seeds for a recursive procedure that tracks the evolution of sFLO-driven time-lagged correlations through the brain (rapidtide, Frederick 2016). We found that shared time-course variances due to sLFOs were stronger across regions of the cortex that shared the same eccentricity. This may be the result of sLFO's following the vasculature that symmetrically stems from the posterior cerebral artery (Tong and Frederick, 2014), and thereby aligns with eccentric organization. Thus, vascular architecture may explain previous results showing strong correlations between voxels that share the same eccentricity (Butt, Benson, Datta, & Aguirre, 2015; Bao and Tjan, 2009; Arcaro et al. 2015). Fortunately, because local correlations are preserved, removing sLFOs does not change the position of estimated pRFs.

Acknowledgement: Washington Research Foundation National Eye Institute and Office of Director, Office of Behavioral and Social Sciences Research

26.429 **A divisive model of midget and parasol ganglion cells explains the contrast sensitivity function** Heiko H Schütt[1,2,3](heiko.schuett@nyu.edu), Felix A Wichmann[1]; [1]Neural Information Processing Group, University of Tübingen, [2]Center for Neuroscience, New York University, [3]Zuckerman Institute, Columbia University

A long standing proposition in psychophysics is that there are two temporal channels in spatial vision: One temporal lowpass filter which is spatially bandpass and one temporal bandpass filter which is spatially lowpass. Here we equate these two channels with the midget and parasol ganglion cells of the primate retina respectively. Parasol cells show a frequency doubling response at high spatial frequencies, i.e. they respond to both polarities of high spatial frequency gratings. This is usually thought to result from them pooling over smaller units. If true, this explanation predicts that signals with both high spatial and high temporal frequency should be detectable, but their spatial orientation and phase should not be perceivable, i.e. parasol cells act not as labelled lines in this scenario. We confirm this prediction by finding a difference between detection and orientation discrimination thresholds at high spatial and temporal frequency, not observed at other spatial-temporal frequency combinations. We model midget and parasol cells using a standard divisive model dividing a generalized Gaussian center by a larger surround. When scaling cells proportional to their known separation in the retina, we can make predictions for the perception performance of human observers assuming optimal decoding after a single quadratic non-linearity. To confirm the predictions of our model we measured contrast sensitivity functions (CSFs) under diverse conditions and fit data from the literature. Our model fits the CSF under different temporal conditions and changes in size with fixed spatial parameters and can thus replace previous CSF models which require new parameters for each condition and have no mechanistic interpretation. Finally, our model provides a counter hypothesis to the textbook explanation for the CSF which describes it as the envelope of the spatial frequency tuned channels in V1; instead, we believe its shape to result from properties of retinal cells.

26.430 **Probing blur adaptation with reverse correlation** Keith A May[1](keith.may@essex.ac.uk), William H McIlhagga[2]; [1]Department of Psychology, University of Essex, UK, [2]Bradford School of Optometry and Vision Sciences, University of Bradford, UK

Prolonged viewing of blurred or sharpened images makes subsequently viewed images look more sharp or blurred, respectively. A possible mechanism is provided by scale-space models of edge detection, which filter the image with Gaussian derivative operators of different scale (i.e. size), and detect edges by finding responses that are peaks across both space and filter scale. The position of the peak across space indicates edge location, and the position of the peak across filter scale indicates edge blur. To create the peak across filter scale (σ), the output of each filter is multiplied by σ^γ. γ is conventionally chosen so that the peak occurs in a filter matched in scale to the edge blur. If γ deviates from this default value, then the peak across scale occurs in a filter whose scale is a constant multiple of the edge blur (either larger or smaller). This provides a potential mechanism for blur adaptation: prolonged viewing of blurred or sharpened images could cause the value of γ to be adjusted, causing the peak across scale to occur in a filter with scale larger or smaller than the true edge blur, thereby leading to biases in perceived blur. We estimated the scale of the filter mediating blur discrimination using a task in which participants see two noisy edges and have to say which is the most blurred. By correlating the observer's responses with the noise samples, we obtain a classification image, a linear approximation of the filter used to do the task. Participants adapted to a blurred or sharpened square wave grating, with Fourier components of frequency f multiplied by 1/f (for blurred gratings) or f (for sharpened gratings). Surprisingly, the classification images were unaffected by blur adaptation. This suggests that the mechanism for blur adaptation is located downstream of low-level blur analysis.

26.431 **Effects of Target Amplitude Uncertainty, Background Contrast Uncertainty, and Prior Probability Are Predicted by the Normalized Template-Matching Observer** Can Oluk[1,2](cnoluk@gmail.com), Wilson S Geisler[1,2]; [1]Center for Perceptual Systems, University of Texas at Austin, Austin, TX, USA, [2]Department of Psychology, University of Texas at Austin, Austin, TX, USA

When detecting targets under natural conditions, the visual system almost always faces multiple, simultaneous, dimensions of extrinsic uncertainty. Each dimension of uncertainty (i.e., each dimension of random variation in background and target properties) has individual effects on behavioral performance. Measuring how these individual effects combine is essential for understanding the normal functioning of the visual system. Furthermore, an important real-world factor that interacts with uncertainty is target prior probability. Our aim is to measure and model the combined effects of the various dimensions of uncertainty, together with the effect of target prior probability. Here, we consider a simple task: detection of a horizontal windowed sinewave target with random amplitude in Gaussian white noise with random contrast, for target prior probabilities of 0.5 and 0.2.We examined these two dimensions of uncertainty first, because exact expressions for model performance can be derived.On each trial, the amplitude of the target and the contrast of the noise were randomly and independently sampled from uniform distributions having eight discrete levels that covered a broad range (i.e., each trial was a random sample from 64 conditions).Participants were asked to report whether the target is present or absent. We derived the performance of the ideal observer (IO), which has a dynamic decision criterion, a template-matching (TM) observer with a single criterion, and a contrast normalized template-matching (NTM) observer with a single criterion. Interestingly maximum-likelihood fits showed that human accuracy as a function of target amplitude and background contrast were well predicted by all three models, when the target prior was 0.5, but that only the IO and NTM observers were able to predict accuracy when the prior was 0.2.The results reveal the value contrast normalization under real-world conditions where target priors are low, and the value of manipulating target priors for discriminating models.

Acknowledgement: NIH grant EY024662

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26.432 **Using dynamic contrast estimation to assess interocular summation for non-rivalrous stimuli** Kimberly Meier[1](kimmeier@uw.edu), Kristina Kristina Tarczy-Hornoch[2], Ione Fine[1], Geoffrey M Boynton[1]; [1]Department of Psychology, University of Washington, [2]Department of Ophthalmology, Seattle Children's Hospital

Purpose:Interocular summation has been measured using a wide variety of stimuli, measurements, and models. Our goal was to develop an intuitive and robust measure of interocular summation that reflects naturalistic (non-rivalrous) conditions and provides a direct measure of the perceptual experience of the observer.Methods:Observers fixated a Gabor (2 cpd; 4 deg radius, orientation rotating at 1 deg/sec to minimize adaptation effects) through a stereoscope. Gabor contrast was slowly modulated at 1/8 Hz in one eye, and 1/6 Hz in the other. Subjects dynamically reported perceived contrast over time by manipulating a Thrustmaster Pro joystick. In a separate task, we quantified each observer's interocular contrast ratio by asking subjects to estimate the apparent phase of 100% contrast Gabor stimuli that were phase-offset across the two eyes (Kwon et al. 2014).Results:Using dynamic contrast estimation, with less than an hour of data per subject it was possible to estimate individual contrast response functions for each eye, and robustly fit a model of binocular summation. Data were well fit by a very simple model of binocular summation: R = (KL*CLn + KR*CRn)(1/n), where CL and CR are the stimulus contrast response functions and KL and KR are gain parameters for left (L) and right (R) eyes. Exponential parameters n show that binocular summation varied across individuals, ranging from approximately quadratic summation to a max rule. The interocular contrast ratio was estimated from best fitting model parameters as KL/KR. Interocular contrast ratios from dynamic model fits were closely correlated with those measured using the phase-offset technique.Conclusions: Our dynamic perceived contrast task provides an intuitive, rapid and robust method for assessing the binocular visual system that is likely to be useful in characterizing binocular dysfunction across a wide variety of disorders, including amblyopia and strabismus.

Visual Memory: Models, mechanisms

Saturday, May 18, 2:45 - 6:45 pm, Pavilion

26.433 **Hierarchical Bayesian Modeling for Testing Representational Shift in Visual Working Memory** Hyung-Bum Park[1](hpark053@ucr.edu), Weiwei Zhang[1]; [1]Department of Psychology, University of California, Riverside

The recent visual working memory (VWM) research assessing the quality of retained mnemonic representations independently from the probability of remembering has primarily focused on the variance of internal representations. However, overall memory quality (i.e., the consistency in correspondence between internal representations and stimuli) could also manifest as the accuracy of mnemonic representation. The present study has thus assessed representational shifts, manifested as changes in the third parameter μ in Zhang and Luck mixture model of VWM representing the central tendency of noisy mnemonic representations, due to various experimental manipulations (e.g. attraction/repulsion between memory items, changes in inter-item context, representational momentum, etc.). Although experimental effects on representation shifts in these experiments are central for some hypotheses testing (e.g., serial versus parallel VWM consolidations), the numerical values of these shifts tend to be small. To adequately capture these effects against various sources of noise, we have developed a hierarchical Bayesian modeling (HBM) method simultaneously accounting for multiple sources of variance in recall error and reaction time. Formal model comparison is also implemented to test competing models generated from different theoretical features. The resulting posterior distributions of group-level parameters in HBM provide some strong evidence for representational shifts in these experiments. The advantages of HBM over some conventional methods will be further discussed.

26.434 **Neural resource model explains visual working memory performance in whole-report tasks** Sebastian Schneegans[1](ss2361@cam.ac.uk), Paul M Bays[1]; [1]Department of Psycholgy, University of Cambridge

Neural population models have successfully accounted for human visual working memory performance in a variety of cued recall tasks. These models assume that recall errors are caused by decoding from noisy population activity, and explain limits in memory capacity through normalization of total spiking activity across memory items. We apply this type of model to a new experimental paradigm, the analog whole report task, in which subjects must sequentially reproduce the remembered features of all items from a sample array, in an order either freely chosen or determined randomly. To explain recall performance in this setting, we incorporate two mechanisms into the model that have previously been used in different contexts. First, we propose that the total number of spikes contributing to the memory of each item is used as a measure of confidence in the decoded feature value, and that this determines the order of reports if it is freely chosen. Second, we assume that memorized feature values undergo random drift over extended delays, causing additional impairments in memory quality for the later reported items. We obtained close quantitative fits to response distributions for two different experimental conditions across five different set sizes and up to six different ordinal response positions, using only three free parameters. In particular, the model accounts for the continuous decrease of recall precision across ordinal response positions observed when report order is chosen by the subject. This aspect of the data has previously been interpreted as evidence for a fixed item limit in working memory. In this view, subjects can memorize only a subset of items at higher set sizes, and report those items first while producing pure guesses in their later responses. Our results demonstrate that a model based on continuous memory resources can explain the data without incorporating a fixed item limit.

Acknowledgement: Wellcome Trust

26.435 **I will never forget you: Direct forgetting and the 3-state model of visual working memory.** Samantha N Spitler[1](sspitl1@lsu.edu), Melissa R Beck[1]; [1]Psychology, Louisiana State University

The 3-state model of visual working memory (VWM) proposes three states of memory: Focus of attention (FA), direct access region (DAR), and activated LTM (aLTM), with the FA and DAR representing VWM and aLTM representing a relatively active portion of LTM. Previous research has found the item in the FA to be the most accessible, followed by the item in the DAR, and then task relevant items in aLTM are passively maintained. The goals of the present study were (1) to look for evidence for the 3-state model, and (2) to examine how information is forgotten from VWM and aLTM by using a directed forgetting paradigm. In previous research, the directed forgetting paradigm resulted in a directed forgetting benefit – memory for remember items is significantly better when item(s) are directed to be forgotten. Within the 3-state model, it could be that information is dropped completely from all three states resulting in a directed forgetting benefit across all states. Using eye tracking and gaze-contingent trials, participants were presented six faces on each trial in sequential order. On cue-to-forget trials, after viewing all faces in a trial, an arrow pointed at one face for 500 ms and following a visual mask, participants were shown one face and asked, "Did this face change?" All cue trials were valid and participants were never tested on a cued-to-forget face. The present experiment found support for the 3-state model of VWM, but did not find a directed forgetting benefit for any of the states. This experiment suggests that a directed forgetting benefit is not found with complex stimuli and that the 3-state model of VWM can be robust against directed forgetting.

26.436 **Simultaneous Retrospective Prioritization of Multiple Working Memory Representations** Ashley DiPuma[1](adipuma2014@fau.edu), Kelly Rivera[1], Edward Ester[1]; [1]Department of Psychology, College of Science, Florida Atlantic University

Working memory (WM) has a limited representational capacity, and mechanisms of selective attention are needed to prioritize content in WM for behavioral output. Attentional prioritization in WM can be studied using retrospective cues. For example, memory performance can be facilitated by an informative cue presented during the delay period of a WM task. This effect – termed a retro-cue benefit – occurs frequently when participants are cued to prioritize a single WM representation, but it is unclear whether retro-cue benefits can also extend to multiple memory representations. Here, we report results from six experiments (N = 292) designed to test this possibility. In each experiment, participants were asked to remember displays containing four simple objects (oriented "clock-face" stimuli or colored squares) and later cued to prioritize zero, one, or two of these items. Participants then adjusted a probe to match one of the original memory items (i.e., continuous report) or were required to select the identity of a probed item from a set of discrete options (i.e., forced choice). In each experiment, we quantified how frequently participants reported items that were neither cued-nor-probed, items that were cued-but-unprobed, or items that were cued-and-probed. Unsurprisingly, participants reported cued-and-probed items with the greatest frequency in all conditions. However, during the critical cue-two condition, participants reported the cued-but-unprobed item more frequently than either of the uncued-and-unprobed items, suggesting that the cued-but-unprobed item was afforded a greater level of attentional priority. Based on these results, we conclude that participants

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can retrospectively prioritize multiple WM representations, but that doing so leads to increased competition between cued memory representations and an increase in "swap" errors.

26.437 **The asymmetric mixed-category advantage in visual working memory: a domain-general, not domain-specific account** Nurit Gronau[1](nuritgro@openu.ac.il), Rotem Avital-Cohen[1]; [1]The Open University of Israel

The mixed-category advantage in visual working memory refers to improved memory for an image in a display that includes four images taken from two different categories relative to the same number of images taken from a single category (Cohen et al., 2014). Jiang et al. (2016) found that this advantage characterizes mainly faces and suggested that it is a category-specific effect, due to within-category interference related to the visual characteristics of faces (e.g., their shared spatial configuration). Faces, however, possess evolutionary and social significance that may bias attention toward them, potentially reducing the overall processing resources directed toward their counterpart category in a mixed display. Consequently, any category paired with faces may suffer from little/no mixed-category advantage, or even an inversed effect (i.e., a disadvantage when appearing in a mixed-category, relative to a single-category display). Here, using a change-detection task, we showed that a category (highways) that demonstrated a mixed-category disadvantage when paired with faces, demonstrated a mixed-category advantage when paired with a different, non-facial category (clocks). Furthermore, manipulating the relative significance of a category in mixed-category display trials (by increasing/decreasing the probability of a memory test on that category) altered the category's advantaged/disadvantaged status, suggesting that attention may play an important role in the mixed-category effect. Taken together, the asymmetric mixed-category pattern appears to rely on an attentional bias, rather than on a fixed, category-dependent mechanism. These results suggest that domain-general, not domain-specific factors underlie the asymmetric pattern of the mixed-category advantage in working memory.

Acknowledgement: This research was funded by the Israel Science Foundation (ISF) #1622/15 to NG.

26.438 **Visual working memory representations during a change detection task persist in long-term memory** Praveen K Kenderla[1](praveenk@bu.edu), Melissa M Kibbe[1,2]; [1]Department of Psychology and Brain Sciences, Boston University, [2]Center for Systems Neuroscience, Boston University

Visual working memory holds task-relevant visual information for very brief intervals. Yet, previous work also has shown that subjects can store in long-term memory details of items presented briefly only once. Here, we examined whether visual working memory representations of simple displays during a change detection task persist in long-term memory. In two experiments, subjects performed a standard color change detection task. Interspersed between blocks of 6-10 change detection trials were set recall trials, in which subjects were shown a set of colored squares and were asked to report whether they had seen the set before. Half of set recall trials showed a set previously seen within the first four trials of the change detection block, while the other half showed new arrays. In Experiment 1 (Set Size 3; n=50), subjects performed near ceiling on change detection trials (91.83% correct), and also performed significantly above chance on set recall trials (59.17% correct; $t(49)=6.6$; $p< 0.001$; BF(10)=680,927.3), suggesting they maintained long-term representations of arrays presented during change detection trials, even across multiple intervening and perceptually similar change detection trials. In ongoing Experiment 2 (n=23), we increased set size to 5 and found that subjects were again successful on both change detection (78.07% correct) and the critical set recall trials (56.39% correct; $t(22)=2.44$; $p=0.014$; BF(10)=3.47). Change detection accuracy differed significantly between Experiments 1 and 2 ($p< 0.001$), but there was no difference in set recall performance across the two experiments ($p=0.59$). Regardless of set size, accuracy on change detection trials predicted performance on set recall trials, with a .73% increase in set recall accuracy for every 1% increase in change detection accuracy. Together, these results suggest that, representations of the content and configuration of sets of simple, single-feature items persist in long-term memory even after these representations are no longer task-relevant.

26.439 **Spatial working memory and visual working memory share common storage resources** Zeyu Li[1](zeyulee@163.com), Zhi Li[2]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University, [2]Department of Psychology and Behavioral Sciences, Zhejiang University

There is solid evidence that visual processing can be separated into two main pathways, one for object identification and recognition, and the other for processing the object's spatial location. However, it is still on debate whether, in working memory, object identity information and spatial information are stored separately. In the present study, we conducted two experiments using the dual-memory-task paradigm to examine this issue. Previous dual-task studies on the same topic often used the change detection task as the memory test, which only measures memory capacity. To distinguish potential interference in memory capacity and in memory precision, in the present study, we developed a spatial working memory task using the mixture modeling method (Zhang & Luck, 2008), which probes both memory capacity and memory precision. This spatial working memory task was combined with two visual working memory tasks that were also based on the mixture modeling technique in a dual-task paradigm. Experiment 1 investigated the interference between remembered locations and colors. Experiment 2 investigated the interference between remembered locations and orientations. The results showed that, in both experiments, memory capacity of spatial working memory and of visual working memory were substantially reduced in the dual-task condition as compared to that in the single-task condition. In contrast, the precision of the two memories was not affected by the single-task/dual-task manipulation in Experiment 1, whereas it was impaired in the dual-task condition as compared to in the single-task condition in Experiment 2. The present findings suggest that the spatial working memory and visual working memory may not be stored independently. Instead, the two memory systems may share common storage resources.

26.440 **Visual Working Memory Directly Alters Perception** Chunyue Teng[1](cyteng@gwmail.gwu.edu), Dwight J Kravitz[1]; [1]George Washington University

The ability to maintain and manipulate information in visual working memory (VWM) underlies critical high-level behaviors from directing attention to making complex decisions, but its direct impact on perception remains unclear. The sensory recruitment model (e.g. D'Esposito & Postle, 2015) posits that VWM content is maintained in posterior visual areas, supported by recent fMRI decoding evidence of VWM content in those areas. The current study hypothesized that if VWM maintenance and perceptual processing recruit overlapping neuronal resources in sensory areas, then: 1) interference between perception and VWM should be bidirectional and 2) the degree of interference should be predictable from the tuning properties of sensory areas. To test these predictions, we quantified color and orientation discrimination thresholds while participants maintained a color or orientation in mind. The maintained item attracted the representations of the discrimination stimuli towards itself proportional to its similarity to them in orientation or color space. When the maintained item was between the two discrimination stimuli it drew both towards itself equally, leading to increased thresholds. When it was positioned to either side of the discrimination stimuli it drew the near stimulus towards itself more strongly, leading to decreased thresholds. Critically, this effect was only present when the maintained item and the discrimination stimuli matched (maintaining and discriminating orientation vs. maintaining color and discriminating orientation) even in physically identical trials. Moreover, the discrimination stimuli created bias in VWM representation, demonstrating bidirectionality. Thus, maintaining VWM information in sensory areas causes what you see and what you are holding in mind to be intertwined at the most fundamental stages of processing. More generally, these results open up a new domain in which to directly compare different top-down and bottom-up cognitive processes that have been shown to influence low-level perception, such as visual imagery, VWM, attention, and perceptual priming.

26.441 **Retroactive interference demonstrates a flexible relationship between dual-task demands and the temporal dynamics of visual working memory consolidation** Brandon J Carlos[1](bcarlosavg@gmail.com), Benjamin J Tamber-Rosenau[1]; [1]University of Houston

The temporal dynamics of visual working memory (VWM) consolidation are the subject of conflicting results, with masking paradigms suggesting rapid consolidation but the attentional blink suggesting that consolidation may take hundreds of milliseconds. Nieuwenstein and Wyble (JEP:General, 2014) showed retroactive interference by a speeded 2-alternative forced-choice parity judgment during the VWM delay on VWM consolidation (VWM

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sample: 4 letters). This effect lasted even longer than the AB—up to at least 1 second. This result presents another conflicting finding on the time course of VWM consolidation, and also contradicts the typical dual-task finding of proactive interference by VWM consolidation on a subsequent task. Here, we sought to establish the boundary conditions of retroactive interference on VWM consolidation in 3 experiments. After closely replicating the retroactive interference effects on VWM consolidation (Experiment 1), we demonstrated that response demands do not explain the results by shifting from whole-report to change-detection paradigms (Experiment 2). Specifically, when participants completed randomly intermixed single- and dual-task trials, we observed a significant interaction between delay duration and the presence of a second task, exactly as in whole-report. We hypothesized that obtaining retroactive interference instead of proactive interference might be driven by the relative prioritization of the speeded parity judgment over the unspeeded VWM task. Thus, Experiment 3 decreased parity judgment priority by making the responses unspeeded. This change in task prioritization abolished the interaction between delay duration and the presence of a second task, consistent with our hypothesis. In the future, we will use direct manipulations of task priority (differential allocation of points and inter-trial delays to parity or VWM performance) as a stronger test of our account.

26.442 **Unambiguous evidence in favor of a signal detection model of visual working memory** Mark W Schurgin[1](maschurgin@gmail.com), John T Wixted[1], Timothy F Brady[1]; [1]Department of Psychology, University of California, San Diego

It has recently been shown that a signal detection model taking into account psychophysical scaling can account for nearly all aspects of visual working memory performance (Schurgin, Wixted & Brady, 2018). A critical prediction of signal detection theory is that when memory is weak, people should frequently 'false alarm', sometimes with high confidence. For example, if you are expecting an important call and are therefore carefully monitoring your phone, you might sometimes falsely feel it vibrate, as neural noise in the relevant sensory channel can exceed your threshold for detection. Similarly in memory, looking for weak signals at test (e.g., set size 6) should result in high-confidence false alarms, even to test colors that are categorically distinct from what was encoded. By contrast, if false alarms arise from random guessing, such high-confidence false alarms should not occur, as guessing should be accompanied by low confidence, not high confidence. Across two prominent working memory tasks, we find clear evidence in favor of signal detection. In a change detection task (N=90), we find that participants have a non-trivial number of high-confidence false alarms (and ROCs are curvilinear; see also Wilken & Ma, 2004). In addition, in continuous report tasks (N=30), we also observe high-confidence false alarms, even when accounting for swap errors (e.g., 10% of continuous report errors >90° at the highest confidence level). These results provide strong support for a theory of working memory where noise -- and discerning signal in the presence of noise -- is the limitation on performance, rather than a limit on the number of items that can be represented. Furthermore, we show strong links between change detection and continuous report, arguing that rather than quantifying separate psychological states ("guessing" and "precision"), responses in both tasks are the result of the same underlying signal detection-based process.

Acknowledgement: NSF CAREER BCS-1653457 to TFB

26.443 **Attraction and Response Probe Similarity Effects in a Multiple Ensemble Judgment Task** Cindy Xiong[1](cxiong@u.northwestern.edu), Cristina R Ceja[1], Casimir Ludwig[2], Steven Franconeri[1]; [1]Psychology Department, Northwestern University, [2]School of Experimental Psychology, University of Bristol

Our visual system effectively extracts ensemble statistics to make sense of distributed visual information (Alvarez, 2011; Whitney, Haberman, & Sweeny, 2014). Existing explorations have focused on single ensembles, and have used probes varying in degree of similarity to the stimuli, e.g., using mouse clicks to determine centroids (Whitaker, McGraw, Pacey & Barrett, 1996), drawing lines to determine line lengths (Chong & Treisman, 2003) or rotating Gabor patches to determine perceived orientations (Choo, Levinthal & Franconeri, 2014). In the real world, however, ensembles rarely exist in isolation, and the style of response probe may also influence extraction. We emulated how people extract ensemble statistics in a realistic situation (visually communicated data) from among multiple ensembles, using different response probes. Participants viewed either one or two randomly fluctuating lines around different means and were pre-cued to attend to one line. They estimated the average vertical position of the cued line, either moving a horizontal line (probe similar to stimulus) or an asterisk (probe dissimilar to stimulus). Using a mixture model, we observed a 10% systematic underestimation of line position when using a horizontal line as a probe, meaning participants consistently perceived lines to be vertically lower than their actual positions (N=12, p< 0.001). Furthermore, in situations where two lines were presented simultaneously, the target position estimate was biased towards the non-target line (p< 0.001), suggesting an attraction effect during ensemble extraction among multiple ensembles. Interestingly, this underestimation effect diminished (p< 0.01) when participants used the asterisk as probe instead to estimate the position (N=12, p=0.63), while the attraction effect persists. The present study provides surprising implications for potentially probe-dependent results of ensemble extraction tasks, suggesting a dependence of ensemble estimation on attraction effects and an interference between perceived stimuli and response probe.

26.444 **I won't forget that: Partial forgetting in visual working memory is not due to binding errors.** Katherine C Moen[1](kmoen1@lsu.edu), Melissa R Beck[1]; [1]Psychology, Louisiana State University

It is still unknown if and when cues to forget information in visual working memory (VWM) will lead to complete loss versus partial loss of information. Furthermore, instances of partial forgetting of to-be-forgotten (TBF) stimuli may be due to poor object-location binding or to loss of object details. The goal of the current study was to determine if partial forgetting occurs in VWM even when object-location binding errors are ruled out, and if memory detail (encoding time) and stability (cue onset) impact explicit and implicit memory for to-be forgotten information. Participants encoded four real-world objects for 1,200ms or 2,000ms (encoding time) followed by a fixation cross for 50ms or 250ms (cue onset) before a cue appeared, indicating the to-be-remembered (TBR) side of the display. Three types of changes occurred: (1) a new stimulus replaced a TBR stimulus (new change), (2) the TBR stimuli changed locations (location change), or (3) a stimulus from the TBF side of the display replaced a TBR stimulus (TBF change). Replicating previous research, participants had higher accuracy for TBR information on cue trials relative to no cue trials, suggesting that some forgetting occurred. However, participants had significantly lower accuracy on TBF change trials relative to new change trials, indicating that participants were not completely forgetting the TBF information. Additionally, location change accuracy was equivalent to new change accuracy, suggesting that partial forgetting of TBF items was not due to object-location binding errors. This partial loss of TBF information occurred similarly for both encoding times and cue onsets. Furthermore, eye movement data revealed implicit memory for TBR information when participants encoded stimuli for 2,000ms. Overall, these results suggest that forgetting in VWM does not lead to complete loss of TBF information.

26.445 **Neural evidence for a dissociation between the pointer system and the representations of visual working memory** Halely Balaban[1,2](halelyba@mail.tau.ac.il), Trafton Drew[3], Roy Luria[1,2]; [1]Sagol School of Neuroscience, Tel Aviv University, [2]The School of Psychological Sciences, Tel Aviv University, [3]Psychology Department, University of Utah

Our goal was to show that visual working memory (VWM) representations are distinct from the pointer system that supports them. The pointer system is a stable mapping between an item in the environment and its VWM-representation, which allows VWM to track and access the appropriate representation. Accordingly, when this mapping is invalidated, VWM resets by discarding the original representations and creating new representations and pointers. This happens, for example, when a uniform object separates into halves, because a single pointer cannot support the two independent objects following the separation. Similar object-separation results in updating the original representation (without resetting) when there are two pointers to begin with, e.g., when each half can be individuated based on distinct colors. We used a shape change-detection paradigm, where each shape-half had a different task-irrelevant color. The items moved during the memory array, which was task-irrelevant but allowed us to manipulate grouping or ungrouping. In the critical condition, two shape-halves first moved separately, then met and moved together, but then re-separated. The neural marker of VWM (the contralateral delay activity) indicated that two pointers were allocated and maintained throughout the trial, because the separation was not followed by a resetting process. Conversely, the movement caused VWM-representations to transform from separate to grouped (following the joint movement) to ungrouped (following the re-separation). This dissociates the number of representations, which changed from two to one and back to two, from the number of active pointers, which remained two throughout the trial. We argue that one pointer is allocated to one object, but several distinct objects along with their pointers can be grouped into a single VWM-repre-

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sentation. The grouping can be undone, by accessing the still-valid independent pointers. This dissociates VWM-representations and their supporting pointers, thus revealing an important characteristic of our cognitive system.

Eye Movements: Saccades

Saturday, May 18, 2:45 - 6:45 pm, Pavilion

26.446 **Rapid and robust online saccade detection** Richard Schweitzer[1,2,3](richard.schweitzer@hu-berlin.de), Martin Rolfs[1,2]; [1]Department of Psychology, Humboldt-Universität zu Berlin, Germany, [2]Bernstein Center for Computational Neuroscience Berlin, Germany, [3]Berlin School of Mind and Brain, Humboldt-Universität zu Berlin, Germany

Research on active vision heavily relies on gaze-contingent stimulus manipulations triggered by the onset of a saccade. Rapid online saccade detection is particularly essential when investigating trans-saccadic perception. Most paradigms, however, use either spatial-boundary techniques or absolute velocity thresholds. The former is reliable but slow; the latter is faster but unreliable, especially at higher sampling rates or noise levels. Here we present a velocity-based algorithm for online saccade detection (inspired by Engbert and Kliegl's widely used algorithm for microsaccade detection), that outperforms traditional techniques in speed and accuracy while allowing for the flexible adjustment of detection criteria. Saccades are detected using two-dimensional velocity thresholds estimated based on the variance of preceding fixation data, compensating for noisy or dropped samples by smoothing and interpolation. An optional direction criterion limits detection to predefined saccade directions, increasing robustness against false alarms from fixational eye movements and blinks. We validated the algorithm using datasets of >34,000 recorded saccades. Saccades were detected online as early as 3 ms after their onset (ground truth detected offline) with false alarm rates of < 1%. Even when corrupting the data by adding Gaussian noise (SD up to 0.1 degrees of visual angle) and randomly removing up to 30% of all samples, high accuracy was preserved while detection latency increased by 10 ms at most. Finally, we developed a perceptual test to verify the algorithm's usefulness for gaze-contingent, intra-saccadic presentations. Using a projection system operating at 1440 Hz, we displayed a Gabor patch drifting at saccadic peak velocities for 14 ms. While this stimulus was invisible under fixation, it was reliably detected when presented upon online saccade detection. Using a photodiode, we confirmed that stimuli were physically shown 20 ms after saccade onset (average, including all system latencies). Thus, our algorithm provides a useful tool for investigating trans-saccadic perception.

Acknowledgement: Studienstiftung des deutschen Volkes and Berlin School of Mind and Brain (RS) and Deutsche Forschungsgemeinschaft DFG (grants RO3579/2-1, RO3579/8-1, RO3579/10-1) (MR)

26.447 **Competition of salience and informational value in saccadic adaptation** Alexander C Schütz[1](alexander.schuetz@staff.uni-marburg.de), Ilja Wagner[1], Christian Wolf[1,2]; [1]Experimental & Biological Psychology, University of Marburg, [2]General Psychology, Westfaelische Wilhelms-Universität Münster

Humans maintain saccade accuracy through an adaptive learning mechanism, called saccadic adaptation. Classically, this mechanism is studied using a single perceptually irrelevant target. Recent work demonstrated that saccadic adaptation does also occur in response to a perceptual task (Schütz, Kerzel, & Souto, 2014) and in paradigms with multiple stimuli (Madelain, Harwood, Herman, & Wallman, 2010). Furthermore, adaptation to a non-salient target can be disturbed by a salient distractor (Khan, McFadden, Harwood, & Wallman, 2014). Here, we test the hypothesis that saccadic adaptation is not only influenced by stimulus saliency, but also by the informational value of two competing task-relevant targets. Our participants had to judge the orientation of two Gabor patches. At trial beginning, both patches were overlaid and appeared at a horizontal eccentricity of 12.5°. During the saccade, they were vertically displaced by ± 2° in opposite directions. The salient Gabor had low spatial-frequency and high contrast, such that it was highly visible in the periphery. The informative Gabor had high spatial-frequency and low contrast, such that it was poorly visible in the periphery and therefore yielding high information gain by a saccade. We found that with a perceptual task, in which participants had to report their judgments on both Gabors sequentially, saccadic adaptation was directed towards the Gabor they had to report on first. Here, the adaptation profiles differed between the salient and the informative Gabor. With a perceptual task, in which both stimuli were reported simultaneously, however, saccadic adaptation was directed towards the informative Gabor, albeit with a small gain. These findings demonstrate that saccadic adaptation can occur even when there is competition between several task-relevant targets after the saccade. Direction and magnitude of adaptation can be determined by the targets' relative informative value or by temporal priority imposed by task demands.

Acknowledgement: This project was supported by SFB/TRR 135 and IRTG 1901.

26.448 **Saccadic adaptation driven by attentional selection in visual working memory** Ilja Wagner[1](ilja.wagner@uni-marburg.de), Christian Wolf[2], Alexander C. Schütz[1]; [1]Experimental & Biological Psychology, University of Marburg (Germany), [2]General Psychology, Westfaelische Wilhelms-Universität Münster (Germany)

Saccadic adaptation is an adaptive learning mechanism used to ensure saccade accuracy. Previous research demonstrated that saccadic adaptation is driven by post-saccadic errors, which are most effective directly after saccade offset (Shafer, Noto, & Fuchs, 2000). Here, we test the hypothesis that error signals driving saccadic adaptation can also be evaluated in visual working memory – long after saccade offset. Participants were instructed to execute a saccade and judge the orientation of one out of two appearing Gabor patches. Before the saccade, only a perceptually-irrelevant saccade target was displayed at a horizontal eccentricity of 10°. At saccade onset, two Gabor patches appeared for 150 ms near the saccade target, vertically displaced from each other by 4°. Two seconds after the Gabors' offset, an auditory cue signaled which Gabor had to be judged subsequently. Which Gabor was cued varied randomly across trials. One and a half seconds after the auditory cue, a reference Gabor appeared in-between the locations of the previously presented Gabors and participants had to judge if the orientation of the reference and the cued Gabor matched. Vertical saccade amplitudes showed robust trial-to-trial changes in the direction of the previously cued Gabor. The magnitude of adaptation was comparable to a control experiment, in which only a single, task-relevant Gabor was shown at random locations directly after saccade onset. Our findings demonstrate that error signals can be evaluated in visual working memory, long after the offset of visual targets and the saccade. Either errors are calculated directly after the saccade, and selected subsequently in memory, or competing target locations are stored in memory and errors are computed on the memorized locations. Both cases might be accomplished by orienting attention in visual working memory (Griffin & Nobre, 2003).

Acknowledgement: This project was funded by the SFB/TRR 135 and the International Research Training Group, IRTG 1901,

26.449 **Alternating Between Stimulus-Driven and Minimally-Delayed Prosaccades: Switch-Costs Manifest via Response Suppression** Benjamin Tari[1](btari@uwo.ca), Mohammed Fadel[1], Matthew Heath[1]; [1]School of Kinesiology, University of Western Ontario, London, ON, Canada

A salient feature of executive function is the ability to rapidly alternate between tasks to allow online reconfiguration of attentional and motor goals.Notably, task-switching efficiency is asymmetrically dependent on the demands of the trial preceding a switch.For example, a prosaccade preceded by an antisaccade (i.e., task-switch trial) results in longer reaction times (RT) than when a prosaccade is preceded by its same task counterpart (i.e., task-repeat trial).In contrast, RTs for antisaccade task-repeat and task-switch trials do not reliably differ.The unidirectional prosaccade switch-cost has been attributed to the inertial activation of an executive-mediated non-standard task-set.It is, however, unclear whether the task-set inertia derives from the antisaccade requirements of inhibiting a pre-potent response (i.e., response suppression) or the decoupling of stimulus-response spatial relations (i.e., vector inversion).To address this issue, we arranged stimulus-driven (SD: i.e., saccade at target onset) and minimally delayed (MD: i.e., saccade at target offset) prosaccades in an AABB paradigm.MD prosaccades were employed because they provide the same response suppression as antisaccades without the need for vector inversion.Results showed that RT for SD task-switch trials were longer – and more variable – than their task-repeat counterparts, whereas values for MD task-repeat and task-switch trials did not reliably differ.Moreover, SD task-repeat and task-switch movement times and amplitudes did not vary and thus demonstrates that the aforementioned switch-cost was unrelated to a speed-accuracy trade-off.Accordingly, our results suggest that response suppression engenders the persistent activation of a non-standard task-set that proactively – and selectively – delays the planning of a subsequent stimulus-driven prosaccade.

Acknowledgement: NSERC

Saturday PM

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26.450 Online perturbations of illusory size and actual size affect saccades with the same time course

Zhongting Chen[1](z-tchen@psy.ecnu.edu.cn), Pin Yang[1], Jing Chen[2]; [1]East China Normal University, [2]Shanghai University of Sport

Abundant evidence has shown that saccades are affected by size illusions like the Müller-Lyer illusion, but the magnitude vary widely. Researchers have tested multiple factors (e.g. task, response delay, saccades latency, presentation time etc.) and consistently found that the magnitude of the illusion effect on saccades mainly relies the time of visual processing before saccades are initialized. However, these studies all asked subjects to initialize their saccades after the presentation of the illusion, allowing a potential planning for the saccades. Studies in visuomotor control have shown that online control is less influenced by illusion than planned movements are. This is possibly the cases in oculomotor control as well. To test this possibility, the current study investigated the Müller-Lyer illusion effect on saccade using delayed perturbation. On each trial, a line section with small fins were presented first and subjects were required to saccade from one vertex to the other as soon as the signal was given. On half of the trials, the orientations of the fins were reversed after the saccade signal was given and the delay from the presentation of saccade signal to the perturbation varied from 50ms to 150ms. Throughout this manipulation, the time gap from perturbation to the start of saccade varied relatively widely across the trials of the delayed perturbation condition. We observed that the illusion perturbation started to affect saccades when the gap was about 100ms and reached to the peak when the gap was about 200-250ms (the peak illusion effect of the delayed perturbation was compatible to ones observed in the unperturbed conditions). Moreover, illusion perturbation was compared with actual size perturbation in another experiment. Same time course of the perturbation effect were observed for both types of perturbation, indicating that illusory size information requires no further visual processing to the oculomotor system.

Acknowledgement: National Natural Science Foundation of China (NO. 31800949)

26.451 Dynamic interplay of position- and velocity signals during interceptive saccades in monkeys and humans

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Despite internal processing delays monkeys and humans perform accurate interceptive saccades toward moving targets. This is possible through an estimate of the target position at saccade end through the combination of position and velocity information. We investigated interceptive saccades of two macaque monkeys and 4 human subjects in response to step-ramps of eight different relative angular directions between their step and ramp components. The directions differed by 45° covering the whole 360° direction space. A target appeared at an eccentric location, then a step to the center occurred and the target immediately moved at 10°/s in one of the eight directions. In addition we presented static targets for each direction with matched saccadic amplitudes. Despite different average saccade latencies (humans: 150 ms; monkeys 120 ms) monkeys and humans showed highly similar oculomotor behavior. The accuracy of initial saccades depended on the direction difference between steps and ramps. Initial saccades to orthogonal step-ramps reflected the stimulus movement quite accurately. Saccades to co-directional step-ramps appeared to lag ~1° behind the stimulus, while saccades to opposite-directional step-ramps were ahead by ~1°, probably due to general saccadic undershoot. We found - in agreement with Guan et al. (EBR, 2005) - that initial saccades towards moving targets differed in their main sequence dependent on the relative directions of step and ramp. For co-directional step-ramps the peak saccade velocity was significantly lower, than for step-ramps pointing in opposite directions. The saccade velocities for orthogonal step-ramps were in-between the two. This result is in line with findings in monkeys that neuronal activity in a subcortical saccade control area - the superior colliculus - does not fully account for the amplitudes of interceptive saccades. As a next step, we will investigate the contribution of the parietal eye field – monkey area LIP - to accurate interceptive saccades.

Acknowledgement: Deutsche Forschungsgemeinschaft CRC/TRR-135 A1

26.452 From Gaussian Blobs to Natural Scenes: Comparable results for saccade-pursuit interactions across stimuli of different complexity

Alexander Goettker[1](Alexander.Goettker@psychol.uni-giessen.de), Ioannis Agtzidis[2], Doris I Braun[1], Michael Dorr[2], Karl R Gegenfurtner[1]; [1]Justus-Liebig University Giessen, [2]Technical University of Munich

Saccadic and smooth pursuit eye movements are used to bring objects onto our foveae and to keep them there. Both have been intensively studied, but mainly in isolation and with highly controlled stimuli. Our goal was to compare eye movements to reduced stimuli and natural videos. We investigated how the relative angle between sequential saccade and pursuit eye movements affects saccadic position error and pursuit gain. We calculated both measurements in different experiments with varying levels of experimental control and stimulus complexity. We used a large set of natural videos, the GazeCom dataset, for which we additionally hand-labeled pursuit targets to extract their trajectories. In experiment 1, we presented these trajectories with an isolated Gaussian blob, lacking any context information. In experiment 2, moving objects followed the same trajectories in natural scenes extracted from the videos. In both experiments an initial fixation cross was presented at a fixed distance to the start of the movement. It was collinear with the direction of the movement or shifted by 30° up- or downwards. In experiment 3 participants just watched the whole set of natural videos without any constraints and we extracted saccade-pursuit combinations comparable to experiment 1 and 2. For all experiments we found a ~10 % reduction in saccadic position error and a ~10% increase in pursuit gain for collinear saccade-pursuit combinations. While the benefit for pursuit eye movements could possibly be explained by simple muscular constraints, like the inertia of the eye, the benefit for saccades indicates a direct influence of the upcoming pursuit on the saccadic eye movement. Despite some small absolute differences in the magnitude of some measurements like the saccade position error (~1 deg with isolated blobs vs. ~1.5 deg in natural videos), we observed comparable results for highly-controlled lab stimuli and free viewing of natural scenes.

Acknowledgement: DFG TRR 135 IRTG 1901

26.453 The Spatiotemporal Influences of Bottom-up Input on double-step Saccade Planning

Shane Kelly[1](skelly18@masonlive.gmu.edu), Matt S Peterson[1], Wilsaan M Joiner[2]; [1]George Mason University, [2]University of California, Davis

An entire body of vision research has investigated the effects on perception when target stimuli and backgrounds have perceptually similar luminance levels (isoluminance). This literature reports that luminance contrast is specifically carried by oculomotor pathways responsible for stimulus-driven involuntary saccades (magnocellular pathway in particular; Leonard and Luck 2011). The current study investigates how this perceptual mechanism manifests itself in relation to the spatial and temporal properties of saccade planning. By keeping saccade target stimuli isoluminant with the background, we can experimentally remove a significant portion of stimulus-driven, bottom-up information and isolate the goal-directed, top-down signals used for updating the saccade motor plan. Here, we examined the amount of time required to change the initial saccade trajectory to a new target location for several spatial separations (20o, 40o, and 60o) when the stimuli were isoluminant or had luminance contrast with the background. We found across separations and stimuli luminance contrast, saccades that were directed between the two targets occurred when approximately 90 to 150 ms was available to readjust the movement plan. However, the window in which these “intermediate” saccades occurred was narrowed with both increasing target separation and importantly, when using stimuli with a luminance contrast. Suggesting that the removal of stimulus-driven signals in the magnocellular pathway slows the oculomotor system’s ability to update saccade plans.

26.454 Pre-saccadic enhancement and suppression as continuous shifts in spatial information weighting

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Right before the onset of a saccade, a local increase in sensitivity at the intended target location (pre-saccadic attention shift) co-occurs with a reduction in visual sensitivity across the visual field (saccadic suppression). Previous studies investigated these mechanisms separately, using perceptual probes briefly flashed before saccade onset. We hypothesized that both, pre-saccadic attention and suppression, are the result of a shift in the

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attentional landscape towards the target. Assuming that stimulus information is sampled continuously, this shift should be accompanied by changes in the weighting of individual samples at any given location when these have to be integrated over time. Participants judged the mean orientation of two streams of Gabor patches presented at two locations in the visual field (eccentricity: 10.5 dva; spatial frequencies: 0.2-2.5 cpd). After stimulus onset, participants were cued to execute a saccade to one of the two locations. Upon saccade detection, all stimuli were removed from the screen. The orientation of each Gabor changed every 25 ms, drawn independently from Gaussian distributions (M = ±3° away from a reference line; SD = 5°), such that the distance and direction of deviation (clockwise/counterclockwise) from the reference line varied from sample to sample. We used a reverse correlation approach to assess the weighting of individual orientations across time and if these predicted the response at each stimulus location. At saccade targets, we found an increased weighting of orientations starting ~75ms before saccade onset. This increase was most pronounced for high-spatial-frequency stimuli. At non-target locations, stimulus information was down-weighted within the same interval. These shifts in weighting were accompanied by higher accuracy at target locations. These results suggest that just before the onset of saccades, changes in the attentional landscape affect how information is weighted and influence behavioral performance accordingly.

Acknowledgement: Einstein Center for Neurosciences Berlin (FG), Deutsche Forschungsgemeinschaft DFG (grants RO3579/8-1, RO3579/10-1) (MR)

26.455 **Effects of saccades and contrast steps on visual sensitivity** Zhetuo Zhao[1](zzhaoaa@gmail.com), Giorgio Merli[2], Michele Rucci[1]; [1]Department of Brain & Cognitive Sciences, University of Rochester, [2]Department of Biomedical and Neuromotor Sciences, University of Bologna

The primary function of saccades is to sequentially orient the high-acuity fovea toward informative locations in the scene. This process also yields luminance transients on the retina, which are commonly substituted in the laboratory by an abrupt onset of the stimulus (a contrast or luminance step) while the subject maintains fixation.However, these two types of transients differ considerably, as the retinal image follows stereotypical velocity and acceleration profiles during saccades. To investigate the functional relevance of this difference, we compared contrast sensitivity in the two conditions in which the same stimulus was brought into the fovea by a 6.75 deg saccade and by a contrast step during fixation. We measured contrast thresholds in N=9 emmetropic observers when exposed for 100 ms to gratings at 1, 4, and 8 cycles/degrees. While individual variability existed, on average across observers the saccades selectively enhanced the mid-range of frequency: contrast sensitivity was significantly higher at 4 cpd following a saccade than in the step condition (p< 0.01; Wilcoxon), whereas no differences were observed at the other two spatial frequencies. The resulting shape of the contrast sensitivity function was significantly more band-pass following saccades than following a contrast transient at fixation (sensitivity ratio 4/1 cpd: 1.37 saccades; 0.89 fixation; p< 0.02; Wilcoxon). These results are consistent with the responses of a model of transients V1 complex cells that were exposed to reconstructions of the retinal stimulations experienced by subjects in the two conditions. In the model, the average responses of arrays of cells with receptive fields at different phases and locations were multiplied by a biphasic gain function to model saccadic suppression and enhancement. These results suggest important visual contributions from the specific dynamics of saccade transients and caution against equating these modulations to stimulus steps in laboratory experiments.

Acknowledgement: NIH EY18363, NSF 1457238, 1420212 and EU grant H2020-MSCA-734227 – PLATYPUS

26.456 **Mental Model Updating and Eye Movement Metrics** Hanbin Go[1](h2go@uwaterloo.ca), Britt Anderson[1], James Danckert[1]; [1]Psychology, University of Waterloo

We investigated whether mental model updating can be inferred from eye movement metrics. Prior studies (O'Reilly et al., 2013) suggest that an unexpected or "surprising" event facilitates the updating of one's mental model. To probe this further we designed a saccadic planning task to capture individuals' mental model updating, while recording saccadic reaction time and dwell time. Saccadic reaction time was decomposed into latency and movement components. Participants learned distributions of target dots presented on a perimeter of an (invisible) circle. We periodically introduced unannounced changes to the distribution of target dots, which participants had to infer from trial history. For each distribution we computed how the eye movement metrics differed between high and low probability events. Saccadic latency and saccadic duration were faster for high probability events, however there was no difference in dwell time for the two probability outcomes. When presented with a new distribution, there was no difference in the saccadic duration, but there was an increase in saccadic latency and dwell time. These results suggest that, having learned a distribution, individuals plan for high probability events, and spend more time looking at targets that are surprising (i.e., unexpected low probability occurrences). Our results provide additional evidence in support of eye movement metrics for inferring when mental models have been learned and are being updated.

26.457 **Visual processing of symbology in head-fixed large Field-of-View displays** Frank L Kooi[1](frank.kooi@tno.nl), Alexander Toet[1], Sofie Hoving[1]; [1]AEOLUS Human Performance Innovation Center, TNO

Background. A Head Mounted Display (HMD) is unlike all other displays fixed to the head, making eye movements the sole option to scan the display. While the largest saccades easily exceed 50 deg (Collewijn et al., 1988), naturally occurring saccades typically stay within 15 degrees (Adler & Stark, 1975). While attractive for many applications, a HMD also forms a liability: large-FoV HMDs are known to cause eye-strain (Kooi, 1997) and the rate of information uptake is expected to decrease towards the edges. Methods. We measured the ability of 12 subjects to quickly determine the orientation (T vs ⊥) of a target T surrounded by 4 randomly oriented (up, down, left, right) flanker T's as a function of 1) target-flanker spacing or 'crowding' (small / medium/large), 2) flanker polarity, and 3) eccentricity (15/30/45 deg). The one-hour test was repeated in reverse order after a 15 min break. Visual comfort was assessed with questionnaires. Results. Reaction time increased with crowding, symbol eccentricity, and decreased with opposite target-flanker polarity (all p values < 0.001). Contrary to our expectations, reaction time decreased after the break, suggesting saccadic motility improves over time (Parsons & Ivry, 2018). Eye strain showed a small increase with eccentricity (p < 0.037). Conclusions. These results confirm that ocular motility appears to be trainable. The dynamics of HMD information uptake resembles Fitts' law. Practical implications. Initial training reduces eye strain. Combined with the ocular motility data from the references, a 30 deg Field-of-View is a compromise between maximal overall symbology uptake and minimal eye strain.

Acknowledgement: Air Force Office of Scientific Research, Air Force Material Command, USAF grant number FA9550-18-1-7022

26.458 **Fixational eye movements index slow fluctuations of activity in macaque visual cortex** Richard Johnston[1,2](richard.johnston@pitt.edu), Matthew A Smith[1,2,3]; [1]Department of Ophthalmology, University of Pittsburgh, [2]Center for the Neural Basis of Cognition, University of Pittsburgh and Carnegie Mellon University, [3]Department of Bioengineering, University of Pittsburgh

Very recent research identified a fluctuation of activity in macaque visual cortex over the timescale of minutes to tens of minutes (Cowley et al., 2018, Society for Neuroscience). This "slow drift" was associated with behaviour on a perceptual task, and also very strongly associated with simultaneously recorded data in the prefrontal cortex, which suggests that slow drift may index a global aspect of cortical processing. However, the source underlying the slow drift is unclear. Another pervading hallmark of cortical processing is eye movement-related activity, which is seen in the neural activity across a wide span of cortex. Several studies have shown that small fixational eye movements, termed microsaccades, are related closely to moment-to-moment visual perception and attention. These findings motivated us to investigate if fixational eye movements index slow fluctuations of activity in visual cortex. We recorded from populations of neurons in visual cortex (area V4) of two macaque monkeys using chronically implanted microelectrode arrays. The animals performed an orientation change-detection task in which pairs of Gabor stimuli were repeatedly flashed with a fixed likelihood of a change in orientation on each flash. To identify slow drift, dimensionality reduction (PCA) was applied to population spiking data binned in large thirty minute bins. Microsaccade rate was calculated on each trial during a period of fixation prior to the onset of the stimulus sequence. As described above, slow drift was significantly associated with gradual changes in task performance over time (specifically, hit rate and false alarm rate). Interestingly, we also found that slow drift was significantly associated with gradual changes in microsaccade rate over time. These findings shed light on the underlying source of slow drift in visual cortex. They point to a strong link between slow drift and structures that have been implicated in eye-movement control and perceptual decision-making.

26.459 **Impaired anti-saccade production in posterior parietal cortex damaged patients** Julie Ouerfelli-Ethier[1,2](j.o.ethier@hotmail.com), Aarlenne Z. Khan[1], Laure Pisella[2]; [1]School of Optometry, University of Montreal, [2]Neurosciences and Cognition, University Claude Bernard Lyon I

Performing an anti-saccade relies on two mechanisms: 1) inhibiting an automatic saccade to a target, and 2) generating, instead, a voluntary saccade to a location other than this visual target. It remains unclear where and how these two processes are implemented to ensure the production of correct anti-saccades. Previous research in optic ataxia has implicated the posterior parietal cortex (PPC) in anti-pointing (Blangero et al. 2011), implying a possible role of the PPC in anti-saccade production. Here, we tested how three patients with unilateral or bilateral damage to the PPC, as well as six neurologically intact controls, perform different types of anti-saccade: classic anti-saccades (180° rotation) or mirror saccades (90° rotation) across and within hemi-fields. We showed that PPC damaged patients were impaired in anti-saccade production for their contralesional visual fields. This was reflected in a longer period of erroneous pro-saccades, longer latencies associated with correct anti-saccades to the contralesional visual field and more imprecise anti-saccades. Our results thus suggest that PPC damage results in delayed and prolonged competing saccade planning processes between two locations (i.e., visual target and saccade goal location). Taken together, our results provide evidence for a crucial role of the PPC in parallel mechanisms underlying anti-saccade performance.

26.460 **Demonstration and quantification of memory-guided saccades in the common marmoset (with comparison to the macaque)** Hayden C Carney[1](haydenccarney@gmail.com), Eric Hart[1], Alexander C Huk[1]; [1]Center for Perceptual Systems, University of Texas at Austin

INTRODUCTION: The common marmoset has garnered significant interest in recent years as a model system for studying vision in the non-human primate. However, it has been thought that their less driven temperament and lower cognitive capabilities would prevent them from performing cognitive and memory tasks developed in the rhesus macaque, especially tasks requiring delaying responses to salient stimuli. We sought to test whether marmosets could perform classical memory-guided saccades and compare their performance with rhesus macaques performing the same task. METHODS: Marmosets begin by fixating on a central target for 150-300 ms, initiating a cue period. The target to be remembered appears 4.5-5.5 degrees (roughly half their comfortable oculomotor range) from the central target in a random direction for 100-250 ms. The animals maintain fixation for 600-1000 ms until the central target is extinguished. The animal then saccades to the remembered location of the cue. With only small tweaks to standard macaque operant training, marmosets readily learn this task. RESULTS: We demonstrate that marmosets can be trained to perform memory-guided saccades, which allows us to compare their performance quantitatively to a rhesus macaque performing the same task. We show that, within their more limited oculomotor range, marmosets have comparable performance to the macaque. Marmosets are significantly more accurate than chance, with a median saccadic error of 2.25°, compared to 5° expected for random guesses. Macaques, with a larger oculomotor range, exhibit proportionally larger median error, but also a greater difference between shuffled and unshuffled target-saccade distances (indicating higher accuracy). Marmosets exhibited substantial completion rates for the longest delay periods tested (1 sec). Combined with techniques for stitching together electrophysiological data from multiple recording sessions, we demonstrate the feasibility of studying the neural basis of persistent activity in this species, with tight connections to the better-studied rhesus macaque.

Acknowledgement: National Institutes of Health

Methods: Theory, experiment, software

Saturday, May 18, 2:45 - 6:45 pm, Pavilion

26.461 **An open-source implementation of the Quick CSF method** Dominic Canare[1](dacanare@shockers.wichita.edu), Rui Ni[1], Tianshi Lu[2]; [1]Psychology, Liberal Arts & Sciences, Wichita State University, [2]Mathetmatics, Liberal Arts & Sciences, Wichita State University

Contrast sensitivity is an important feature of functional vision, but traditional psychometric assessment methods require too many trials to estimate a complete contrast sensitivity function across the full range of spatial frequencies relevant to normal vision in humans. To overcome this challenge, Quick CSF (qCSF), a Bayesian adaptive procedure to estimate an observer's contrast sensitivity function (Lesmes, Lu, Baek, & Albright, 2010), assumes a four-parameter model of the contrast sensitivity function (Watson & Ahumada, 2005). The parametric nature of this model allows for a more rapid evaluation through Bayesian inference. Stimuli parameters of contrast and spatial frequency are adaptively selected based on previous responses. As few as 25-50 trials can be collected to give a usable broad sensitivity metric across the frequency range. With 100-300 trials, contrast sensitivity function estimates reach similar precision levels of traditional laboratory CSF measurements (Lesmes, et al., 2010). We present an open-source implementation of the Quick CSF method. Our implementation of Quick CSF is written in the Python programming language as a standard Python package. The software operates as a typical full-screen desktop application, presenting a 2AFC detection task. Many settings are configurable, including stimulus size, orientation, eccentricity, color, display time, etc. Alternatively, the software can be used as a library to generate stimuli contrast/spatial frequency values and calculate the parameters of the contrast sensitivity function estimation. This allows the qCSF method to be easily integrated with new or existing software projects. The open source nature of our qCSF implementation makes it accessible to any researchers or clinicians interested in using it for their work.

Acknowledgement: Research reported in this abstract was partially supported by the Cognitive and Neurobiological Approaches to Plasticity (CNAP) Center of Biomedical Research Excellence (COBRE) of the National Institutes of Health under grant number P20GM113109.

26.462 **AutoExperiment: A program for easy creation and sharing of psychophysical studies** Sarah B Herald[1](sarah.b.herald.gr@dartmouth.edu), Brad Duchaine[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College

Creating visual experiments often requires programming expertise, especially if precise control over the stimulus presentation is necessary. Coding visual experiments can be time-consuming, imprecise, and error-prone for those who know how to program and impossible for those who don't. These issues not only impede psychophysical research, but also make it difficult to openly share one's experiment or to reuse it for future studies. AutoExperiment is a program built with Psychtoolbox in Matlab that reads a spreadsheet containing stimulus, timing, and response information and runs the experiment exactly as specified. The spreadsheet format is simple and easy to understand, so it requires no coding experience to create an experiment. AutoExperiment can handle any number of simultaneous stimuli as well as combinations of images, videos, and audio. It can be used to run behavioral tasks at a computer on in an fMRI scanner, requiring minimal to no changes. Easy-to-read diagnostic information is automatically provided to ensure no problems occurred. With this approach, AutoExperiment presents a two-fold solution to the problems discussed above. First, AutoExperiment abstracts away the coding and implementation from the design of the experiment. Second, AutoExperiment provides a flexible but precise framework for creating and running visual experiments that can be easily shared. We show that our program can be used to easily create precise visual experiments across a wide range of paradigms, including match-to-sample, judgment tasks, and visual search. Although not all experiments can be written in this spreadsheet format, AutoExperiment can greatly speed up the creation of experiments, allow non-programmers to create precise visual experiments, provide easy verification that no visual or timing issues arose during the experiment, and make visual experiments more accessible and shareable.

Acknowledgement: NSF Graduate Research Fellowship

26.463 **Test-retest reliability for common tasks in vision science** Kait Clark[1](kait.clark@uwe.ac.uk), Charlotte R Pennington[1], Craig Hedge[2], Joshua T Lee[1], Austin C P Petrie[1]; [1]Department of Health and Social Sciences, University of the West of England, [2]School of Psychology, Cardiff University

Historically, research in cognitive psychology has sought to evaluate cognitive mechanisms according to the average response to a manipulation. Differences between individuals have been dismissed as "noise" with an aim toward characterising an overall effect and how it can inform human cognition. More recently, research has shifted toward appreciating the value of individual differences between participants and the insight gained by exploring the impacts of between-subject variation on human cognition. However, recent research has suggested that many robust, well-established cognitive tasks suffer from surprisingly low levels of test-retest reliability (Hedge, Powell, & Sumner, 2018). While the tasks may produce reliable effects at the group level (i.e., they are replicable), they may not produce a reliable measurement of a given individual. If individual performance on a task is not consistent from one time point to another, the task is therefore

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unfit for the assessment of individual differences. To evaluate the reliability of commonly used tasks in vision science, we tested a large sample of undergraduate students in two sessions (separated by 1-3 weeks). Our battery included tasks that spanned the range of visual processing from basic sensitivity (motion coherence) to transient spatial attention (useful field of view) to sustained attention (multiple-object tracking) to visual working memory (change detection). Reliabilities (intraclass correlations) ranged from 0.4 to 0.7, suggesting that most of these measures suffer from lower reliability than would be desired for research in individual differences. These results do not detract from the value of the tasks in an experimental setting; however, higher levels of test-retest reliability would be required for a meaningful assessment of individual differences. Implications for using tools from vision science to understand processing in both healthy and neuropsychological populations are discussed.

26.464 **A new method to compute classification error** Abhranil Das[1](abhranil@abhranil.net), R Calen Walshe[1], Wilson S Geisler[1]; [1]The University of Texas at Austin

The sensitivity index d' is used ubiquitously to express the error rate in classification and detection tasks. In the general case with multiple cues that can have arbitrary variances and pairwise correlations, and unequal prior class probabilities, the decision boundary separating the classes is a complex surface. This makes it challenging to compute the error rate integral, and there currently exists no single algorithm that works reliably in all cases. Standard integration procedures may require grids that are inefficiently large and fine, converge slowly, yet may miss relevant parts of the space unless tailored case-by-case. These obstacles impede the testing and optimization of models. We present a new method to compute error rates simply, reliably and fast, for all cases up to 3 dimensions. This is founded on a mathematical transformation of the feature space that converts all cases into a single canonical form that is simple and spherically symmetric. In polar coordinates that can exploit this symmetry, the radius integral has a known analytical form, and the angle integral is computed over the same bounded grid of angles, for all cases. Our open-source MATLAB function based on this method computes error rates and d', returns the optimal decision boundary, accommodates custom suboptimal boundaries, and produces plots to visualize the distributions and the decision boundary. We have applied this method to compute error rates for an ideal observer analysis of a detection task in natural scenes. This was a particularly challenging case for a traditional integration method because: i.) there are three correlated cues used for detection, ii.) error rates are extremely small (below machine precision) in some conditions, and iii.) the decision boundary varies unpredictably across conditions. We find that this method recovers the true error rate quickly and accurately, and to an arbitrary level of precision.

Acknowledgement: NIH grant EY11747

26.465 **Is there a reproducibility crisis around here? Maybe not, but we still need to change.** Alex O Holcombe[1](alex.holcombe@sydney.edu.au), Charles Ludowici[1], Steve Haroz[2]; [1]School of Psychology, The University of Sydney, [2]Inria, Saclay, France

Those of us who study large effects may believe ourselves to be unaffected by the reproducibility problems that plague other areas. However, we will argue that initiatives to address the reproducibility crisis, such as preregistration and data sharing, are worth adopting even under optimistic scenarios of high rates of replication success. We searched the text of articles published in the Journal of Vision from January through October of 2018 for URLs (our code is here: https://osf.io/cv6ed/) and examined them for raw data, experiment code, analysis code, and preregistrations. We also reviewed the articles' supplemental material. Of the 165 articles, approximately 12% provide raw data, 4% provide experiment code, and 5% provide analysis code. Only one article contained a preregistration. When feasible, preregistration is important because p-values are not interpretable unless the number of comparisons performed is known, and selective reporting appears to be common across fields. In the absence of preregistration, then, and in the context of the low rates of successful replication found across multiple fields, many claims in vision science are shrouded by uncertain credence. Sharing de-identified data, experiment code, and data analysis code not only increases credibility and ameliorates the negative impact of errors, it also accelerates science. Open practices allow researchers to build on others' work more quickly and with more confidence. Given our results and the broader context of concern by funders, evident in the recent NSF statement that "transparency is a necessary condition when designing scientifically valid research" and "pre-registration… can help ensure the integrity and transparency of the proposed research", there is much to discuss.

26.466 **The influence of observer lapses on maximum-likelihood difference scaling** Bernhard Lang[1](bernhard.lang@student.uni-tuebingen.de), Guillermo Aguilar[2], Marianne Maertens[2], Felix A Wichmann[1]; [1]Eberhard Karls Universität Tübingen, [2]Technische Universität Berlin

The psychometric function relates an observer's performance to some physical stimulus quantity in a psychophysical task. Performance is characterized by several parameters of the psychometric function such as the point of subjective equality or the slope. Apart from these primary parameters of interest, two other parameters have been modelled to increase goodness-of-fit: guesses and lapses. Lapses refer to mistakes that are independent of the stimulus level. For example, when an observer mixes up response buttons or lapses in attention. Here, we explore the question whether an explicit modelling of the lapse rate would also improve the estimation of perceptual scales in procedures such as Maximum Likelihood Difference Scaling (MLDS). MLDS is a psychophysical method to derive perceptual scales from forced-choice judgments of suprathreshold stimulus differences. It was tested for its robustness against violations of several model assumptions (Maloney and Yang, 2003), but the influence of lapses on estimated scales has not yet been studied systematically. We run computer simulations to test how a stimulus-independent error rate influences scale estimates in MLDS. We simulated data from different statistical models: we include the classical implementation of MLDS as a generalized linear model (GLM), a Bayesian implementation of the same GLM, as well as two models that explicitly model the lapse rate. We also used the models to reanalyse data from a previous study (Wiebel, Aguilar, and Maertens, 2017), to test the effect of modelling the lapse rate in actual data. In the simulations, lapses lead to an overestimation of the internal noise. In the reanalysis of the experimental data we found that for experienced observers with a low noise estimate the different models did not differ much. For observers with a higher internal noise estimate, models that considered the lapse rate resulted in scales with a smaller internal noise estimate.

Acknowledgement: Landesgraduiertenförderung to Bernhard Lang, DFG MA5127/3-1 and DFG MA5127/4-1 to Marianne Maertens

26.467 **Linking assumptions: towards reliable measurements of perceptual scales** Guillermo Aguilar[1](guillermo@bccn-berlin.de), Marianne Maertens[1]; [1]Technische Universität Berlin

A central question in psychophysical research is how physical differences along a dimension of interest translate into perceptual differences. Knowing the true psychophysical scale would reveal how an external stimulus is converted to an internal event (Krueger, 1989). It would be particularly instructive to know whether and how the conversion changes under varying viewing conditions. Various methods have been advocated to derive perceptual scales, ranging from Fechner's integration of just noticeable differences to Stevens' direct scaling techniques. Yet, practically, the scale estimation is often bypassed by simply measuring appearance matches, which are an expression of the underlying scaling function but do not allow to estimate the scale directly. More recently two methods have been developed, MLDS (Maximum Likelihood Difference Scaling) and MLCM (Maximum Likelihood Conjoint Measurement), that promise to reliably estimate perceptual scales. Here we explore the requirements and limitations of these methods. We adopt three different observer models in the domain of lightness perception and, using simulations, we predict the response behavior for an MLDS, MLCM and matching experiment. We also tested observers with all three methods in two tasks favoring two different theoretical observer models. Both simulation and empirical data favor the scales estimated by MLCM. Scales estimated in MLCM do not suffer from arbitrary anchoring as those in MLDS, but both methods make strong assumptions about the noise, and we will discuss their justification.

Acknowledgement: Supported by the German Research Foundation (DFG MA5127/3-1 and /4-1 to Marianne Maertens)

26.468 **Linking general recognition theory and classification images to study invariance and configurality of visual representations** Fabian A Soto[1](fabian.soto@fiu.edu); [1]Department of Psychology, Florida International University

Many research questions involve determining whether the visual system represents two stimulus properties "independently" or "invariantly" versus "configurally" or "holistically". General recognition theory (GRT) is an extension of signal detection theory that provides formal definitions of such concepts and allows researchers to dissociate perceptual from decisional factors in their study. Unfortunately, because GRT reduces the representation of each property to a single "perceptual evidence" variable, it cannot

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provide insight on exactly how the representations of two or more properties interact. Here, we link GRT to the linear-nonlinear observer model that is the basis of classification image techniques, to allow for the study of representational separability and configurality. We define template separability as a form of independence at the level of the perceptual templates assumed by this model, and link it to perceptual separability from the traditional GRT. Simulations show that their relation depends critically on stimulus factors, which should be taken into account when making conclusions about separability and configurality. Commonly used naturalistic stimuli, such as faces, readily produce patterns of interactivity in a GRT model even when there is no perceptual interaction in the underlying observer model. The theory can also account for reports of unexpected violations of separability found in the literature (e.g., between line orientation and size). Finally, we estimate classification images for several face identity and expression tasks (discrimination of identity, happiness, and sadness), and use them to re-interpret the results of GRT-based analyses. We show that our analyses using observer models offer two advantages over traditional GRT analyses of perceptual independence: (1) they provide information about external sources of interaction between properties, which are usually confused with true representational interactions, and (2) they provide precise information about how one stimulus property influences sampling of information about another when true interactions are at work.

Acknowledgement: Research reported here was supported by the National Institute Of Mental Health of the National Institutes of Health under Award Number R21MH112013. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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Shape, Motion, Color and Depth: Integration

Sunday, May 19, 8:15 - 9:45 am, Talk Room 1

Moderator: Talia Konkle

31.11, 8:15 am **Perceptual Resolution with Simultaneous Ambiguous Color and Form**Andrew J Coia[1](acoia@uchicago.edu), Steven K Shevell[1,2,3]; [1]Institute for Mind and Biology, University of Chicago, [2]Department of Psychology, University of Chicago, [3]Ophthalmology and Visual Science, University of Chicago

Color and form are features that can link separate regions of the visual field, but how do multiple linking features interact? One possibility is that common color and form enhance grouping of separate regions more than either feature alone. An alternative is that grouping is mediated by only one feature at a time. This study separates the perceptual grouping from color and from form when both features are ambiguous. METHODS: Two separate equiluminant patterns were presented above and below fixation in chromatic interocular switch rivalry (Christiansen, D'Antona, and Shevell, 2017). The dichoptic patterns rivaled in chromaticity (appearing red or green) and spatial frequency (2 or 5 cpd) with the dichoptic gratings always presented orthogonally. In some conditions, both features within the two separate patterns were the same (e.g. both 2 cpd/green); in other conditions, chromaticity and form were mismatched between the two rivalrous patterns. In separate trials, observers held buttons when (a) both patterns appeared the same color or (b) both appeared the same form. Independence predictions for the two patterns were derived by measuring percepts for each dichoptic pattern presented alone. RESULTS: While all observers showed perceptual grouping of the regions when stimuli had both features in common, grouping was less consistent though still found with a single feature in common. In these trials, observers fell along a continuum, with some showing a bias toward grouping by color, others a bias towards grouping by form, and others showing no significant bias. CONCLUSION: Having both chromaticity and form in common enhance grouping only compared to when the weaker of the two features alone was in common. The magnitude of grouping for two common features is limited by the strength of grouping for the stronger feature, in contrast to the general principle that an additional common feature enhances grouping.

Acknowledgement: Supported by NIH EY-026618

31.12, 8:30 am **The Coding of Color, Shape, and their Conjunction Across the Human Ventral Visual System** JohnMark E Taylor[1](johnmarktaylor@g.harvard.edu), Yaoda Xu[2]; [1]Department of Psychology, Harvard University, [2]Department of Psychology, Yale University

How does the brain combine color and shape information into integrated representations of whole objects? Some evidence suggests that color and shape are initially processed independently, requiring a subsequent binding step; this evidence includes the existence of illusory conjunctions, slower visual search for feature conjunctions, and neuropsychological dissociations between color and shape processing. Other psychophysical and neural results, however, suggest that color and shape information is integrated at very early stages of visual processing, seemingly dissolving the binding problem. To reconcile these two seemingly disparate sets of findings, in two fMRI MVPA experiments using the methodology developed by Seymour et al., (2009, Cerebral Cortex), we examined the coding of color, shape, and their conjunction in a set of early visual areas and higher ventral visual regions known to be involved in object shape or color processing. We examined neural coding both for the conjunction of colors with simple shapes (spirals) and with more complex shapes, testing whether brain regions could decode single features, and whether they could discriminate two pairs of stimuli containing the same four features conjoined in different ways—a direct test for conjunctive coding. We found evidence of simple color/shape conjunction coding in early visual regions, but not in any of the higher-level visual regions examined. By contrast, we found no evidence for conjunctive coding of complex color/shape combinations. Meanwhile, we found that color and shape information was decodable across all of early visual cortex and much of the ventral visual pathway, even in higher ventral regions defined by their selectivity to shape or color. Taken together, these results are consistent with the hypothesis that the visual system can directly encode simple color/shape conjunctions with dedicated "conjunction detectors", but would need to employ a different strategy for more complex features to avoid the problem of combinatorial explosion.

Acknowledgement: National Science Foundation Graduate Research Fellowship

31.13, 8:45 am **Slant-dependent image modulation for perceiving translucent objects** Masataka Sawayama[1](masa.sawayama@gmail.com), Taiki Fukiage[1], Shin'ya Nishida[1]; [1]NTT Communication Science Laboratories, Nippon Telegraph and Telephone Corporation, Japan

Our visual scene frequently includes objects with translucent material properties such as silk curtains or plastic bags. Since they interact with incident lights in different ways from opaque objects, other image features can be produced depending on their three-dimensional shapes. For instance, the light transmittance of a thin translucent object tends to be higher when the surface normal is toward the direction of the eye than when it is slanted with regard to the eye direction. These physical properties can produce the following modulations in the image when the surface is slanted: 1) the image contrast of the background scene through the translucent surface is decreased, and 2) the surface color (shading) of the translucent surface is enhanced. To elucidate what image features the visual system relies on for perceiving material and shape of translucent objects, the present study investigated each contribution of the background contrast and the translucent surface shading. The stimulus was synthesized by the image-based blending of a natural texture with the slant map of a corrugated CG sheet. Specifically, the blending consisted of the contrast modulation of the texture by the slant map and the addition of the slant shading. When only the contrast modulation was applied, observers could perceive the translucent impression of the CG sheet, but not its three-dimensional shape. In contrast, when both the contrast modulation and the shading addition were applied, not only the translucent impression but also the three-dimensional shape impression could be obtained. Furthermore, the perceived shapes of translucent objects were similar to those obtained from their slant shading. These findings suggest that the contrast modulation of the background is effective for translucent material perception, and for translucent shape perception the cue needs to be combined with luminance signals from the translucent surface shading.

Acknowledgement: This work was supported by JSPS KAKENHI Grant Number JP15H05915.

31.14, 9:00 am **Perceived shape from motion parallax and stereopsis in physical and virtual objects** Brittney A Hartle[1](brit1317@yorku.ca), Laurie M Wilcox[1]; [1]Department of Psychology and Centre for Vision Research, York University

Observer-induced motion parallax and binocular disparity share geometric similarities and have interact to determine perceived 3D object shape. However, it has been demonstrated that depth is often misperceived, even when both cues are available. These results are likely due to conflicts with unmodeled cues (e.g. focal blur) that are endemic to computerized displays. In comparison, perceived 3D shape for physical targets in near space is veridical when binocular disparity is present and shows little improvement with the addition of motion parallax. Here we evaluate the impact of display-based cue conflicts on depth cue integration by directly comparing perceived shape for physical and virtual objects. Truncated square pyramids were rendered using Blender and 3D printed. In both physical and virtual viewing conditions we assessed perceived depth using a ratio task with 1) motion parallax, 2) binocular disparity, and 3) their combination. Virtual stimuli were viewed using a head-mounted display. Physical stimuli were presented using an apparatus with precise control over position and lighting. To create motion parallax observers made lateral head movements using a chin rest mounted on a horizontal motion platform. Using the method of constant stimuli, observers indicated if the width of the front face was greater or less than the distance between this surface and the pyramid base (i.e. the depth of the pyramid). We found that depth estimation accuracy was similar for virtual and physical pyramids. However, precision was higher for physical targets. Further, in both physical and virtual conditions estimates were more precise when depth was defined by binocular disparity than by motion parallax. Our analysis (using a probabilistic model) shows that a linear weighted combination model does not adequately describe performance in either physical or virtual test conditions. Our work highlights the importance of maximizing ecological validity using carefully controlled natural stimuli and tasks.

31.15, 9:15 am **Reliability-Weighted Template Matching Predicts Human Detection Performance in Natural Scenes** Eric Seemiller[1](eric.seemiller@gmail.com), Wilson S. Geisler[1]; [1]Center for Perceptual Systems, University of Texas-Austin

In a recent study, using a constrained image sampling approach, Sebastian et al. (PNAS, 2017) found that the thresholds of the template-matching (TM) observer in natural backgrounds are the separable product of the local background luminance (L), contrast (C) and cosine similarity to the target (S): threshold is proportional to L x C x S. Further, they found that human thresholds matched those of the TM observer over the range of conditions tested in the humans.However, in natural scenes these background properties are often not homogenous across the target region, potentially impacting the visibility of different parts of the target.The approximately-optimal strategy for dealing with inhomogeneous backgrounds is to normalize the template by the estimated local variance at each pixel location within the template. The threshold of the resulting reliability-weighted, template-matching (RWTM) observer is proportional to (L x C x S) / E, where E is the square root of the energy of the reliability-weighted template.To test this prediction, calibrated natural image patches were sorted into 3D histograms based on their luminance, contrast and similarity.Within 4 of these bins, image patches were further divided into 5 sub-bins based on their reliability weighted template energy.For all the sub-bins within a bin, the values of L, C and S are approximately constant, and hence the TM observer predicts approximately constant thresholds, whereas the RWTM observer predicts thresholds to fall inversely with E.Across all 20 (4 x 5) conditions, the RWTM observer accounts for 89% of the variance in the human thresholds, whereas the MT observer for only 11% of the variance.Furthermore, the RWTM observer was a better predictor of trial-by-trial responses in human observers (i.e., larger decision-variable correlations).We conclude that a RWTM observer based directly on natural scene statistics predicts human detection performance in natural backgrounds.

Acknowledgement: NIH EY024662

31.16, 9:30 am **Emergence of Multiple Retinotopic Maps Without a Feature Hierarchy** Talia Konkle[1](tkonkle@fas.harvard.edu); [1]Department of Psychology, Harvard University

The visual areas V1, V2, and V3 are defined based on a systematic mapping of visual space on to the cortex, following alternating vertical and horizontal meridian representations around a common fovea-to-periphery axis.Why do we have multiple visual areas and why are they organized this way? To gain insight into these questions, we used a self-organizing map algorithm which has successfully predicted both micro-scale pinwheel organizations within V1 and large-scale motor cortex organization (Durbin & Mitchison, 1990; Graziano & Aflalo, 2007). This algorithm takes a high-dimensional space as input and projects it onto a two-dimensional map such that each map-unit has a tuning curve over the input space and adjacent map-units have similar tuning (Kohonen, 1982). To construct an input space, we first discretized the visual hemifield into a high-dimensional space of visual field locations (e.g. 15x30=450 dimensions). Gaussian filters of different sizes were constructed at each location, where each filter corresponds to a point in this high-dimensional space, and the full space is specified in a matrix (filters x locations). Using the self-organizing map algorithm, we found that mapping these multi-scale filter bank input spaces naturally yield the major motifs of the visual field organization: a large-scale eccentricity organization with an upper and lower visual field divide and alternations along the vertical and horizontal meridians. Surprisingly, multiple mirrored visual "areas" emerged in the simulated cortical map without the specification of a hierarchical relationship between features. While early visual areas are often studied separately and their hierarchical relationship is emphasized, this modeling work suggests that their functional role may also be understood together. Broadly, these results provide a computational-level argument that the large-scale organization of early visual field maps can be explained by the simple goal of smoothly mapping a multi-scale filter bank on a two-dimensional cortex.

Visual Memory: Neural mechanisms

Sunday, May 19, 8:15 - 9:45 am, Talk Room 2

Moderator: John Serences

31.21, 8:15 am **Neural markers of visual working memory encoding and maintenance track attentional prioritization** Christine Salahub[1](cs13aj@brocku.ca), Holly A Lockhart[1], Blaire Dube[2], Naseem Al-Aidroos[2], Stephen M Emrich[1]; [1]Psychology Department, Brock University, [2]Psychology Department, University of Guelph

There is a limit to how much information can be stored in visual working memory (VWM). Previous models of this limitation have focused on the effects of VWM load, finding that behavioral recall of memory items becomes worse as load increases. Similarly, ERP studies examining the neural markers of VWM have focused primarily on load effects, exploring a component that tracks memory load: the contralateral delay activity (CDA). However, there is evidence that load is not the only limiting factor of performance, as behavior is better predicted by attentional resource allocation across items than by load alone. Given that attention can be flexibly distributed across items, we tested whether the CDA reflects the allocation of attention in addition to memory load. In Experiment 1, we examined the CDA during low (one) and high (four) memory loads; critically, in one condition we also manipulated the allocation of attentional resources by presenting a cue indicating that one of four items would be probed on 50% of trials. When one item was prioritized, the CDA was intermediate between the low and high load conditions, suggesting that the CDA was modulated by resource allocation rather than load alone. In Experiment 2, we examined a wider range of cueing probabilities (i.e. 100%, 75%, 25%, or 0% probe likelihood) while holding load constant. Stimuli were also presented along the vertical and horizontal midline to examine ERP components reflecting attentional enhancement (N2pc) and suppression (PD) during encoding. The results revealed that the amplitudes of the N2pc and CDA (but not the PD) increased proportionally with priority, and that these amplitudes predicted individuals' behavioral precision. Our findings suggest that ERP markers of VWM encoding and maintenance reflect attentional prioritization in addition to load.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC) Doctoral Post-Graduate Scholarship, NSERC Discovery Grant [#435945], and the NSERC Research Tools and Instruments Grant [#458707]

31.22, 8:30 am **The influence of task-relevant vs. task-irrelevant interruption on dissociable sub-component processes of the focus of attention** Nicole Hakim[1,2](nhakim@uchicago.edu), Tobias Feldmann-Wustefeld[3], Edward Awh[1,2,4], Edward K Vogel[1,2,4]; [1]University of Chicago, Department of Psychology, [2]University of Chicago, Institute for Mind and Biology, [3]University of Southampton, Department of Psychology, [4]University of Chicago, Grossman Institute for Neuroscience, Quantitative Biology, and Human Behavior

Object representations and spatial attention are deeply intertwined constructs that are often behaviorally confounded. However, recent work has illustrated that these two processes are neurally dissociable sub-components of the focus of attention (Hakim, et al., in press). Here, we use two "online" measures to more finely delineate how task-relevant and task-irrelevant interruption influence these two sub-processes of the focus of attention. We use lateralized alpha (8-12 Hz) power as an index of sustained spatial attention (Thut et al., 2006) and contralateral delay activity as an index of the number of object representations (Vogel & Machizawa, 2004). In Experiment 1 (n=20), participants performed lateral change detection with four midline interrupters (circles or squares) that appeared on 50% of trials. In one block, participants were told to ignore the midline interrupters. In the other block, they had to report the shape of the interrupters, in addition to performing the change detection task. Following task-irrelevant interruption, spatial attention was immediately captured, but recovered. Object representations persisted without spatial attention for a few hundred milliseconds, but were lost by the end of the trial. When interrupters were relevant, spatial attention was immediately captured and object representations were immediately lost. In Experiment 2 (n=20), participants performed the same task as Experiment 1, but the change detection task was on the midline and the interrupters were lateralized. This allowed us to determine how the interrupters were processed. We found that when interrupters were present, they were actively suppressed as indexed by the Pd component. The results from these two experiments further suggest a dissociation between spatial attention and object representations. Additionally, they provide positive evidence that object representations can temporarily persist without spatial attention,

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a topic of central importance in working memory models. Futhermore, top-down control is able to influence both spatial attention and object representations.

31.23, 8:45 am **Complementary visual and motor-based strategies for encoding information in working memory** Margaret M Henderson[1](mmhender@ucsd.edu), Rosanne L Rademaker[2], John T Serences[1,2,3]; [1]Neurosciences Graduate Program, University of California, San Diego, [2]Department of Psychology, University of California, San Diego, [3]Kavli Foundation for the Brain and Mind, University of California, San Diego

Working memory (WM) allows observers to hold information in mind to eventually guide behavior. In some cases, information is stored in a sensory-like format so the details of an object can later be distinguished from similar items. In other cases, it is advantageous to use a more motor-like coding scheme, for example, instead of remembering the visual details of your route to work, you remember a series of motor commands. Here, we used fMRI and an inverted encoding model to compare feature representations under conditions encouraging sensory-like or motor-like strategies. Subjects remembered the orientation of a briefly (500ms) presented grating over a variable delay (2–8s). Next, a spinning dial was shown, rotating at a fixed speed for 3s. Subjects pressed a button when the dial matched the remembered orientation; no feedback was given. We manipulated the predictability of the dial starting position and rotation direction. On trials where both were known beforehand, subjects could plan their motor response as soon as the grating appeared, while on trials where one or both were unknown, subjects could not directly divert to a motor plan. We found that during the fully predictable condition, representations in primary motor cortex were poorly modeled by a sensory training set, but were robust when trained and tested within the memory task itself. The other three conditions showed the opposite effect, suggesting the neural code was less sensory-like when responses could be planned in advance. This effect developed gradually along the posterior-anterior axis of the brain. Additionally, when rotation direction was predictable, both neural reconstructions and behavioral responses were biased away from the expected rotation direction, suggesting that subjects were attempting to compensate for their response latency. Overall, these findings demonstrate that the brain can employ multiple complementary strategies for encoding information that are not mutually exclusive.

Acknowledgement: Predoctoral Fellowship from Institute for Neural Computation, UC San Diego

31.24, 9:00 am **Transformation of event representations along middle temporal gyrus** Anna Leshinskaya[1](alesh@sas.upenn.edu), Sharon L Thompson-Schill[1]; [1]University of Pennsylvania

When learning about events through visual experience, one must not only identify which events are visually similar, but also retrieve those events' associates—which may be visually dissimilar—and recognize when different events have similar predictive relations. How are these demands balanced? To address this question, we taught participants the predictive structures among four events, which appeared in four different sequences, each cued by a distinct object. In each, one event ('cause') was predictably followed by another ('effect'). Sequences in the same relational category had similar predictive structure, while across categories, the effect and cause events were reversed. Using fMRI data, we measured associative coding, indicated by correlated responses between effect and cause events; perceptual coding, indicated by correlated responses to visually similar events; and relational category coding, indicated by correlated responses to objects in the same relational category. All three models characterized responses within right middle temporal gyrus (MTG), but in different ways: perceptual and associative coding diverged along the posterior to anterior axis, while relational categories emerged anteriorly in tandem with associative coding. Thus, along the posterior-anterior axis of MTG, the representation of the visual attributes of events is transformed into a representation of both specific and generalizable relational attributes.

Acknowledgement: R01EY021717, R01DC015359, and R01DC009209

31.25, 9:15 am **Neural encoding models of color working memory reveal categorical representations in sensory cortex** Thomas B Christophel[1,2,3](tbchristophel@gmail.com), Chang Yan[1,2], Carsten Allefeld[1,2], John-Dylan Haynes[1,2,4,5,6]; [1]Bernstein Center for Computational Neuroscience, Charité Universitätsmedizin, Berlin, 10115, Germany, [2]Berlin Center for Advanced Neuroimaging, Charité Universitätsmedizin, Berlin, 10117, Germany, [3]Center for Adaptive Rationality, Max Planck Institue for Human Development, Berlin, 14195, Germany, [4]Cluster of Excellence NeuroCure, Charité Universitätsmedizin, Berlin, 10117, Germany, [5]Department of Psychology, Humboldt Universität zu Berlin, Berlin, 10099, Germany, [6]Berlin School of Mind and Brain, Humboldt Universität, Berlin, 10099, Germany

Working memory is represented by distributed regions of the human neocortex which are believed to form a gradient of abstraction from detailed representations in sensory cortex to more abstract mnemonic traces in frontal areas. Variations in neural tuning found in non-human primates tentatively support this notion, but this tenet lacks rigorous investigation. Here, we used fMRI and multivariate encoding models to assess whether mnemonic representation of remembered colors can be categorized as either detailed-continuous or categorical. To this end, we asked 10 healthy participants (4 MRI sessions, each) to perform a conventional color working memory task using prolonged (10 s) delays and a retro-cue procedure in the MRI scanner. Critically, we sampled the memorized colors from a rigorously calibrated color space in a fine-grained fashion to closely capture the similarity-structure of neural activity patterns representing color across hue. We then used cvMANOVA MVPA to identify regions representing memorized colors during the working memory delay. We then estimated the variance explained by (1) van-Mises-based models (continuous models, typically used for IEM) and (2) models informed by the subjects' individual boundaries and prototypes of typical color categories (categorical models). Using an anatomical regions of interest approach, we found robust mnemonic color representations in V1, V4 and V01. Importantly, we found that during working memory, categorical models explained color representations in V4 and V01 significantly better than conventional continuous models. In contrast, we found no such differences in are V1 or when subjects were engaged in an immediate recall task with little demands on working memory. Our results support a view of working memory where storage relies on distributed circuits utilizing neural tuning functions with varying granularity and abstraction. Our results further suggest that some regions might change their tuning properties in the course of the working memory delay.

31.26, 9:30 am **A neural correlate of image memorability in inferotemporal cortex** Vahid Mehrpour[1](v.mehrpour@gmail.com), Yalda Mohsenzadeh[2], Andrew Jaegle[1], Travis Meyer[1], Aude Oliva[2], Nicole C. Rust[1]; [1]Department of Psychology, University of Pennsylvania, [2]Computer Science & Artificial Intelligence Laboratory, Massachusetts Institute of Technology

We have a remarkable ability to remember the images that we have seen. At the same time, we also remember some images better than others. Image memorability could arise from multiple sources, including differences in how images are encoded in high-level brain areas such as inferotemporal cortex (IT), where the identities of objects and scenes are thought to be reflected as patterns of spikes across the population. We hypothesized that image memorability arises from a complementary coding scheme in IT, as a consequence of the total number of spikes evoked by an image. To test this hypothesis, we recorded IT neural responses as two rhesus monkeys performed a visual memory task in which they reported whether images were novel or familiar. The memorability of each image was determined by a deep convolutional neural network designed to predict image memorability for humans. We found that the images that were predicted to be the most memorable for humans were also the most memorable for the monkeys. Additionally, the correlation between image memorability scores and IT population response magnitudes was strong ($r = 0.68$; $p=10\text{-}15$), consistent with our hypothesis. Finally, to probe the degree to which this variation follows naturally from a system designed to identify (as opposed to remember) image content, we probed convolutional neural network (CNN) models trained to categorize objects but not explicitly trained to predict memorability. We found that correlations between image memorability and population response magnitudes emerged at the higher stages of these networks, where visual representations are most analogous to IT representations. Together, these results suggest that image memorability is directly related to variation in the magnitude of the IT population response, and that this variation is a natural consequence of visual systems designed to identify objects.

Faces: Dynamics, convolutional neural networks

Sunday, May 19, 10:45 am - 12:30 pm, Talk Room 1

Moderator: Chris Baker

32.11, 10:45 am **Holistic perception of faces in 17 milliseconds: Evidence from three measures** Xiaoyi Liu[1](kellxy0728@gmail.com), James W. Tanaka[1]; [1]Department of Psychology, University of Victoria, BC

In the face processing literature, the parts/wholes, inversion and composite paradigms are regarded as the gold standards of holistic face processing. Although converging results from these paradigms support the holistic perception of faces, surprisingly, little is known about the precise onset of this process. To address this issue, in Experiment 1, participants viewed a study face for brief exposures of 17, 50, 250 and 500 ms, followed by a diffeomorphic mask that eliminates the low-level properties (e.g., contrast, luminance) of the face stimulus (Stojanoski & Cusack, 2014). The parts/wholes paradigm was employed to test recognition of the eyes (or mouth) presented in isolation or in the whole face. The main finding was that 17 ms and 50 ms of encoding time was sufficient to produce holistic recognition of the eye and mouth parts, respectively. In Experiment 2, study faces were randomly presented in either their upright or inverted orientation for 17, 50, 250, 500 ms. Replicating the findings of Experiment 1, the eyes and mouth were better recognized in the whole face than in isolation in presentation times as brief as 17 ms. Critically, the whole face advantage was abolished when the same faces were presented and tested in their inverted orientations. In Experiment 3, we adopted a composite paradigm where participants viewed a study face for 17, 50, 150 ms and asked to make a same/different judgement to the cued top (or bottom) half of a test face. In exposure durations of 17 ms, judgement was better in the congruent condition than in the incongruent condition (i.e., the congruency effect). The congruency effect was stronger when the cued and uncued halves were aligned than misaligned. Thus, results from the three gold standard tests of holistic processing show that 17 ms is sufficient to elicit the holistic perception of faces.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

32.12, 11:00 am **Spatial frequency tuning of single-glance familiar face recognition in a dynamic visual stream** Xiaoqian Yan[1](yanxqpsy@gmail.com), Valérie Goffaux[1], Bruno Rossion[1,2,3]; [1]Institute of Research in Psychological Science, Institute of Neuroscience, Université de Louvain, Belgium, [2]Université de Lorraine, CNRS, CRAN, F-54000 Nancy, France, [3]CHRU-Nancy, Service de Neurologie, F-5400, France

Effective human interactions depend on our ability to rapidly recognize a familiar face in a dynamic visual environment. We investigated how much visual information (spatial frequencies, or SF) is needed to achieve this fundamental brain function. Human participants viewed 63-s sequences of unfamiliar face images presented at a fast rate of 6 Hz, with different images of different familiar faces embedded every 6th image (1 Hz). Each sequence comprised 9 SF steps at two stimulation orders: (1) from coarse and indistinguishable images to fine and clearly recognizable images; or (2) the reverse order. We captured an objective and sensitive neural index of automatic familiar face recognition in participants' Electroencephalogram (EEG) at 1 Hz and harmonics. In the coarse to fine sequences, the neural recognition response emerged over the occipito-temporal cortex at around 8 cycles/image. Response increased significantly and plateaued at 11 cycles/image (by a factor of 7). In the reverse sequence order (fine to coarse), significant recognition responses were observed for faces filtered around 40 – 15 cycles/image without inter-SF step differences, which were equivalent with the response amplitudes observed from the other stimulation order at the same SF steps. However, the familiarity recognition responses reduced strongly (by a factor of 8) at around 11 cycles/image. Our results provide neural thresholds and tuning functions consistent with observations in behavioral studies that a middle SF range (8-12 cycles/image) is important for individual face recognition, showing here that this is valid for automatic rapid recognition of ecological images of familiar faces embedded in a stream of unfamiliar faces. While the lack of hysteresis effectmay be due to the high variability of identity and views appearing in the stimulation sequences, we attribute the delayed threshold for reversed sequences to unnatural stimulation conditions (i.e., from fine to coarse).

32.13, 11:15 am **Rapid processing of illusory faces in inanimate objects by the human brain** Susan G Wardle[1](susan.wardle@nih.gov), Jessica Taubert[1], Lina Teichmann[2], Chris I Baker[1]; [1]Laboratory of Brain & Cognition, National Institute of Mental Health, [2]Department of Cognitive Science, Macquarie University

The human brain is specialized for face processing, with a complex network of brain regions supporting face perception. Despite this expertise, we sometimes spontaneously perceive illusory faces in inanimate objects, a capacity we share with other non-human primates (Taubert et al., 2017). In order to understand the temporal dynamics of processing for these natural 'errors' of face detection, we used event-related fMRI (N=21) and MEG (N=22) to measure the brain activation patterns of human participants in response to 96 photographs including 32 illusory faces in inanimate objects (e.g. coffee cup, bell pepper, mop), 32 matched objects, and 32 human faces. Multivariate pattern analysis of the fMRI data showed differences in the representation of illusory faces compared to human faces and matched objects in category-selective high-level visual cortex. The MEG data supported this distinction but further revealed the dynamic nature of the representation of illusory faces. Representational similarity analysis revealed that at ~130ms after stimulus onset, some examples of illusory faces were represented more similarly to human faces than to matched objects. By ~160ms, three clusters emerged in the whole-brain representation: human faces, illusory faces, and non-face objects. This timepoint corresponded to the first peak in category-level decoding from the MEG activation patterns. Only 100ms later, this representation evolved into a clear distinction between human faces and all other objects regardless of whether they contained an illusory face. Comparison of the brain's representational structure with that of existing saliency models and deep neural networks pre-trained on object and face recognition was consistent with the recruitment of a broadly-tuned low-level visual template for face detection. Together the results show that illusory faces are processed incredibly rapidly by the human brain, however, the representational structure quickly stabilizes into one organized by object content rather than by face perception.

32.14, 11:30 am **Setting the Record Straight: Dynamic but not Static Facial Expressions are Better Recognized** Anne-Raphaelle Richoz[1](anne-raphaelle.richoz@unifr.ch), Valentina Ticcinelli[1], Pauline Schaller[1], Junpeng Lao[1], Roberto Caldara[1]; [1]Eye and Brain Mapping Laboratory (iBMLab), Department of Psychology, University of Fribourg, Fribourg, Switzerland

Humans communicate social internal states through complex facial movement signals that have been shaped by biological and evolutionary constraints. The temporal dynamics of facial expressions of emotion are finely optimized to rapidly transmit orthogonal signals to the decoder (Jack et al., 2014). While real life social interactions are flooded with dynamic signals, current knowledge on the recognition of facial expressions essentially arises from studies using static face images. This experimental bias might arise from a large and consistent body of evidence reporting that young adults do not benefit from the richer dynamic over static information, whereas children, elderly and clinical populations do (Richoz et al., 2015; 2018). These counterintuitive observations in young adults suggest the existence of a near-optimal facial expression decoding system, insensitive to dynamic cues. Surprisingly, no study has yet tested the idea that such evidence might be rooted in a ceiling effect. To this aim, we used the QUEST threshold-seeking algorithm to determine the perceptual thresholds of 70 healthy young adults recognizing static and dynamic versions of the six basic facial expressions of emotion, while parametrically and randomly varying their phase-signals (0-100%) normalized for amplitude and spectra. We observed the expected recognition profiles, with happiness requiring minimum signals to be accurately categorized and fear the maximum. Overall, dynamic facial expressions of emotion were all better decoded when presented with low phase-signals (peaking at 20%). With the exception of fear, this advantage gradually decreased with increasing phase-signals, disappearing at 40% and reaching a ceiling effect at 70%. Our data show that facial movements play a critical role in our ability to reliably identify the emotional states of others with suboptimal visual signals typical of everyday life interactions. Dynamic signals are more effective and sensitive than static inputs for decoding all facial expressions of emotion, for all human observers.

 See page 3 for Abstract Numbering System

32.15, 11:45 am **The Sustained Familiarity Effect: A robust neural correlate of familiar face recognition** Holger Wiese[1](holger.wiese@durham.ac.uk), Simone C. Tüttenberg[1], Mike Burton[2], Andrew W. Young[2]; [1]Department of Psychology, Durham University, [2]Department of Psychology, University of York

Humans are remarkably accurate at recognizing familiar faces, even from degraded and novel pictures, while the recognition of unfamiliar faces in different pictures is often prone to error. Researchers therefore propose image-independent representations for familiar but pictorial representations for unfamiliar faces. While differences between familiar and unfamiliar face recognition are easy to demonstrate in behavioral studies, however, cognitive neuroscience has so far largely failed to show a large and robust neural correlate of image-independent familiar face recognition. Here, we examined event-related brain potentials elicited by highly personally familiar (close friends, relatives) and unfamiliar faces. We presented multiple different "ambient" images per identity, varying naturally in lighting conditions, viewing angles, emotional expressions etc., while participants responded to randomly intermixed pictures of butterflies. Familiar faces elicited more negative amplitudes than unfamiliar faces in the N250 time range (200–400 ms), which is considered to reflect the activation of stored face representations. Importantly, an increased (> 4μV) familiarity effect was observed in the subsequent 400-600 ms time range. Similar to N250, this Sustained Familiarity Effect (SFE) had a right-lateralized, occipito-temporal scalp distribution. It was reliably detected in 84% of individual participants, while it was not observed in any participant in a control experiment in which all faces were unfamiliar. Additional experiments revealed that the SFE is smaller for personally, but less familiar faces (e.g., university lecturers) and absent for pictures of celebrities. Moreover, while the N250 familiarity effect does not strongly depend on attentional resources, the SFE is substantially smaller when participants' attention is directed away from the face stimuli. We interpret the SFE as reflecting the integration of visual with additional person-related (e.g., semantic, affective) information needed to guide potential interactions. We propose that this integrative process is at the very core of identifying a highly familiar person.

32.16, 12:00 pm **A Human-like View-invariant Representation of Faces in Deep Neural Networks Trained with Faces but not with Objects** Naphtali Abudarham[1](naphtool@gmail.com), Galit Yovel[1,2]; [1]School of Psychological Sciences, Tel Aviv University, Tel Aviv, Israel, [2]Sagol School of Neuroscience, Tel Aviv University, Tel Aviv, Israel

Face-recognition Deep Convolutional Neural-Networks (DCNNs) show excellent generalization under variations in face appearance, such as changes in pose, illumination or expression. To what extent this view-invariant representation depends on training with faces, or may also emerge following training with non-face objects? To examine the emergence of a view-invariant representation across the network's layers, we measured the representation similarity of different head views across different identities in DCNNs trained with faces or with objects. We found similar, view-selective representation, in lower layers of the face and object networks. A view-invariant representation emerged at higher layers of the face-trained network, but not the object-trained network, which was view-selective across all its layers. To examine whether these representations depend on facial information used by humans to extract view-invariant information from faces, we examined the sensitivity of the face and object networks to a subset of facial features that remain invariant across head views. This subset of facial features were also shown to be critical for human face recognition. Lower layers of the face network and all layers of the object network were not sensitive to this subset of critical, view-invariant features, whereas higher layers of the face network were sensitive to these view-invariant facial features. We conclude that a face-trained DCNN, but not an object-trained DCNN, displays a hierarchical process of extracting view-invariant facial features, similar to humans. These findings imply that invariant face recognition depends on experience with faces, during which the system learns to extract these invariant features, and demonstrate the advantage of separate neural systems for faces and objects. These results may generate predictions for neurophysiological studies aimed at discovering the type of facial information used through the hierarchy of the face and object-processing systems.

32.17, 12:15 pm **Facial Expression Information in Deep Convolutional Neural Networks Trained for Face Identification** Y. Ivette Colon[1](yolanda.colon@utdallas.edu), Matthew Q Hill[1], Connor J Parde[1], Carlos D Castillo[2], Rajeev Ranjan[2], Alice J O'Toole[1]; [1]Behavioral and Brain Sciences, The University of Texas at Dallas, [2]University of Maryland Institute for Advanced Computer Studies

Deep convolutional neural networks (DCNNs) are state-of-the-art learning algorithms inspired by the primate visual system (e.g., Fukushima, 1988; Krizhevsky et al., 2012). Face identification DCNNs produce a top-layer representation that supports face identification across changes in pose, illumination, and expression. Counter-intuitively, this representation also contains information not relevant for identification (e.g., viewpoint, illumination) (Parde et al., 2016). We asked whether DCNN identity codes also retain information about facial expression. Facial expressions are a type of identity-irrelevant information, though there are opposing neuropsychological theories about the independence of facial identity and facial expression processing (Fox and Barton, 2007; Calder and Young, 2005). Using the Karolinksa database (KDEF), a controlled dataset of expressions (Lindqvist et al., 1998), we examined whether the top-layer features of a high-performing DCNN trained for face recognition (Ranjan et al., 2017) could be used to classify expression. The KDEF dataset contains 4,900 images of 70 actors posing 7 facial expressions (happy, sad, angry, surprised, fearful, disgusted, and neutral), photographed from 5 viewpoints (90- and 45-degree left and right profiles, and frontal). All images were processed by the DCNN to generate 512-element face representations comprised of the top-layer DCNN features. Linear discriminant analysis revealed that the tested expressions were predicted accurately from the features, with happy expressions predicted most accurately (72% correct), followed by surprise (67.5%), disgust (67.5%), anger (65%), neutral (55.5%), sad (51%), and fearful (39%); (chance = 14.29%). We also examined the interaction between viewpoint and expression using a cosine similarity measure between the representations of different images in the dataset. Heatmaps and histograms of inter-image similarity indicated that there is a higher cost to identification with viewpoint change than with expression change. These results reveal a potential link between facial identity and facial expression processing and encoding in artificial neurons.

Acknowledgement: This research is based upon work supported by the Office of the Director of National Intelligence (ODNI), Intelligence Advanced Research Projects Activity (IARPA), via IARPA R&D Contract No. 2014-14071600012. The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of the ODNI, IARPA, or the U.S. Government. The U.S. Government is authorized to reproduce and distribute reprints for Governmental purposes notwithstanding any copyright annotation thereon. We thank NVIDIA for donating of the K40 GPU used in this work.

Perceptual Organization

Sunday, May 19, 10:45 am - 12:30 pm, Talk Room 2

Moderator: Sung-Ho Kim

32.21, 10:45 am **Adaptation to non-numeric features reveals mechanisms of visual number encoding** Cory D Bonn[1](corydbonn@gmail.com), Darko Odic[1]; [1]Department of Psychology, Faculty of Arts, University of British Columbia

When observing a simple visual scene such as an array of dots, observers can easily and automatically extract their number. How does our visual system accomplish this? Current theories on visual number encoding have argued that a variety of primary visual features – from low and high spatial frequency, size, contrast, etc., — might all contribute to our visual percept of number. Here, we test the role of spatial frequency by adapting observers to sinusoidal gratings, observing whether this adaptation has an effect on their subsequent perception of number. In Experiment 1 (N = 40; Figure 1A and 1B), on each trial, observers were adapted to six, randomly generated Gabor gratings at either a low-spatial frequency (M = 0.94 c/deg) or a high-spatial frequency (M = 12.25 c/deg); the adapter was presented on either the left or the right side of fixation. Subsequently, observers judged which side of the screen had a higher number of dots. We found a strong number-adaptation effect to low-spatial frequency gratings (i.e., participants significantly underestimated the number of dots on the adapted side) and a significantly reduced adaptation effect for high-spatial frequency gratings. In Experiment 2 (N = 20; Figure 1B) we demonstrate that adaptation to a solid grey patch fails to produce a number-adaptation effect, suggesting that the results in Experiment 1 are not due to a generic response bias. Further experiments

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with adaptation to mixed spatial frequencies show attenuated effects. Together, our results point towards a key role for low-spatial frequency in visual number encoding, consistent with some existing models of visual number perception (e.g., Dakin et al., 2011) and not with others (e.g., Dehaene & Changeaux, 1993). They also provide a novel methodology for using adaptation to discover the primitives of visual number encoding.

Acknowledgement: NSERC Discovery Grant

32.22, 11:00 am **Constant Curvature Representations of Contour Shape** Nicholas Baker[1](nbaker9@ucla.edu), Philip J. Kellman[1]; [1]University of California, Los Angeles

A fundamental problem in visual perception is explaining how an object's bounding contour is recoded from subsymbolic inputs (e.g., activation of local contrast-sensitive units) into a symbolic representation of shape. Recoding should be informationally compact and support constancies such as invariance to planar transformations and scaling. One theory posits that this is accomplished in part by higher-order detectors of constant curvature (CC) segments (Garrigan & Kellman, 2011). We conducted psychophysical tests to specify a computational model of how shape might be built up from CC primitives. In Experiment 1, we tested subjects' ability to detect differences in curvature between adjacent, smoothly connected CC segments. Subjects clicked on a point on an open contour to divide it into two segments and were tested with varied curvature differences to determine the minimum detectable curvature difference threshold. In Experiment 2, we measured the degree of fidelity of CC representations to the initial shape contour, where high fidelity representations include more segments. We briefly displayed a novel contour, then showed a second contour either identical to the first or an abstraction made up of a variable number of CC segments; subjects judged whether they were identical or not. The threshold at which the CC abstraction is indistinguishable from the original display represents the precision of an abstract representation. From these results, we formulated a fully specified computational model of shape representation from CC primitives. Experiment 3 tested the model by comparing subjects' sensitivity to contour changes that do or do not result in a change in the CC representation based on whether the contour's curvature changes systematically. Pilot data suggests that changes that result in a representational change are more detectable than changes that do not, even after equating the magnitude of change in each condition.

Acknowledgement: NSF grant DGE-1829071 National Science Foundation Research Traineeship for ModEling and uNdersTanding human behaviOR (MENTOR)

32.23, 11:15 am **The judgment of causality for deformations of stretchy materials** Takahiro Kawabe[1](kawabe.takahiro@lab.ntt.co.jp); [1]NTT Communication Science Laboratories, Nippon Telegraph and Telephone Corporation, Japan

When a material is stretched along one spatial axis, the material is compressed along a perpendicular axis, so-called the Poisson effect. Poisson's ratio is known as a measure of the Poisson effect, which corresponds to the ratio of transverse contraction strain to longitudinal extension strain in stretched direction.For common stretchy materials, the Poisson's ratio is in range 0-0.5; more than 0.5 the volume of the material is reduced in comparison with the material's original state. The present study investigated how human observers judged the causality of the orthogonal deformations in the Poisson effect. In stimuli, a bright rectangle against a neutral gray background was horizontally stretched while the upper and lower sides of the rectangle was vertically compressed with sinusoidal spatial modulation. We controlled the initial horizontal width of the rectangle and the amplitude of vertical compression because the Poisson's ratios vary with those two parameters. The magnitude of horizontal stretch was constant among all conditions. The observers were asked to report whether the vertical compression of the rectangle was causally related with the horizontal stretch. The proportions of reports for non-causality increased with the amplitude of the vertical compression. Thresholds for non-causality judgments increased with the initial horizontal width of the rectangle. However, the pattern of the threshold variations was not consistently accounted for by the Poisson's ratios. Rather, the results were well accounted for by the ratio of the area of the rectangle before the deformations to the area of the shrunk rectangle after the deformations. The results indicate that human observers judge the causality for orthogonal deformations due to material stretch not by estimating physical parameters but by utilizing simple visual features such as the change in areas between before and after the deformations.

32.24, 11:30 am **Objects with salient parts break apart easily: The influence of object shape in the perceptual organization of a dynamic event and its causal structure** Jaeeun Lee[1](jaeeun.lee4531@gmail.com), Yoonsang Lee[1,2], Sung-Ho Kim[1]; [1]Department of Psychology, Ewha Womans University, [2]Department of Education and Psychology, Freie Universität Berlin.

Unlike previous studies of part-based shape representations which mostly investigated static images, we explored how geometric cues to part boundaries affect the perception of ambiguous dynamic events involving globally inconsistent kinetic occlusion. When an object moved horizontally across another stationary object with either its upper or lower half occluded by the other object (and the other half occluding the stationary object), observers perceived one object to be split into halves by the other. In Experiments 1-2, we manipulated an object's part structure by introducing concave or convex cusps along its contour where we found that concave objects were more likely perceived as being split than convex objects and that this tendency grew as concavity increased. Experiment 3 examined the interaction between the geometric shape cues and the stereoscopic depth cues in object-split perception. The relative stereoscopic depth of the moving object's two halves was manipulated such that the half occluded by the stationary object could be placed in either the same depth plane as, or a slightly farther depth than the other half occluding the stationary object. Throughout this event, the horizontal midline of the whole display was occluded by a thin belt to hide the depth discontinuity between the two halves. We found that the actual stereoscopically-split moving object was likely to be seen as splitting the stationary object as long as its shape is convex, suggesting that shape representation can override metric depth information in object-split perception. Overall, our study suggests that salient parts are not only represented as independent units but also likely seen as separated in a physical sense, which in turn alters the perception of a motion event and its causal structure. It provides a new insight into spatiotemporal perceptual organization, integrating seemingly separate processes of perceptual unit formation and event perception.

32.25, 11:45 am **Large physical size and viewing distance enhance contour integration** Anthony D Cate[1,2,3](acate@vt.edu), Alexander J Hawk[1], James M Brown[1]; [1]Psychology Department, Virginia Tech, [2]School of Neuroscience, Virginia Tech, [3]Center for Human-Computer Interaction, Virginia Tech

INTRODUCTION: Are global forms easier to discriminate when they are physically large?Two experiments examined whether display size/distance affects contour integration, the process that allows discrete visual elements to be perceived as a whole contour.METHODS: Displays ranged from 20 cm width/58 cm distance to 130 cm width/370 cm distance and subtended identical visual angles within experiments.All displays used the same DLP projector and custom screen.Participants discriminated (2AFC) the planar orientations of lines made from Gabor patches with either collinear ("snakes") or parallel ("ladders") orientations that were embedded at varying locations within a grid of randomly oriented Gabors, and which were masked after 150ms.Experiment 1 used two tasks that alternated across blocks of trials: global contour orientation judgment and local contour element orientation judgment (which yields opposite responses for snakes versus ladders). Experiment 2 used only the global task.Displays appeared at different distances during different blocks of trials.Snake and ladder stimuli were randomly interleaved within blocks of trials.RESULTS:Both experiments showed significant interactions between display size and stimulus type (snake/ladder).Increasing display size/distance significantly improved contour discrimination for snakes but not ladders, although there was a small trend for improved ladder discrimination at the largest size in experiment 2.Practice effects were accounted for by including a block-repetition factor in ANOVAs, which showed that display size effects were not byproducts of counterbalancing.There were no effects of task (local/global). CONCLUSION:Physical size and/or distance of retinotopically equivalent displays enhanced contour integration (snakes) but not texture segmentation (ladders).Ocular accommodation remains a possible cause of these effects. These results add to growing evidence that mid-level visual processes can be remarkably malleable in the contexts of different task demands.

 See page 3 for Abstract Numbering System

32.26, 12:00 pm **When illusions merge** Aline F. Cretenoud[1](aline.cretenoud@epfl.ch), Michael H. Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

Recently, we found very weak correlations between the magnitudes of visual illusions. However, we found strong correlations between 19 variants of the Ebbinghaus illusion which differed in color, shape or texture, suggesting that different illusions make up their own factors (e.g., an "Ebbinghaus factor"). Here, we asked whether the magnitude of a combination of two illusions is predicted by the basic illusions of the combined illusion. For example, we tested the Müller-Lyer and Ponzo illusions, as well as a combined version of both of them by adding inward and outward fins to the horizontal lines of the Ponzo illusion. A large sample (N = 100) with age ranging from 8 to 81 years was tested with an adjustment task. A regression model showed that the combined illusions were strongly predicted by the basic illusions. In addition, age does not seem to influence the illusory effects. We suggest that in the combined illusions no factor is lost, no factor is created, factors are not even transformed but just additive.

Acknowledgement: The project was funded by Swiss National Science Foundation (SNSF), project "Basics of visual processing: from elements to figures" (n° 320030_176153 / 1).

32.27, 12:15 pm **Integration and segmentation** Elric Elias[1](elric.elias@gmail.com), Timothy D. Sweeny[1]; [1]Department of Psychology, University of Denver

Integration and segmentation are fundamental computations in vision, and they serve opposing purposes. Integration occurs, for example, in ensemble coding, whereby perceivers make fast and efficient generalizations about large amounts of information. In contrast, segmentation perceptually exaggerates visual features away from category boundaries, promoting quick-but-crude binary distinctions. Integration and segmentation must work in parallel, yet they are typically examined in isolation. Understanding of how they may conflict is thus surprisingly incomplete. We conducted three experiments examining the ensemble perception of aspect ratio, a visual feature roughly equivalent to "tallness/flatness", to investigate this potential conflict. In the first two experiments, observers viewed a set of shapes with heterogeneous aspect ratios for 250-ms and used a cursor to adjust a test shape to match the average of the set on each trial. Observers' distribution of errors across trials served as an index of the precision of ensemble coding. We expected conflict when observers attempted to make a summary judgement about sets of features that spanned a category boundary. Indeed, ensemble coding operated less precisely for sets that included tall and flat shapes, compared to sets that included tall or flat shapes. We suspected that this occurred because sets which spanned the category boundary were perceived as more being heterogeneous than those that did not, even though our sets were carefully matched in terms of physical variability. Replicating previous work (Suzuki & Cavanagh, 1998) we showed in a third experiment that segmentation exaggerated the appearance of individual shapes near the tall/flat category boundary. Segmentation may thus disrupt the integration required for efficient ensemble coding by exaggerating a set's perceived heterogeneity. This work adds to the understanding of integration by demonstrating aspect ratio integration, and also by showing that integration can be constrained by another fundamental computation in the visual system, segmentation.

SUNDAY MORNING POSTERS

Perceptual Organization and Scene Perception: Art, aesthetics, image preference

Sunday, May 19, 8:30 am - 12:30 pm, Banyan Breezeway

33.301 **Effect of presentation duration of artworks on aesthetic judgment and its positive serial dependence** Sujin Kim[1](preikestolen89@gmail.com), David Burr[1,2], David Alais[1]; [1]School of Psychology, University of Sydney, Australia, [2]Department of Neuroscience, Psychology, Pharmacology and Child health, University of Florence, Italy

Positive serial dependence is a phenomenon where current visual perception is systematically biased towards the immediate past. We previously showed that attractiveness ratings of artworks are assimilated toward the preceding trial (Kim and Alais, VSS 2018). The current study investigates how long it takes to form an aesthetic judgment and for the positive serial dependence to emerge. Each participant viewed 40 artwork images, each presented 20 times in a random order for 250 ms, followed by a noise mask. Participants rated the painting's attractiveness by adjusting a slide bar on the screen. Results showed that the current painting earned a higher attractiveness rating than its average when it was preceded by a more attractive painting, and vice versa. Interestingly, the mean attractiveness ratings for the stimuli were highly correlated with those from our previous study in which different observers viewed the same paintings for 1 s. Furthermore, we found that paintings with cooler colours were preferred to those with warmer colours in both studies. Unlike the longer duration experiment, however, individual questionnaire data on art interest and knowledge did not correlate with an observer's magnitude of serial bias. In sum, we found that aesthetic ratings of artworks can be formed surprisingly quickly and are sequentially dependent. The finding that aesthetics ratings obtained using brief, post-masked stimuli correlated well with ratings from different observers given longer viewing times, as well the dependence of ratings on colour in both experiments, suggest that aesthetic judgments are at least partly driven by early perceptual processes. Cognitive sources relevant to art appreciation appear to require a longer time scale, as the dependence on art knowledge and interest seen for 1 s presentations was absent for 250 ms trials.

33.302 **Measuring complexity of images using Multiscale Entropy** Elizabeth Y Zhou[1](elizabeth.yue.zhou@gmail.com), Claudia Damiano[1], John Wilder[1], Dirk B Walther[1]; [1]Department of Psychology, University of Toronto

Stimulus complexity is relevant for a variety of perceptual phenomena; for example, more complex shapes are harder to detect in a cluttered environment. Lacking a way to concretely measure complexity, such studies frequently rely on subjective ratings of complexity by humans. Here we propose an objective method for measuring the complexity of an image using Multiscale Entropy (MSE). MSE has previously been used to measure the complexity of time series (Costa, Goldberger, & Peng, 2002), measuring regularity across different frequencies. Here we adapt this method for use with images. Given an input image, we compute a Gaussian pyramid, where each layer corresponds to a different spatial scale. We measure the Shannon entropy of the luminance distribution at each scale and combine these scores into a single complexity rating. We isolate the effect of color by computing MSE separately for the hue, saturation, and brightness of each image. We obtained human ratings of complexity for 690 images of real-world nature scenes – approximately 50 ratings per image – using Amazon Mechanical Turk, and compared our method to human ratings. Our method is highly predictive of human complexity ratings for real-world scenes ($r = 0.66$), outperforming Shannon entropy computed only for the original image ($r = 0.38$). MSE is simple to implement and has potential applications in many different areas where image complexity is of importance. One such area is aesthetics of images, where the emotional valence of an image has been shown to be related to the complexity of the image. Having a concrete measure of complexity that matches human ratings will allow for a more in-depth study of this relationship, allowing, for instance, for balancing of stimulus sets for visual complexity.

33.303 **What makes an image interesting?** Bhavin Sheth[1,2](brsheth@uh.edu), Maham Gardezi[3], King Hei Fung[3], Mariam Ismail[3], Mirza Baig[3]; [1]Department of Electrical & Computer Engineering, University of Houston, [2]Center for Neuroengineering and Cognitive Science, University of Houston, [3]University of Houston

At VSS2018, we demonstrated that of the various scene categories (aerials, cityscapes, indoors, landscapes, people), observers rated landscapes as most interesting and indoor scenes as least interesting. Here we ask: are there eye-movement proxies of viewer interest, what makes an individual scene interesting to a viewer, and can information present in the scene predict its interestingness? We studied eye scan patterns while 44 observers free viewed scenes and found that the average duration of fixations best matched subjective interest ratings, more so than number of fixations/saccades, average saccade duration or viewing duration. New stimuli grab our attention. Does presenting a scene from a new, altogether different category spike viewer interest? For this, 68 observers viewed ten scenes of people, then one scene from a non-people category, and the sequence was repeated three additional times (44 scenes total). Interest ratings of the intermittently shown non-people scenes were significantly higher than those of the more frequently shown scenes of people. In a separate experiment, scenes of people were replaced by landscapes with a similar 10:1 landscape to non-landscape ratio. Interest ratings (63 observers) of the intermittently shown non-landscapes were significantly lower than those of the more frequently shown landscapes. In summary, novelty of image category does not spike viewer interest, but rather the actual image category does. Note that viewing durations were not commensurate with interest ratings. Are more complex images more interesting? We presented two scenes side by side (40 pairs) and had 40 observers free view the scenes while they were displayed for a fixed duration. Each pair was carefully chosen so that the two images differed in Jansen-Shannon complexity. More time was spent viewing the more complex image of the pair on ~70% of trials. Further analysis is ongoing.

33.304 **Tracking aesthetic engagement: Behavioral and brain responses to artistic landscape videos** Ilkay Isik[1](ilkay.isik@aesthetics.mpg.de), Edward A Vessel[1]; [1]Max Planck Institute for Empirical Aesthetics

Aesthetic experiences unfold in time, yet most of what is known about the psychological and neural basis of such experiences comes from studies with static images (paintings, photography, landscape). Previous imaging studies with artworks suggest that aesthetically pleasing experiences modulate activity not only in subcortical reward regions (ventral striatum), but also in portions of the ventral visual pathway and the default-mode network (DMN). We investigated behavioral and neural responses to temporally extended, aesthetically engaging stimuli (videos), using fMRI in combination with continuous behavioral ratings. Participants (n=26) were scanned as they viewed 40 video clips of landscapes (30 s) and indicated their moment-to-moment liking, as well as a final summary rating at the end of each clip. Category-selective visual regions in ventral occipitotemporal cortex (e.g. PPA, OPA, FFA) were identified using a functional localizer scan, and core regions of the DMN were identified using a "rest" scan, in each individual. In a behavioral pretest, we found that overall aesthetic judgments of landscape videos contain a high degree of variance from person-to-person ("mean-minus-one" agreement score MM1=0.44, 95% CI 0.31–0.56) more so than for static landscape images (previously reported MM1=0.60, 95% CI 0.53-0.66). Moment-to-moment ratings, however, were slightly more concordant (MM1=0.52, 95% CI 0.45–0.58). In addition, the degree of temporal variation in continuous ratings over time was more affected by observer than by stimulus. A parametric regression analysis of the fMRI data using overall ratings as regressors revealed sensitivity to aesthetic appreciation in several scene selective regions (parahippocampal place area, retrosplenial cortex and occipital place area) as well as ventral striatum and inferior frontal sulcus, but not in the DMN. These results suggest that aesthetically pleasing landscape videos may modulate a wider network of higher-level visual regions than their static counterparts, and rely less on top-down information for their aesthetic appeal.

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33.305 **Preference of facing/lighting direction for portraits paintings**
Sho Kishigami[1](kishigami18@vpac.cs.tut.ac.jp), Yuma Taniyama[1], Shigeki Nakauchi[1], Tetsuto Minami[2]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, [2]Electronics-Inspired Interdisciplinary Research Institute (EIIRIS), Toyohashi University of Technology

Background:There are more portrait paintings with model facing to the right than those facing to the left (Humphrey and McManus, 1973). Correspondingly, paintings with a light source positioned on the right side are reported to be more natural than the left side (Carbon and Pastukhov, 2018). This study examined how the direction of the face and the position of the light source affect the preference for portraits, for Japanese and indigenous Malaysian participants. Method:2-AFC paradigm was used to measure the preference for portrait paintings. Japanese (n = 20: male = 15, female = 5) and Malaysian (n = 9: male = 8, female = 1) were asked to choose which they prefer between original or horizontally inverted portrait. Approximately 14,500 portrait paintings were collected from WikiArt. The aspect ratio and the average illuminance of the stimuli were controlled, then classified by 3 conditions, the direction of the face, position of the light source and the gender of the model. 120 portraits (15 from each condition) were selected and used in this experiment. The results and Discussions:Result showed the main effect of facing direction on preference in both groups, no effect was found in the position of light source. Also, we found a difference in the preference of the face direction between Japanese and Malaysian people. Japanese preferred the model facing right, and Malaysian preferred the left. Furthermore, these result suggested that the biased preference by the model face direction was also existent not just in photographs but also in portrait paintings. Taken together, our study showed that there are cross-cultural differences on the preference of the face direction in the portraits between Japanese and Malaysian (Indigenous) people, which might be due to the cultural background; for example, the familiarity with western cultures.

33.306 **The power of visual art: Higher felt inspiration following aesthetically pleasing visual prompts in a creative writing task**
Dominik Welke[1](dominik.welke@ae.mpg.de), Isaac Purton[2], Edward A. Vessel[1]; [1]Max-Planck-Institute for Empirical Aesthetics, Frankfurt a.M., Germany, [2]New York University, New York City, USA

Anecdotal reports indicate that visual art might be particularly potent in inducing moments of "creative inspiration" – a state that can be described as externally evoked motivation for creative activity (Thrash & Elliot 2004). In two behavioral experiments we tested the hypothesis that visual aesthetic experiences can increase self-reported creative inspiration by presenting 'aesthetic' and 'non-aesthetic' visual stimuli as prompts in a creative writing task. In Experiment 1, 25 participants were shown prompts (10s) consisting of 6 previously high-rated visual artworks (aesthetic prompt) or 6 triads of unrelated words (non-aesthetic prompt) and after every prompt were given three minutes to write a short creative vignette. Participants then rated how "inspired" they had felt during idea generation. Responses were taken to fit linear-mixed-effects-regression models (LMM). Ratings of felt inspiration were significantly higher for aesthetic vs non-aesthetic prompts ($p < 0.001$). In Experiment 2, 34 participants performed the same task with prompts consisting of 4 previously high-rated artworks (liked), 4 previously low-rated artworks (disliked), or 4 previously unseen artworks (novel, preference rated post-hoc). Pre-exposure to the stimuli (known vs. novel) had no significant effect ($p = 0.71$), while felt inspiration was significantly higher for liked vs. disliked prompts ($p = 0.0013$). Furthermore, we observed a significant linear relation between rated inspiration and post-hoc aesthetic rating in novel stimuli ($p < 0.001$). Our results provide initial support for the hypothesis that states of aesthetic appreciation evoked by visual art can increase the incidence of felt inspiration. This being true, states of "aesthetic appreciation" and "creative inspiration" should share certain mental and neural resources. Our findings have implications for further studies of aesthetic- and creative processes as well as for the potential role of the arts in educational settings.

33.307 **Fractal statistics in the aesthetic appreciation of images, textures and sound**
Catherine Viengkham[1](c.r.viengkham@gmail.com), Zoey J Isherwood[1, 2], Branka Spehar[1]; [1]School of Psychology, UNSW Sydney, [2]School of Psychology, University of Wollongong

Many natural phenomena exhibit properties that follow a 1/f fractal-like distribution. In vision, this is most readily observed in the amplitude spectra and edge geometry of natural scenes and visual art. As a result, fractal geometries have been widely considered in the explanation of universal aesthetic experience and beauty. We investigated the aesthetic perception of 1/f statistics at their most fundamental physical manifestations across three sensory domains: vision, touch and audition. In our first experiment ($n = 51$), we compared the preferences for visual and tactile stimuli varying in discrete increments of amplitude spectrum slope (α). For visual stimuli, α was independently manipulated across both the spatial structure of a 1/f image, and the temporal structure of a 1/f image sequence varying across time. Tactile stimuli were created by extruding 1/f images into 3D models then printed into blocks of physical textures. Preference was measured using a two-alternative forced choice procedure. We found visual preference for spatially varying 1/f images peaked for intermediate slopes - equivalent to those typically found in natural scenes. For temporally varying 1/f images and tactile textures the steepest slopes were the most preferred. Perceptually, these equated to the slowest moving images and the smoothest surface textures. In a subsequent study, musical melodies were created with α-adjusted 1/f pitch sequences and presented to participants in a 2AFC preference task ($n = 72$). We found sequences with the most predictable and regular melodies were the most preferred. Our results support the appeal of natural fractal statistics in still visual images. Interestingly, this preference appears to shift towards steeper values of α for stimuli presenting a temporal component, such as those found in moving images, the exploration of surfaces and the progression of musical melodies. Individual differences and internal consistency in preference across modalities will be discussed.

33.308 **The interaction between spectral slope and symmetry on visual aesthetic preference**
Chia-Ching Wu[1](ccwu@gm.fgu.edu.tw), Chien-Chung Chen[2]; [1]Fo Guang University, [2]National Taiwan University

It is shown that human observers prefer images and artworks whose amplitude spectral slope is similar to that of natural scenes. It is also found that certain image spatial structure, such as symmetry, plays an important role in aesthetic preference. It is unclear whether and how these two factors interact on aesthetic preference. We investigated the effect of spectral slope and the number of symmetry axes on aesthetic preference. There were 30 types of images, with one of the 5 slopes (from −2 to 0 by a step of 0.5) and 6 symmetry levels (with 0, 1, 2, 4, 8 and 16 symmetry axes). The observers' task was to rate aesthetic preference for these images on a 6-point Likert scale. In each trial, a test stimulus was presented at the center of the display and remained there until the observer made a response. Our results showed that there was main effect of spectral slope. The preference rating was an inverted-U shape function of spectral slope and peaked at slope = -1, consistent with previously reported results. There was also significant effect for the number of axes, with preference rating increased with the number of symmetry axes. Most importantly, there was interaction between the two factors. The non-symmetric patterns had little, if any, spectral slope effect while the symmetric patterns had a pronounced effect. The lack of spectral slope effect in the non-symmetric patterns implies that the scale-invariance effect on aesthetic preference may have been over-estimated in the previous research. The spatial structure, such as symmetry, may be more important than slope for aesthetic preference. The scale-invariance property, represented by spectral slope, is to modulate the spatial structure effect on preference ratings.

Acknowledgement: MOST 107-2410-H-431-007-MY2

33.309 **The default mode network, but not ventral occipitotemporal cortex, contains a domain-general representation of visual aesthetic appeal**
Edward A Vessel[1](ed.vessel@ae.mpg.de), Ayse Ilkay Isik[1], Amy M Belfi[2], Jonathan L. Stahl[3], G. Gabrielle Starr[4]; [1]Max Planck Institute for Empirical Aesthetics, [2]Missouri University of Science and Technology, [3]The Ohio State University, [4]Pomona College

Judgments of aesthetic appeal are critical for decision-making, and aesthetic experiences strongly impact well-being. A wide variety of visual objects can be evaluated aesthetically, from landscapes to artworks. Aesthetic evaluations recruit the ventral visual pathway, subcortical reward circuitry, and parts of the medial prefrontal cortex overlapping with the default-mode network (DMN). However, it is unknown whether any of these networks represent aesthetic appeal in a domain-general fashion, independent of domain-specific representations of stimulus content. Using a classification approach, we tested whether the DMN or ventral occipitotemporal cortex (VOT) contains a domain-general representation of aesthetic appeal. Classifiers were trained on multivoxel fMRI response patterns collected while 18 observers made aesthetic judgments about images from one aesthetic domain (e.g. artwork). Classifier performance (high vs. low aesthetic appeal) was then tested on response patterns from held-out trials from the same domain to derive a measure of domain-specific coding, or from trials of a different domain (e.g. architecture or landscape) to derive a measure of domain-general coding. Activity patterns in the category-selective VOT contained a degree of

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domain-specific information about aesthetic appeal, but did not generalize across domains. Activity patterns from the DMN, however, were predictive of aesthetic appeal across domains. Importantly, variation in classifier performance across observers reflected the distances (d') between each observers' behavioral ratings of images labeled as "high" or "low" aesthetic appeal, rather than random measurement noise ($R2 = 0.53$). These findings support a model of aesthetic appreciation whereby domain-specific representations of the content of visual experiences in VOT feed in to a "core" domain-general representation of visual aesthetic appeal in the DMN. Whole-brain "searchlight" analyses identified additional prefrontal regions containing information relevant for appreciation of cultural artifacts (artwork and architecture) but not of landscapes.

33.310 **Contour features predict positive and negative emotional valence judgements** Claudia Damiano[1](claudia.damiano@mail.utoronto.ca), Dirk B Walther[1], William A Cunningham[1]; [1]Department of Psychology, University of Toronto

Objects with sharp contours are preferred less than objects with smooth contours, as sharp angles are thought to be an indicator of threat. In two experiments, we probe the link between low level visual features, such as contour curvature, and affective ratings. In Experiment 1, we used artist-traced line drawings of all images from the International Affective Picture System (IAPS) image set. We computationally extracted the contour curvature, length, and orientation statistics of all images, and explored whether these features are predictive of emotional valence scores. Our results replicate previous research, finding a significant negative relationship between high curvature (i.e., angularity) and emotional valence ($p = 0.012$). Additionally, we find that length is positively related to valence, such that images containing long contours are rated as more positive ($p = 0.049$). In Experiment 2, we composed new, content-free line drawings of contours with different combinations of length, curvature, and orientation values. Sixty-seven participants were presented with these images on Amazon Mechanical Turk (MTurk) and had to categorize them as positive or negative. A linear mixed effects model revealed that low curvature, long, horizontal contours predicted participants' positive responses, while short, high curvature contours predicted participants' negative responses. Taken together, these findings have implications for theories of threat detection such as the Snake Detection Theory, which posits that humans evolved to fear snakes and thus our thalamic nuclei are able to detect snakes rapidly and automatically. It is unlikely, however, that the thalamus has a true representation of "snake". Our findings suggest a more plausible scenario, whereby visual features associated with threatening stimuli, such as snakes, are quickly detected and passed on to visual cortex for further processing. We have also identified the low-level contour features that are associated with positive valence.

Acknowledgement: NSERC, SSHRC

33.311 **Feeling beauty requires the ability to experience pleasure** Aenne A Brielmann[1](aenne.brielmann@nyu.edu), Denis G Pelli[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Since the beginning of psychology, researchers have tried to understand beauty. Here, we address two of the oldest questions about it. First, Fechner (1876) claimed that beauty is immediate pleasure, and that an object's pleasure determines its value. Focusing on the first claim, if beauty is pleasure then inability to experience pleasure (anhedonia) should prevent the experience of beauty. Second, ever since Fechner, psychologists have asked how much beauty depends on the object versus the observer. We address this by determining the relative contribution of shared versus individual taste for diverse images. We asked 757 participants to rate how intensely they felt beauty from each image. We used 900 OASIS images along with their available valence (pleasure vs. displeasure) and arousal ratings. We then obtained self-reports of anhedonia (TEPS), mood, and depression (PHQ-9). The feeling of beauty is closely related to pleasure ($r = 0.75$), yet unrelated to arousal. For normally beautiful images, the feeling of beauty is correlated with anhedonia ($r \sim -0.3$) and mood ($r \sim 0.3$), yet unrelated to depression. Follow-up repeated measures show that shared taste contributes only one third (19%) as much as personal taste (58%) to beauty-rating variance. Addressing age-old questions, these results indicate that beauty is a kind of pleasure, and that beauty is more relative than absolute, i.e., 1.7 times more correlated with individual than with shared taste.

33.312 **Absolute beauty ratings predict mean relative beauty ratings** Qihan Wu[1](qw686@nyu.edu), Aenne A Brielmann[1], Denis G Pelli[1,2]; [1]New York University, Department of Psychology, [2]New York University, Center for Neural Science

Can you compare the beauty of the Mona Lisa to Starry Night? Would your beauty ratings of single images predict your rating of their relative beauty? Twenty-five participants were tested with 14 OASIS images and 6 self-selected images. There were 2 tasks. In the relative task, each participant saw all possible two-image pairs twice, chose which image was more beautiful and rated by how much on a 1-9 scale. In the absolute task, they saw all 20 images randomly presented one by one 4 times and rated how much beauty they felt from each, 1-9. We find that the participants made consistent absolute and relative beauty judgments (absolute: test-retest $r = 0.98$, $\sigma 2 = 0.29$; relative: test-retest $r = 0.84$, $\sigma 2 = 1.37$). We used absolute beauty ratings to predict relative beauty ratings by subtracting one image's absolute beauty rating from the other's. This simple model precisely predicts mean beauty difference ratings ($r = 0.79$) and 80% of the choices. Thus, the mean beauty difference ratings are predicted by mean absolute beauty ratings. But the variance in our data is 2.4 times as large as predicted by our model, suggesting a noisy comparison process.

33.313 **Preference judgement for art paintings: large-scale subjects (30K) experiment revealing age-dependency** Shigeki Nakauchi[1](nakauchi@tut.jp), Masaya Nishimoto[1], Hideki Tamura[1]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology

Background: It has been reported that when observers were asked to select the preferred one among original and hue-rotated art paintings, they preferred the original paintings although they have never seen them before (Kondo et al., 2017; Nakauchi et al., VSS2018). This study aims to explore the robustness of this "original-preferred judgement" for art paintings by recruiting a large number of participants with broad age groups. Method: 4-AFC paradigm was used to measure the preference for art paintings. Participants (n=30,777: male=16,837, female=13,940; mean age=46.6, S.D.=15.4, ranging from 15 to 97 years old; only Japanese participants) were asked to select the most preferable one among four images: original (0 deg) and three hue-rotated images (90, 180 and 270 deg) with the same luminance and mean chromaticity as the original. Art paintings used in the experiment were collected from the genres of abstract, flower, poster, still life and symbolic. Results and Discussions: Original paintings were selected as most preferable (44.12 % among four choices) and the original-selection rate was significantly correlated with color statistics of art paintings (e.g. skewness of a*, correlation of L*-b*), duplicating previous findings (Nakauchi et al., VSS2018). Furthermore, the large-scale subjects in this experiment enabled us to analyze more precisely the distribution of the original-selection rate of observers. We found that center of the original-selection rate distribution (mean, median and mode) increased with the advance of age, meaning that the originals were selected with higher probability as people get older. This finding strongly implies that the original-preference judgement for art paintings is acquired not only during school age in the educational environment as shown in the previous report investigating children of 6-to-12 years old (Imura et al., ECVP2018), but it should be concluded that it might be continuously happen across the human life-span.

Acknowledgement: This work was supported by NTTDATA Institute of Management Consulting, Inc. for recruiting observers and data collection, and by KAKENHI (No.15H05922 and No.18KK0280).

33.314 **The role of warmth and complexity in aesthetic evaluation of color photographs.** Alexander J Bies[1](alexander.bies@mtsu.edu), Margaret E Sereno[2]; [1]Psychology Department, College of Arts and Sciences, Gonzaga University, [2]Department of Psychology, College of Arts and Sciences, University of Oregon

Salient characteristics of images such as color and texture attract our attention, but at present it is unclear how these combine to impact higher-level judgments such as aesthetic evaluation. In the present study, we compare the relative contributions of perceptions of "warmth" (an evaluative judgment about qualities linked to color) and "complexity" (an evaluative judgement purportedly linked to the physical properties of edge and texture complexity) to aesthetic evaluations of landscape photographs. 40 participants (29 females) each rated 200 color landscape photographs in a repeated measures design across a series of six blocks. In sequential pairs of blocks, participants rated the images on one of three properties: "aesthetic value," "complexity," or "warmth." During each trial a single image was displayed while the participant rated the image on a continuous scale

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from 0 to 1, where ratings closer to 0 indicated lower values of the judgment (e.g., lower aesthetic value) and ratings closer to 1 indicated higher values (e.g., higher aesthetic value). Thus, for each participant, we were able to compute reliability scores that reflect the relationship between the first and second ratings on each parameter (aesthetic value, complexity, warmth). Participants whose responses produced significant correlations on all three within-rating comparisons were retained for analysis of the relationship among the three parameters. At the within-participant level, models derived from these participants' data (N = 20, 14F) revealed that complexity and warmth contribute significantly to the prediction of aesthetic evaluation, and that each contributes a significant amount of unique variance in the cognitive models derived from nearly all participants' responses. This may mean that the physical qualities linked to complexity and warmth are interpreted similarly across individuals. In addition, correlations across individuals were moderately strong, on average. This suggests there is a degree of typicality in determinations of which images are aesthetically appealing.

Acknowledgement: American Psychological Association Dissertation Research Award

33.315 **P3 asymmetry elicited by original-pseudo art paintings using an oddball paradigm** Yuma Taniyama[1](taniyama17@vpac.cs.tut.ac.jp), Yuji Nihei[1], Tetsuto Minami[2], Shigeki Nakauchi[1]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, [2]Electronics-Inspired Interdisciplinary Research Institute (EIIRIS), Toyohashi University of Technology

Previous studies reported original art paintings were preferable than hue-rotated pseudo art paintings (Kondo et al., 2017) and subjective preference for them tended to be correlated with their naturalness (Taniyama et al., VSS2018). Correspondingly, event-related potentials (ERPs) study showed that P3 amplitude during an oddball task reflects the naturalness of the stimuli (Minami et al., 2009). Here, we aim to investigate the naturalness of the original and pseudo paintings by focusing on the asymmetry of P3 amplitude during an oddball task. Stimuli were selected from "Abstract" and "Flower" categories in WikiArt. They were selected under two conditions: 0-180 deg and 90-270 deg pairs with two target-standard roles (standard-target and target-standard). ERPs were concurrently recorded while an oddball task was conducted with ratio of standard:target = 4:1. On each trial, participants were asked to count the number of the target stimuli in order to focus on the context (silent-counting oddball task). Behavioral results showed that the accuracy of the silent-counting oddball task in the 0-180 pair was higher than the 90-270 pair. This result implies that difference in naturalness between the stimuli pairs was more evident in the 0-180 pair. In parallel with this, P3 amplitude of the target stimuli with 180 deg was larger than those with 0 deg (P3 asymmetry for the 0-180 pair), while no amplitude difference was found for the 90-270 pair. P3 asymmetry is known to reflect unnaturalness and unfamiliarity of visual stimuli, hence this finding supports previous behavioral results (Minami et al., 2009; Taniyama et al., VSS2018). Furthermore, this physiological method using P3 asymmetry elicited by switching the target in an oddball task might be able to estimate the difference of naturalness between two paintings, which is closely related to subjective preference.

Attention: Selective

Sunday, May 19, 8:30 am - 12:30 pm, Banyan Breezeway

33.316 **The magnitude of the Double-Drift illusion is lessened by a reference object with high positional certainty** Sharif Saleki[1](sharif.saleki.gr@dartmouth.edu), Marvin Maechler[1], Patrick Cavanagh[1,2,3], Peter Tse[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College, [2]Department of Psychology, Glendon College, [3]Center for Visual Research, York University

In the double-drift illusion (Lisi & Cavanagh, 2015; aka, curveball illusion: Shapiro et al., 2010; infinite regress illusion: Hsieh and Tse, 2006) a Gabor patch moves in one direction in the periphery while its internal texture moves in the orthogonal direction. In this case, the perceived path deviates dramatically from the physical path. To study the effect of an anchoring object on the magnitude of illusion, a single line with high positional certainty (boundary line) was placed parallel to the gabor's physical path at different distances from it. During each trial, a boundary line was presented at a random position ranging from 2.5 degrees distance to the left or right of the gabor. Following the presentation, participants adjusted a single line at fixation to match the angle of the gabor's perceived path. Fitting a linear regression model with distance as a predictor to each participant's reported angles and comparing the slopes against zero showed that as the boundary line approached the gabor, it significantly reduced the magnitude of the perceived illusion. This suggests that the double-drift illusion is dependent on the positional uncertainty of the gabor patch (driven by the Guassian mask, eccentricity, contrast, spatial frequency, etc.) and that an anchoring reference can reduce this uncertainty and therefore reduce the illusion.

Acknowledgement: NSF EPSCoR Award #1632738

33.317 **Attending to individual size modulates mean size computation** Yong Min Choi[1](minius93@yonsei.ac.kr), Sang Chul Chong[1, 2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

Forming summary representations is important to process complex information. Indeed, numerous studies have shown evidence for efficient computations of statistical summaries such as mean size. Yet few studies have examined how the individual size contributes to the mean size computation. Here, we investigated how attended individual size influenced mean size estimation process. Specifically, we tested if varying individual size attended by either a pre- or post-cue could modulate mean size computation. In each trial, the test set comprising 8 gratings with different sizes and orientations was presented. Participants were asked to report both an individual orientation designated by a cue as well as the mean size of the gratings. One of the gratings with four size levels (size condition) were cued by an arrow either before (pre-cue condition) or after (post-cue condition) the test set. The orientation task performance was statistically above chance with no significant difference between size conditions. This result indicates that attention was successfully allocated to the cued grating. To test how the attended size contributed to the mean size computation, we analyzed the mean size bias by calculating the percentage difference between the reported and actual mean sizes. We found that the estimated mean size got larger as the size of the cued grating increased. However, the systematic trend was different between the cueing conditions. In the pre-cue condition, there was a significant linear trend depending on the attended size whereas the post-cue condition showed a significantly large estimation solely in the largest size condition. The overall results showed that mean size estimation changes systematically as a function of the attended individual size in summary representation. These post- and pre- attentional effects in the present study suggest that mean size is computed based on the representation of individual sizes themselves.

Acknowledgement: This research was supported by the Brain Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (NRF-2017M3C7A1029658).

33.318 **Characterizing the influence of spatial attention on stimulus-evoked cortical representations** Joshua J Foster[1](joshuafoster@uchicago.edu), Edward Awh[1]; [1]Department of Psychology, University of Chicago

Past work suggests that covert attention shifts spatial receptive fields (RFs) towards attended locations, increasing the neuronal resources devoted to representing the attended location (Anton-Erxleben & Carrasco, 2013). If such shifts of spatial RFs occur on a large scale, the size of the cortical representation of visual stimuli should expand because attended stimuli will fall within the RFs of a broader range of neurons. Past work with fMRI, however, has found increases in the amplitude of the stimulus representations, but no substantial change in their size (Sprague & Serences, 2013; Võ et al., 2017), a finding that is hard to reconcile with the hypothesis that attention shifts spatial RFs towards attended locations. Two factors motivate further examination of this question. First, prior studies have shown that increases in BOLD activity at attended locations are additive (i.e., independent) of stimulus contrast, suggesting that this measure may not tap into modulations of stimulus-evoked responses (Murray, 2008). Second, direct comparisons of fMRI and EEG activity have revealed qualitatively distinct modulations by attention (Itthipuripat et al., 2018). Thus, we re-examined this question with a focus on stimulus-evoked EEG activity. We measured the response evoked by attended and unattended stimuli. Using an IEM, we reconstructed spatial channel-tuning functions (CTFs) from the broadband EEG response evoked by the stimuli. This analysis revealed that both the amplitude and the size of the stimulus-evoked CTF was larger for attended than for unattended stimuli. The change in the size of the spatial CTFs cannot be explained by sensory gain alone, which can only change the amplitude of CTFs. Thus, our results suggest that covert spatial attention shifts RFs towards the attended location, expanding the cortical representation evoked by stimuli in that location.

33.319 **How exogenous attention alters perceived contrast**
Lucas Huszar[1](lukehuszar@gmail.com), Antoine Barbot[1,2], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Introduction: Attention enhances the appearance of low-level visual attributes, such as contrast and spatial frequency (Carrasco & Barbot, 2018). Little is known about how attention modulates the underlying perceptual representations of these phenomenological changes. Here we investigated how exogenous (involuntary) attention alters contrast appearance through psychophysical reverse correlation, in which signal-like fluctuations in noise predict trial-to-trial variability in perceptual judgments. If attention alters appearance by enhancing sensitivity to low-level stimulus attributes, participant's sensitivity to stimulus energy should differ with attention. Methods: We adapted the appearance protocol (Carrasco, Ling & Read, 2004) for reverse correlation analyses. On each trial, two tilted Gabors embedded in smoothed Gaussian noise were presented simultaneously. Participants were asked to report the orientation of the Gabor of higher contrast. The contrast of the standard patch was fixed at 40%, while the test patch's contrast varied from 8-100%. Attention was manipulated through peripheral precues. Attention effects were measured by computing the proportion of trials in which participants reported the test patch as higher contrast than the standard patch while cueing either the test or the standard stimulus location. The point of subjective equality (PSE) was estimated for each cueing condition, and compared to the point of physical equality. Using reverse correlation, we assessed whether and how differences in energy sensitivity with attention mediate changes in perceived contrast. Results and Conclusion: Attention shifted the PSEs: cueing a stimulus embedded in noise increased its perceived contrast. Using reverse correlation we could quantify how signal-like fluctuations in noise predict observers' trial to trial variability in perceived contrast judgments. We found that attention increased observers' sensitivity to stimulus energy differences between the test- and standard patches, without changes in tuning. These results further our understanging of how attentional enhancement in contrast sensitivity alters perceived contrast.

Acknowledgement: NIH NEI RO1-EY019693

33.320 **Visual short-term memory load weakens attentional selection by increasing the size of attentional zoom**
Hyuksu Lee[1](hyuksulee@kbri.re.kr), Su Keun Jeong[1]; [1]Department of Structure and Function of Neural Network, Korean Brain Research Institute

Visual short-term memory (VSTM) load has been known to modulate attentional selection, but the direction of the modulation is inconsistent across studies (Konstantinou et al. 2014; Roper & Vecera, 2014; Zhang & Luck, 2015; Lee & Yi, 2018). A recent study showed that high VSTM load hampers attentional selection (Zhang & Luck, 2015). However, the size of attentional zoom has also been shown to influence selective attention (Eriksen & St. James, 1986), and VSTM load is typically correlated with the size of attentional zoom as a greater number of items occupies a larger area of the display in high VSTM load. In the current study, we aimed to dissociate VSTM load and the size of attentional zoom to better understand the effects of VSTM load on attentional selection. Participants conducted a flanker task whilst maintaining 1 or 4 colored squares. In the high load condition, four color patches appeared simultaneously on the periphery (high load/wide zoom). In the low load conditions, one color patch appeared in the center of the display (low load/narrow zoom) or on the periphery with three white placeholders to keep the size of attentional zoom widened (low load/wide zoom). Results showed that the flanker interference of high load/wide zoom condition was greater than that of the low load/narrow zoom condition, replicating Zhang & Luck (2015). Interestingly, the low load/wide zoom condition showed the same amount of interference effect as the high load/wide zoom condition, suggesting that attentional selection was modulated by the size of attentional zoom regardless of VSTM load. The current result implies the attentional zoom is an essential factor for modulating attentional selection.

Acknowledgement: 18-BR-01-07 & IBS-R001-D1-2018-b01

33.321 **How exogenous spatial attention affects visual representation**
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Purpose: Orienting covert spatial attention to a target location enhances visual sensitivity and benefits performance in many visual tasks. Attention alters the representation of low-level visual features by modulating gain, tuning width, or both. Endogenous spatial attention only boosts the gain of the orientation tuning corresponding to the attended stimulus. Pre-saccadic attention, the deployment of attention to the saccade target prior to the saccade onset, both enhances orientation gain and narrows tuning width, and increases sensitivity to high spatial frequencies. It is unknown whether exogenous spatial attention alters representations similarly to endogenous and/or pre-saccadic attention. Here we investigate how exogenous spatial attention affects the representation of orientation and spatial frequency using reverse correlation. Methods: Fifteen observers detected a vertical target grating embedded in noise. Following a valid, invalid or neutral pre-cue, stimuli were simultaneously presented at each of four peripheral locations (10º eccentricity). Whether a target was embedded in the noise was independently randomized for each location. A response cue determined the test stimulus observers had to detect. The feature content of the noise was correlated with behavioral responses (Reverse Correlation) to derive perceptual tuning curves for each of the three cue conditions for both the orientation and spatial frequency domains. Results: Exogenous attention enhanced the gain of the target orientation without affecting its tuning width. Moreover, exogenous attention did not affect spatial frequency tuning. Conclusions: The effects of exogenous attention were similar to those of endogenous attention but differed from those of presaccadic attention. We conclude that covert spatial attention modulates orientation information strictly by boosting gain.

Acknowledgement: NIH NEI RO1-EY019693

33.322 **The effect of exogenous spatial attention on the contrast sensitivity function across eccentricity**
Michael Jigo[1](michael.jigo@nyu.edu), Marisa Carrasco[1,2]; [1]Center for Neural Science, New York University, [2]Department of Psychology, New York University

Introduction: Covert exogenous spatial attention, the stimulus-driven orienting response to a salient spatial location, reflexively and transiently enhances the visual system's contrast sensitivity. Previous reports demonstrate that contrast sensitivity is enhanced across a wide range of spatial frequencies and separately across eccentricities. However, how the effect of attention varies as a function of both spatial frequency and eccentricity has yet to be explored systematically. Here, we addressed this gap by parametrically manipulating contrast, eccentricity, spatial frequency, and attention in a single study with the same observers. Methods: Contrast sensitivity was measured with a 2AFC orientation discrimination task. Sinusoidal gratings of 6 possible spatial frequencies (0.5–11 cpd) were presented at 4 possible eccentricities (0–12 dva) along the horizontal meridian and were tilted ±45°. Each grating was displayed at 5 possible contrast levels, encompassing the participant's dynamic range for each spatial frequency and eccentricity condition. Exogenous spatial attention was manipulated with valid (focal) pre-cues and was compared to a neutral condition during which pre-cues were distributed across all possible target locations. Contrast thresholds were estimated for each spatial frequency, eccentricity, and cueing condition. Results: Contrast sensitivity functions (CSFs; threshold-1 as a function of spatial frequency) were estimated for each cueing condition and eccentricity. CSFs were bandpass at each eccentricity, peaking at progressively lower spatial frequencies as eccentricity increased. Attention enhanced sensitivity across conditions. Overall, attention preferentially enhanced sensitivity to spatial frequencies 1–2 octaves above the preferred spatial frequency in the neutral condition.Conclusion: Exogenous spatial attention operates similarly across eccentricity. Attention generally enhances sensitivity to higher spatial frequencies, relative to the preferred spatial frequency at each eccentricity. Our results highlight how the visual system reflexively reshapes SF selectivity.

Acknowledgement: NIH NEI R01-EY019693

33.323 **Switch costs of reorientation between different depth planes**
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Reorientation of visuospatial attention is associated with cost. This holds true not only for attentional shifts within a fronto-parallel plane but also when attention is shifted between stereoscopic depth planes. These effects are often observed within experimental trials. In the present series of experiments participants performed a visual search task in two distinct depth planes (near and far depth plane) that required spatial reorientation across trials. The search array was randomly displayed in one depth plane while there was no predictive information regarding the target depth plane. Due to the sequence of events two trial types were defined: Repetition trials (target depth plane equal to previous trial) and switch trials (target depth plane different than previous trial). Furthermore, in one experimental condition a valid or invalid spatial cue was displayed in the same depth plane as the target or in the opposite plane in order to increase the spatial character of the task. It was hypothesized that faster responses will be observed when attention remains in the same depth plane (repetition trials). The results were ambiguous with regard to the comparison of repetition and switch trials.

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In Experiment 1 no differences between both conditions were observed. In contrast, introducing a spatial cue (Experiment 2) did not only cause a strong validity effect. Reaction times were also significantly shorter in repetition trials and in trails displayed in the near depth plane. Likewise, fewer errors were associated with repetition trials. Apparently, participants orient their attentional focus to distinct depth planes as long as spatial information proves beneficial for response execution. The results also suggest that this process may be performed along an egocentric gradient through space and that attention (incidentally) remains in depth planes that were previously task relevant.

Acknowledgement: This work was supported by the Research Training Group 1855, founded by the German Research Foundation (DFG) and the Center of Excellence for Logistics and IT, founded by the Ministry of Innovation, Science and Research of the State of North Rhine- Westphalia, Germany.

33.324 **Does the near/far effect on target detection depend on distance from the observer or from the fixation plane? The case of a simulated driving task with distance indicated by pictorial cues and forward motion** Jiali Song[1](songj16@mcmaster.ca), Hong-Jin Sun[1], Patrick J. Bennett[1], Allison B. Sekuler[1,2,3]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University, [2]Rotman Research Institute, Baycrest Health Sciences, [3]Department of Psychology, University of Toronto

Visual attention is modulated by simulated viewing distance: Where one looks affects how one attends. For example, Song et al. (VSS 2016) reported that targets presented at a close apparent distance are detected more quickly and accurately than targets presented at a far apparent distance, even when the retinal characteristics of the targets were equated across distances. However, in that study, closer objects were always located near the plane of fixation. Therefore, it is unclear whether the “near advantage” was based on fixation-centered or observer-centered coordinates: the detectability of visual targets might decrease as a function of the distance from the plane of fixation or as a function of the distance from the observer. The current study differentiates these two alternatives. We measured the detectability of visual targets presented at two eccentricities (12 & 24 deg) and at three simulated distances (9, 18.5, & 37 m). We induced fixation at a constant distance by asking participants to follow a lead car at a distance of approximately 18.5 virtual meters. Hence, targets could appear at a distance that was shorter than the distance to the lead car, at the same distance as the lead car, or beyond the lead car. Preliminary results (N = 12) showed that, at both eccentricities, target detection was best (i.e., highest accuracy & lowest reaction time) when targets appeared at the same distance as the lead car, providing support for the fixation-centered hypothesis. These results provide further support for the idea that distance, even when simulated, modulates attention, and have potential implications for the development of real-world attention aids, such as heads-up displays.

Acknowledgement: National Science and Engineering Research Council

33.325 **Rapid covert visual attention to conceptual targets** Brad Wyble[1](bwyble@gmail.com), Michael Hess[2], Chloe Callahan-Flintoft[1], Charles Folk[3]; [1]Department of Psychology, Liberal Arts, Penn State University, [2]Donders Institute, Radboud University, [3]Department of Psychological and Brain Sciences, Villanova University

One can search for a familiar type of object, such as a hat, without knowing its shape or color but it remains unclear exactly whether naturalistic targets evoke rapid, contingent, covert shifts of attention in like fashion to targets defined by simpler stimuli such as color. To detect covert attention in such search, two experiments tested whether images containing conceptually defined targets such as dinner food or four-legged animal elicited behavioral and electrophysiological signifiers of visuospatial attention. The paradigm used dual RSVP streams of natural images. Learning and intrinsic salience confounds were minimized by presenting each target image only once per participant, and counterbalancing target sets across subjects so that an image that matched the target set for one subject would be a false target for another subject.The pre-registered behavioral analyses showed that when two targets were presented in rapid sequence, subjects reported the second target more often when it was in the same spatial location as the first. This finding suggests that the leading target evoked a spatial attention shift that affected processing of the second item. The second pre-registered experiment used EEG and showed that N2pc and P3 EEG components were elicited by images that matched the conceptually specified target set. Moreover, by comparing the latency of the N2pc evoked by targets in this task, with featural targets and singletons from previous experiments, it is observed that latencies become with increasing target complexity. However latencies for the natural image search is still within the bounds of typical N2pc components, suggesting that such attention is triggered by later stages of ventral stream processing, rather than a completely distinct process.These results indicate rapid, selective deployment of spatial attention to images that match current search goals at a conceptual level in the absence of featural signifiers.

Acknowledgement: National Science Foundation 1734220, 1331073

33.326 **Oculomotor behavior is inhibited during duration estimation** Noam Tal[1](p.noamtal@gmail.com), Shlomit Yuval-Greenberg[1,2]; [1]School of Psychological Sciences, Tel-Aviv University, [2]Sagol School of Neuroscience, Tel-Aviv University

Temporal expectations are predictions regarding the timing of events, that are formed based on previously-experienced temporal regularities. Two recent studies suggested that there is a tight link between eye movements and temporal expectations: prior to predictable visual targets, while expectations are being formed, saccades and blinks are inhibited. However, it is still unknown whether this pre-target oculomotor inhibition is related to the anticipation of a future predictable target, or to the process of timing itself, i.e. to the estimation of the duration of the interval prior to the target. The purpose of the present study was to examine this question by comparing a task that requires duration estimation (explicit assessment of time) with a task that requires anticipation of a target (implicit assessment of time). Trials consisted of two intervals (I1 and I2), each followed by a briefly (33ms) displayed tilted Gabor patches (S1 and S2). The duration of I1 was always 1s in the temporally-regular condition, and varied between 1-3s (0.5s increments) in the temporally-irregular condition. I2 was set individually per participant using a staircase procedure. During the implicit-timing condition, participants were required to judge which of the two Gabor patches was more vertically tilted. During the explicit-timing condition, participants were required to judge which of the two intervals was longer. Importantly, both condition were identical in their stimulation protocol and varied only by task. Saccade and blink rate were measured relative to the onset of S1. Results showed that temporal regularity led to pre-target oculomotor inhibition in both implicit- and explicit- timing conditions. These findings indicate that pre-target inhibition of eye movements is related to duration estimation rather than to anticipation of predictable targets. This is first evidence for a tight link between the cognitive process of duration estimation and control mechanisms of the oculomotor system.

33.327 **Can the N2pc ERP component track visual attention?** Pénélope Pelland-Goulet[1](penelope.pellandg@gmail.com), Pierre Jolicoeur[1], Martin Arguin[1]; [1]Department of Psychology, Université de Montréal

The N2pc ERP component is a well-known index for the deployment of visual attention to the one visual hemifield. So far, it has been used with elementary visual displays made of coloured geometric shapes and the targets for attentional selection were strongly lateralized. We ask whether N2pc can track visual attention along a finely graded horizontal spatial extent made of a normally spaced (as in words) letter string. Participants were required to attend a particular letter within a row of four letters horizontally centred at fixation. The centre-to-centre distance between consecutive letters was of 1.5° of visual angle. Trials consisted of a central arrow cue indicating the letter location to attend followed 750 ms later by a string of random letters. The onset time for each letter (33 ms duration) was determined randomly and independently within a 150ms period. After a 2-second delay, participants named the letter at the cued location. Each participant completed 1200 trials, half of which consisted of the cue only. These served to subtract the EEG activity elicited by the cue from that of the whole trial. The time window of 200-400ms following the onset of the target was selected to compute the N2pc. This component is obtained by subtracting the EEG activity of the electrode (PO7/PO8) ipsilateral to the target from that of the contralateral electrode. The N2pc computed separately for each target location easily discriminated between an attention focus to the left or right visual hemifield. Moreover, the N2pc associated with an attention focus to the inner targets was more negative than that to outer targets. These findings indicate that N2pc can reliably track the location of visual attention along a horizontal spatial extent with a margin of error as small as ±.75°.

Sunday AM

Sunday AM

33.328 Induced pupil oscillations characterize the size of the attentional window at different levels of attentional load

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The size of the attentional window may depend on attentional, perceptual and cognitive demands. Here, we test whether pupillometry can be used to assess such changes in attentional-window size. At three locations in the visual field, centrally and 8.2 degrees left and right, we presented streams of colored, oriented bars at a rate of 300 ms per item. In a low-load condition, observers had to respond to the appearance of a single feature at the central location: either a specific color (irrespective of orientation), or a specific orientation (irrespective of color). The task-relevant feature was blocked. In a high-load condition, observers had to respond to two conjunctions of color and orientation (e.g., to red-vertical and blue-horizontal). The peripheral streams were irrelevant to the task and embedded in circular discs (2.7 degrees in diameter) that oscillated sinusoidally from black to white at 1.2 Hz. With all observers, performance was worse and reaction times slower in the high-load as compared to the low-load condition, indicating a successful manipulation of attentional demands. We found differences in target-evoked pupil responses: responses tended to be earlier in the low-load condition, corroborating the reaction time results. Pupil responses to successfully detected targets tended to be larger in the high-load than in the low-load condition, again supporting the successful manipulation of load. Most importantly, we found the Fourier amplitude at 1.2 Hz to be significantly larger for the low-load than for the high-load condition. This indicates a narrowing of the attentional window under high load - fewer resources are allocated to the peripheral streams and oscillating discs if demands increase. Hence, the induced pupil fluctuations are reduced under high-load. Together, our results show that pupillometry can be used to map the narrowing of the attentional window under different task demands.

Acknowledgement: German-Israeli Foundation for Scientific Research and Development (grant no: I-1418-105.4/2017)

33.329 Bias in space and time: the reliability of pseudoneglect

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Pseudoneglect is the presence of a left-ward asymmetry in spatial cognition in neurotypical individuals (Bowers & Heilman, Neuropsychologia, 18(4):491, 1980). This effect is commonly demonstrated using bisection tasks that show participants are more likely to perceive the left-side of a line as longer than in reality (Jewell & McCourt, 2000). Current theories suggest that pseudoneglect is a consequence of hemispheric lateralisation in spatial attention (Bowers & Heilman, 1980), this assumes that the bias should remain consistent across both time and modality. However, the reliability of pseudoneglect is poorly researched, with only a few studies investigating reliability across time (Learmonth et al., PLOSone, 10(9), 2015; Nicholls, Bradshaw, & Mattingley, Neuropsychologia, 37(3):307, 1999). Here we investigate whether biases in pseudoneglect are consistent across both time and modality. We used three different tasks; visuomotor manual line bisection (MLB), visual landmarks bisection and tactile rod bisection (TRB). These tasks were tested over four separate sessions. Cronbach's alpha was used to assess reliability of participants' responses for both hypotheses. Biases in line bisection for both the visual landmarks (alpha = 0.78, $p < .001$) and TRB tasks (alpha = 0.57, $p = .009$) were found to be reliable across sessions. This was not the case for MLB (alpha = 0.01 $p = .459$). We also found poor reliability between tasks (alpha = 0.27, $p = 0.261$) suggesting that biases in spatial attention are not consistent across modalities. This result challenges the theory that hemispheric lateralisation causes pseudoneglect and, importantly, questions whether the right-hemisphere dominance hypothesis can also explain disorders of lateralised attention, such as spatial neglect.

33.330 A Matter of Expectations: Lapses in Spatial Attention May Be Driven by Anticipatory Attentional Shifts

Christopher M Jones[1](jones.6475@osu.edu), Emma W Dowd[1,2], Julie D Golomb[1]; [1]Ohio State University, [2]The University of Texas at Austin

Attention is dynamic, constantly shifting between different locations. How do goal-driven expectations impact dynamic spatial attention? A previous study from our group (Dowd & Golomb, in press, Psych Science) explored object-feature binding when covert attention needed to be either maintained at a single location or shifted from one location to another. Participants received either one or two spatial cues on each trial, followed by an array of four colored and tilted bars. Participants were instructed to reproduce the color, orientation, and location of the bar in the most recently cued spatial location. Unexpectedly, on "Hold attention" trials where participants only received one spatial cue, they sometimes reported the features and location of a different, non-cued object. We posit that these correlated errors represent "lapses" in spatial attention, which are distinct from random guesses in that participants are reporting correctly-bound features of distractor objects—perhaps driven by the sampling of other locations in anticipation of a second spatial cue. To investigate whether these lapses are indeed anticipatory in nature, we conducted a new experiment where participants were assigned to one of three conditions: (1) "Non-Predictive Second-Cue": a replication of the original experiment with intermixed Hold (single-cue) and Shift (double-cue) trials, where the second spatial cue location was not predictable (e.g., could be clockwise or counter-clockwise); (2) "Predictive Second-Cue": intermixed Hold and Shift trials where the location of the second spatial cue (when present) was always clockwise; and (3) "Single-Cue-Only". Lapses of spatial attention were measured by correlated errors wherein participants reported the features and location of the wrong object on Hold (single-cue) trials. Lapses were found on Hold (single-cue) trials in the Predictive and Non-Predictive conditions, but not in the Single-Cue-Only condition, suggesting that these spatial lapses are indeed anticipatory, induced by the expectation of making an attentional shift.

Acknowledgement: NIH R01-EY025648 (JG)

33.331 Our own perceptual experience, but not that of others, influences object detection

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Is adult Theory-of-Mind (ToM) automatic? Kovács et al. (2010) indicated that adults are faster to process an unexpected event if the event would have been expected from another agent's point of view. This suggests that 1) adults attribute beliefs to others spontaneously and 2) these belief representations influence subjects' own perceptual judgments. However, recent replication studies have highlighted alternative explanations for the results, and the available evidence for such processes is inconclusive (Phillips et al., 2015). The present research aimed to take a fresh look at this putative theoretical phenomenon using a novel experimental paradigm. Adults were required to indicate the location of an object revealed at one of two possible locations, after watching one of four different types of animations involving an agent and the object. The animations were such that the object would show up either were the subject believed it to be (i.e. where they had seen it hide last), or where the agent believed it to be (i.e. where the agent saw it hide last). In a second condition, participants had an additional "instructed tracking" task which required them to occasionally report the location that the object visited first, which always corresponded to the agent's belief about the object's location. Participants across conditions were consistently better at detecting the object if its final location corresponded to their own beliefs. However, only in the second condition did the agent's "belief" correlate with participant reactions: subjects made more errors when the object appeared where the agent did not believe it to be, compared to when it appeared where the agent believed it to be. Thus taken together, the results of the current experiments strongly suggest that while first person beliefs clearly influence anticipated object locations, another agent's beliefs do not do so spontaneously.

Acknowledgement: Swedish Research Council, EUR FrontCog

33.332 Distractor filtering via Suppression History: transient, short or long-term plasticity?

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Sudden visual onsets appearing in the visual space grab attention – and the eyes – automatically, giving rise to oculomotor capture. Recently we demonstrated that the oculomotor capture associated with irrelevant visual onsets was significantly affected by the Suppression History acquired by their spatial location, so that it became easier to ignore onsets shown at locations where they had appeared more frequently. Whether this benefit in performance is transient, specifically supporting the online processing of visual stimuli, or whether it can give rise to lasting changes in performance is yet to be explored. To address this question, we carried out two experiments in which participants had to discriminate a visual target while ignoring an onset distractor (present in 64% of trials), while both manual responses and spontaneous saccades were recorded. Each Experiment comprised a Baseline, in which distractors could appear with the same probability across locations,

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and a Training, in which they appeared with higher frequency at two of the six possible locations (HF, 76% of distractor present trials). Finally, participants performed a Test, where location biases were removed. In two groups of different subjects this session took place either immediately after Training (Experiment 1) or 24-hours later (Experiment 2), to investigate any short or long-term impact of the frequency imbalances applied during Training. In line with previous reports, Suppression History markedly modulated attentional and oculomotor performance during the Training, reducing the impact of distractors appearing at HF locations. Strikingly, however, no trace of these filtering benefits has been found in either Test phase. While confirming that distractor filtering is more efficient at locations with a significant Suppression History, these data suggest that the benefit observed are due to ongoing adjustments of spatial priority that affect the immediate deployment of attentional resources, rather than to lasting learning-induced plasticity.

Acknowledgement: Grant "Ricerca di Base 2015" n.B32F15000670001

33.333 **Visual Working Memory Capacity Load Does Not Modulate Distractor Processing** Yang Guo[1](11739007@zju.edu.cn), Nailang Yao[1], Yang Liu[1], Zaifeng Gao[1], Mowei Shen[1], Rende Shui[1]; [1]Department of psychology and behavioral sciences,Zhejiang University

In the recent decade, researchers have explored the influence of visual working memory (WM) load on selective attention by focusing on the modulation of visual WM load on distractor processing. However, there are three distinct hypotheses (perceptual load hypothesis, resolution hypothesis, domain-specific hypothesis) with different predictions. The perceptual load hypothesis suggests that visual WM load serves as a type of perceptual load: Higher visual WM load leads to less distractor processing. The resolution hypothesis holds that the visual WM capacity load serves as a type of cognitive load, while visual WM resolution load functions as a type of perceptual load. However, the domain-specific hypothesis claims that visual WM load serves as a type of cognitive load, but only when there is a content overlap between the WM task and the perceptual task. We attempted to figure out the influence of visual WM load on distractor processing by adding a flanker task into the maintenance phase of a visual WM task. We manipulated the parameters of the task settings (including memory array and flanker task, Experiments 1-4), the perceptual load of flanker task (Experiment 5), the content overlap between WM task and flanker task (Experiment 6), and the exposure time of flanker task (Experiments 7-9). However, against all the three hypotheses, we consistently found that the visual WM load did not modulate the distractor processing in nine experiments. The implications of the current finding were discussed.

Acknowledgement: 2016YFE0130400, YJA190005, 31771202, 31571119

33.334 **Tracking the content of spatial working memory during a bout of acute aerobic exercise.** Jordan Garrett[1,2](jordangarrett@ucsb.edu), Tom Bullock[1,2], Barry Giesbrecht[1,2]; [1]Institute for Collaborative Biotechnologies, University of California, Santa Barbara, CA, [2]Department of Psychological and Brain Sciences, University of California, Santa Barbara, CA

Exercise changes human performance in a range of cognitive domains and these changes often co-occur with fluctuations of neural activity. Electrophysiological studies have shown that brief bouts of low-intensity exercise can increase the visual evoked response, consistent with the notion that exercise induced arousal results in a gain in sensory processing. More recently, studies using encoding models have shown that feature-selective responses reconstructed from patterns of neural activity are also modulated during bouts of exercise. Here, we investigated whether the selectivity of spatial memories are modulated by brief bouts of exercise. Participants (n=4) performed a simple delayed estimation task involving the presentation of a circular stimulus (250ms) at one of eight equally spaced locations around fixation and the subsequent recall of the stimulus location following a brief retention period (1750ms). This task was performed while participants were seated on a stationary bike under two conditions: rest and while cycling at a low-intensity (50 W at 50 RPM). Sixty-four channel electroencephalography was recorded during the task (and during exercise) and gaze-contingent eye-tracking ensured fixation was maintained throughout each trial. We used an inverted encoding modeling technique to estimate location-selective tuning functions (TFs) from spatially distributed alpha activity measured across the scalp during the target and retention period. In both rest and low intensity exercise, the peak amplitude of the TFs was significantly different than a permuted control ($p < .05$). When the conditions were compared directly, the mean amplitude at 0 offset (i.e., the remembered location) during rest (M = .41 μV, SEM = 0.055 μV) was similar to the response during exercise (M = .38 μV, SEM = 0.050 μV). These results show that the spatial selectivity of visual working memory can be reconstructed during exercise and these reconstructions may have the same fidelity as when at rest.

Acknowledgement: This work was generously supported by US Army Research Office Grant W911NF-09-0001.

Attention: Divided

Sunday, May 19, 8:30 am - 12:30 pm, Banyan Breezeway

33.335 **How much does divided attention limit object recognition?** Dina V Popovkina[1](dina4@uw.edu), John Palmer[1], Geoffrey M Boynton[1]; [1]Department of Psychology, University of Washington

In complex visual scenes, one often needs to process multiple objects. Dividing attention over even two simultaneous objects can be challenging if processing capacity is limited. The most extreme situation is all-or-none serial processing: observers process only one stimulus and guess about the other. This situation is rare, but has recently been demonstrated for the categorization of simultaneously presented and masked words (White et al., 2018). To understand whether this extreme effect generalizes to other kinds of stimuli, we asked how much divided attention limits performance in judgments of visual objects. In Experiment 1, we used a view-invariant 3D object recognition task; in Experiment 2, we used a semantic categorization task similar to that previously used for words. Stimuli appeared in a rapid serial visual presentation task presented above and below fixation, and observers were cued to attend to one ("single-task") or both locations ("dual-task"). In Experiment 1, the stimuli were greyscale photographs of isolated 3D objects (Scharff et al., 2013); observers judged whether the cued object matched an object shown from a different viewpoint. In Experiment 2, the stimuli were grayscale photographs of isolated nameable objects; observers judged whether the cued object belonged to a target category (e.g. "animal"). To measure the effect of divided attention, we compared performance in the single- and dual-task conditions. Results from Experiment 1 showed a divided attention effect for the 3D object judgments. However, its magnitude was less than the all-or-none serial prediction, and instead consistent with a fixed-capacity parallel model. Preliminary results from Experiment 2 also showed an intermediate divided attention effect for the semantic categorization of objects. Thus, it appears that divided attention limits performance for judgments of simultaneous objects, but the magnitude of this effect is smaller than for words.

Acknowledgement: NIH R01 EY012925

33.336 **Identification and localization tasks reveal the role of strength of association in Stroop and reverse Stroop effects** Amrita M Puri[1](apuri@uca.edu), Kenith V Sobel[2], Alxandr Kane York[2]; [1]Department of Biology, University of Central Arkansas, [2]Department of Psychology and Counseling, University of Central Arkansas

The fact that the Stroop effect is replicated much more often than the reverse Stroop effect has been attributed to the notion that in the traditional paradigm, which requires a verbal response, responding to the visual color with a color name requires translation of the perceptual stimulus to a verbal code, while reading the word does not (Durgin, 2000). Alternatively, Blais and Besner (2006) argue that the relative robustness of the Stroop compared to the reverse Stroop effect can be predicted by the strength of association between the features and the processing typically associated with the task. Accordingly, if identification of the target's color or the target word (as in the traditional Stroop paradigm) is more strongly associated with semantic processing than perceptual processing, the target's meaning should interfere with identification of the target's color more than the target's color interferes with reporting the word. In contrast, if localization is more strongly associated with perceptual processing, the target's color should interfere with localizing the target word more than vice versa. Participants viewed color words in either the congruent or incongruent ink color, and were asked to either identify the meaning of target words or their color (experiment 1), or localize target words among other words based on either word or visual color cues (experiment 2). Consistent with the strength-of-association explanation, the Stroop effect was larger than the reverse Stroop for identification, but smaller than the reverse Stroop for localization. Experiments 3 and 4 replicated the larger reverse compared to Stroop effect in localization, while also controlling for any contribution of faster overall RTs to the smaller Stroop interference in experiment 2. Thus, whereas the Stroop effect may dominate in identification tasks, the reverse Stroop effect appears to be reliably elicited by localization, supporting the strength-of-association account of Stroop interference.

33.337 **The automatic and non-automatic aspects of unconscious visual processing** Shao-Min (Sean) Hung[1,2](konaes@gmail.com), Daw-An Wu[1], Shinsuke Shimojo[1]; [1]Biology and Biological Engineering, California Institute of Technology, [2]Huntington Medical Research Institutes

Past studies have documented various unconscious influences on a conscious task. However, what characteristics enable an unconscious effect remains elusive. Specifically, in this study we examined the importance of automaticity of unconscious processing and asked (1) When different unconscious information co-exists, will automated information be prioritized? (2) Does unconscious processing share limited attentional resources with conscious processing? We adopted a Stroop paradigm and measured how color (lowly automated) and word (highly automated) consistency between a subliminal prime and a supraliminal target influenced participants' responses on the target. While keeping all other procedure and manipulation identical, participants were either instructed to name the color (Stroop condition) or word (Reverse Stroop condition) via button presses, leading to differential attentional load in the two task conditions. In the word-naming task, we showed that word but not color inconsistency slowed down the response time to the target, suggesting that automatic semantic activation was prioritized. Critically, during color naming, the same effect occurred only after a significant practice effect on the color naming (i.e. reduction of response time) was obtained, suggesting that lowering attentional load of a conscious task released additional attentional resources to enable the unconscious semantic effect. These findings were later replicated in separate experiments that isolated the color and word aspects of the prime. Across all experiments, chance rate performance on a 2-alternative-force-choice task of the subliminal prime location indicated that the interocular suppression was successful. We argue that information automaticity may be one determining factor of an unconscious effect. However, unconscious processing shares attentional resources with conscious processing in the current paradigm, showing its non-automatic nature. These results present a new framework to reconsider the interaction between conscious and unconscious visual information.

Acknowledgement: James Boswell Postdoctoral Fellowship

33.338 **How is Attention Deployed in a Complex Visual Environment?** Karla K Evans[1](karla.evans@york.ac.uk), Lucy S Spencer[1], Annakaisa Ritala[1]; [1]Department of Psychology, The University of York

Visual perception of everyday complex environments involves both the individuation and recognition of objects and the extraction of global image properties and summary statistics of the scene. Evidence suggests different visual attentional mechanisms are engaged for completion of these disparate tasks. Does allocation of one or multiple mechanism afford us this perceptual processing? One option is workings of a single mechanism whose activity ranges on a spectrum from narrowly focused analysis of local binding of features, to global registration of image statistics. Other models suggest that it is a result of two mechanisms working either in parallel or serial manner, where one is selective and effortful and other rapid global and non-selective. We used a dual-task paradigm to test these three possible models, by measuring the effect of simultaneously doing a secondary task on the performance on one of the two primary tasks. One primary task required global processing, to find the direction of average dot motion and the other required focused processing to individuate a single dot's direction of motion within the same display of dots, both equated for difficulty. In two experiments, secondary task requiring global processing (image categorization or average color detection) was performed simultaneously with a primary task either requiring the same or requiring focused processing. Comparing observers' performance on two concurrent tasks to that on single-task conditions showed greater performance reduction for the focused task during dual-tasks condition than for the global task. We observe a double dissociation when the secondary task demanding focused processing (object localization or bisected disk differentiation) was performed concurrently with primary task requiring the same, or that requiring global processing. Then performance on the global task deteriorated significantly more than on the focused task. Results support the view of two visual mechanisms being deployed serially in complex visual environments.

33.339 **Dividing attention across opposing features normalizes fMRI responses in visual cortex** Geoffrey M Boynton[1](gboynton@uw.edu), James M Moreland[1]; [1]Deparment of Psychology, University of Washington

Attending to a specific feature, such as a color or direction of motion enhances the response of neurons that are selective to that feature, even outside the focus of spatial attention(Saenz, Buracas, & Boynton, 2002). This spread of activity across space can act to facilitate perception of behaviorally relevant stimuli. However, when multiple features are relevant, what is the effect on behavior and brain activity? We tested this by comparing behavioral performance and fMRI responses while observers viewed fields of overlapping moving dots (up and down) at two locations (left and right of fixation). Subjects performed a divided attention task in the MRI scanner by detecting target events within one field on each side of fixation. Attention could be directed to fields moving the same direction on both sides, or to different directions.We found that performance was better when dividing attention to the same direction on both sides than to different directions, replicating Saenz et al. (2003). We then used an inverted encoding model approach on fMRI responses (IEM: Brouwer and Heeger 2009; Foster et al. 2017) to examine the effect of attention on neuronal subpopulations selective to specific directions of motion at specific locations.In areas V1, V2, V3 and MT we found larger responses to the attended direction than the unattended direction when subjects attended to the same direction on both sides. However, when subjects attended to different directions, no overall difference was found in the response across the four fields.These results can be explained by a natural extension of the normalization model of attention to include a spatial spread of feature-based attention gain which serves to mutually enhance responses when attention is directed to the same direction on both sides, but suppresses responses when attention is directed to opposite directions of motion.

Acknowledgement: NIH EY12925

33.340 **Conflation of canonical patterns during enumeration under attentional load** Gordon Briggs[1](gordon.briggs@nrl.navy.mil), Christina Wasylyshyn[1], Paul F Bello[1]; [1]U.S. Naval Research Laboratory

Enumeration of canonical patterns (e.g., dot arrangements on dice) is more rapid and accurate than enumeration of randomized arrangements of visual items (Mandler and Shebo, 1982). While previous studies have shown that enumeration of randomized arrangements can be disrupted by attentional load (Olivers & Watson, 2008), the enumeration of canonical patterns under similar conditions has been unexplored. To investigate enumeration of canonical patterns under attentional load, we adapted a spatial dual-task paradigm in which subjects had two potential tasks: report the relative dimensions of a centrally-located cross and enumerate a peripheral cluster of dots appearing in a random quadrant. Subjects were asked to either perform the peripheral task only (full attention trials) or both tasks (divided attention trials). Crowd-sourced participants (n=88) were split between randomized and dice pattern arrangement conditions. A repeated measures ANOVA showed significant within-subjects effects of attentional load, $F(1,86)=106.56$, $p< .001$, and cluster numerosity, $F(4.03,346.96)=157.96$, $p< .001$. Interaction effects were found between numerosity and arrangement, $F(4.03,346.96)=13.14$, $p< .001$, and numerosity and attentional load, $F(4.45,382.52)=5.23$, $p< .001$. We replicated previous findings for randomized arrangements, with enumeration error increasing with cluster numerosity and attentional load. For dice patterns, enumeration error also increased under attentional load. Additionally, contrary to findings from studies on single-task enumeration of dice patterns, we observed conflation of patterns with similar outlines. Specifically, in both full and divided attention trials, participants conflated dice patterns of six and five with four and patterns of three with two. In subsequent experiments, we swapped the peripheral and central tasks, placing the dot cluster in the center. With centrally-located canonical patterns, enumeration accuracy was consistent with results from single-task studies. We hypothesize that subjects may be using shape cues to inform guessing during enumeration tasks when unable to both localize and fully attend to target patterns.

Acknowledgement: This work was supported by a NRC Research Associateship award to GB, and AFOSR MIPR grant #F4FGA07074G001 and ONR grant #N0001416WX00762, both awarded to PB.

33.341 **How does the visual system handle spatially predictable visual interference during a non-visual task?** Dekel Abeles[1](d_abeles@msn.com), Shlomit Yuval-Greenberg[1,2]; [1]School of Psychological Sciences, Tel Aviv University, [2]Sagol School of Neuroscience, Tel Aviv University

Participants often avert their gaze from irrelevant visual stimulation while engaged in non-visual tasks. We have previously suggested the "overt disengagement hypothesis", claiming that the role of gaze aversions is to avoid the automatic processing of complex task-irrelevant visual stimuli in order to free up attentional resources for the non-visual task. While this explanation accounts for gaze aversions in the presence of complex visual stimulation, it does not explain why gaze aversions occur even when there are no complex visual distractors. In the present study we tested the hypothesis that during non-visual tasks, gaze is averted not only from locations where visual stimulation is presented but also from the predicted location of

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appearance of future distractors. Participants performed a continuous mental arithmetic task which required no visual information: they were instructed to continuously subtract or add seven to a 3-digit number presented briefly at the beginning of the trial. In random timings, a crowded display (distractor) appeared briefly in one of the four quartiles of the screen, in a constant location throughout each block. The distractor consisted of either 3-digit numbers (high-relevance to the task) or mirrored images of the same numbers (low-relevance to the task). Results show that, when performing the mental arithmetic task, participants tended to spend most of the time, fixating on the center of the screen. However, when they drifted away from fixation, they tended to do so towards the direction opposite the location of the predicted distractor. There was no difference in behavior between low-relevance and high-relevance distractors.We conclude that gaze aversion behavior is, at least partially, influenced by the predicted location of potential disruption regardless of its contextual relevance. This indicates that gaze aversion behavior is not a mere response to the presentation of a physical stimulus but depends on theoretical statistical inference.

Acknowledgement: Israel Science Foundation (ISF) grant 1427/14

33.342 **On the interaction between Visual Working Memory and pre-saccadic attention.** Soazig Casteau[1](soazig.casteau@durham.ac.uk), Charlotte Bush[1], Mary Chalkley[1], Natalie Rogerson[1], Daniel T Smith[1]; [1]Psychology Department, Durham University

Previous studies have shown that the maintenance of an object in visual working memory (VWM) automatically biases spatial attention toward the location of an object with matching features. Oculomotor theories of attention argue this bias occurs because of competition between the motor plan for the saccade endpoint and location of object held in VWM. Here we looked at the interaction between VWM and motor control by measuring attention when the goal of a saccadic eye-movement is congruent or incongruent with location of an object sharing properties with the content of VWM. In the current study, participants had to perform a saccade towards a specified location (the Saccade Target, ST) and made a discrimination decision (the Discrimination Target, DT). In the experimental condition, they had to retain a colour in VWM for the whole duration of the trial (the Memory Target; MT). There were four different conditions: 1) MT congruent with both ST and DT, 2) MT congruent with DT but incongruent with ST, 3) MT congruent with ST but incongruent with DT, 4) MT incongruent with both ST and DT. In 1/3 or the trial the MT colour was absent from the stimulus array. As expected, pre-saccadic attentional facilitation was greatest when the content of the VWM, the direction of the saccade and the DT location were all congruent, and abolished when ST, DT and MT were at different locations. Critically, when the ST and DT were in the same location but the MT at a different location pre-saccadic attentional facilitation was significantly reduced, suggesting competition between the saccade goal and the MT. Our results are consistent with the idea that automatic guidance of attention by the content of VWM can be operationalised as a competition between different saccade goals in the oculomotor system.

Acknowledgement: ESRC grant (ES/N018842/1)

33.343 **Pupil dilation as a predictor of perceptual capacity in subitizing** Joshua O Eayrs[1](Joshua.Eayrs.13@ucl.ac.uk), Nilli Lavie[1]; [1]Institute of Cognitive Neuroscience, University College London

The phenomenon of subitizing (the rapid detection and individuation of a small number of items in parallel, in contrast to the serial set-size slope for counting larger numbers) has been proposed to reflect a parallel visual perception process with limited capacity. A growing body of studies has related subitizing to visual attention, demonstrating shared capacity between subitizing and various visual attention tasks, such as object tracking (Chesney & Haladjian, 2011); feature versus conjunction target discrimination (Vetter et al. 2008); and the attentional blink (Burr et al. 2010; Olivers & Watson 2011). Indeed, recent work demonstrates that individual differences in subitizing capacity are associated with a common 'perceptual capacity' factor underlying performance across diverse visual attention tasks (Eayrs & Lavie, 2018). Here, we tested the perceptual capacity hypothesis of subitizing further by investigating the pupil dilation pattern in response to subitizing versus counting in visual enumeration. Pupil dilation is a well-established physiological marker of attention demands (e.g. Alnaes et al. 2014). The parallel perceptual processing with limited capacity model of subitizing predicts a bifurcation of the pupil dilation by set-size function at the subitizing capacity limit, with a parallel slope up to the limit and a serial slope beyond. To test this prediction we recorded pupil diameter while participants reported the number of target shapes from brief, luminance-matched displays containing 1-7 target shapes among 8-14 non-target shapes. The overall results showed no linear effect of set-size up to 4 targets and a linear increase thereafter. Importantly, the bifurcation point of an individual's RT by set-size function was correlated with their capacity estimate based on the bifurcation of the pupil diameter function. These results support the perceptual capacity hypothesis of subitizing and demonstrate that individual differences in subitizing capacity can be predicted from pupil dilation patterns.

Acknowledgement: The research was funded by a grant from Toyota Motor Europe

33.344 **Both exhaustive processing and limited-sample amplification contribute to ensemble averaging** Alexey U. Yakovlev[1](-bonashee@gmail.com), Igor S. Utochkin[1]; [1]Higher School of Economics

It has been shown that multiple objects can be efficiently represented as ensemble summary statistics, such as the average. Recently, Kanaya et al. (2018) demonstrated the amplification effect in the perception of average. Their participants judged the mean size or temporal frequency of ensembles, and they tended to exaggerate their estimates, especially larger set sizes. Kanaya et al. explained it by non-exhaustive sampling mechanism favoring ~sqrt(N) most salient items, which are either largest or most frequently ones. But how do the rest of elements contribute to ensemble perception? In our study, we used orientation averaging (which does not have any inevitably salient values) and manipulated the salience of individual items via size. Participants had to adjust the average orientation of 4, 8, or 16 triangles. We measured systematic biases, like Kanaya et al. (2018), and SD of errors that are known to correlate with the physical ensemble range. In Experiment 1, most clockwise elements could be bigger, counterclockwise, middle, or all elements were same-size. We found strong clockwise and counterclockwise biases in the corresponding conditions. The biases increased with set size replicating Kanaya et al. (2018). But we found no SD difference between the conditions suggesting that all items were somehow taken into account. In Experiment 2, we compared distributions with same ranges (full-sets) but salient elements being middle or extreme (most clockwise and counterclockwise). We used distribution with only middle elements or only extremes as controls (half-sets). We found that SD in the full-sets were greater than in the middle half-sets and smaller than in the extreme half-sets suggesting that all items were taken into account. We also found that SD in the extreme full-sets were greater than in the middle full-sets in large set size. We conclude that both exhaustive and amplification types of sampling work in averaging.

33.345 **The number of visible victims shapes visual attention and compassion** Brandon M Tomm[1](brandon.tomm@psych.ubc.ca), Paul Slovic[2,3], Jiaying Zhao[1,4]; [1]Department of Psychology, University of British Columbia, [2]Decision Research, [3]Department of Psychology, University of Oregon, [4]Institute for Resources, Environment, and Sustainability, University of British Columbia

When disaster strikes, compassion fades as the number of victims increases. What causes this compassion fade? We propose that as the number of victims increases, attention to each victim declines, which may help explain compassion fade. In an online experiment, participants (N=452) read a brief story about a recent earthquake in Indonesia with an image showing children who were displaced by the earthquake. After the story, participants made hypothetical donations an organization that provides emergency services to the region. We manipulated the number of children in the image and also the content of the story. Specifically, the image contained 1, 2, or 3 children, and the story contained either statistics of victims and damages in the local region, or not. We used the BubbleView technique to measure visual attention while participants were reading the story and the image. Specifically, the story and the image were initially blurred and participants had to use their cursor to reveal the underlying content via a fovea-like circular area around the mouse. The location of the cursor was tracked as a proxy for visual attention. We found that participants looked less at each child as the number children in the image increased, or when there were statistics in the story compared to no statistics. Importantly, attention sharply declined when the image contained more than one child. In fact, the proportional dwell time per child decreased by 26% from one child to two children, which corresponds to a 12% drop in donations. These results suggest that compassion fade may be driven by divided attention. Each additional victim receives less attention, which reduces the compassion experienced for the victim. The current study offers a novel attentional account for psychic numbing and compassion fatigue.

Sunday AM

33.346 **Spatial distribution of attention under varying task demands**
Suhyeon Jo[1](j77460744@gmail.com), Suk Won Han[1]; [1]Department of Psychology, Chungnam National University

When people are performing a goal-directed task, they are often subject to interference by task-irrelevant distractors. We investigated how attention is distributed between the target and distractors under varying task loads. In the experiment, in half of trials, participants performed a letter-identification task, under three conditions. In the low load condition, only a target and a distractor, whose colors were green, were displayed. The distractor could be the same as or different from the target letter, presented to the left or right of the target. In the high load condition, the target was surrounded by 5 green, non-targets letters. In the dilution condition, the stimuli were identical to high load except that each non-target letter had distinct colors. In the remaining half (probe-discrimination trials), the 200-ms presentation of the letter task stimuli were followed by the presentation of a visual probe stimulus. The probe appeared at the target, non-target, or distractor location, 50,180,250 or 400 ms after the onset of the search task. As results, the magnitude of distractor interference was greater for the low load than for the high load and dilution conditions, p's < .01. The analysis of probe data revealed that in the low load and high load conditions, probe responses were significantly slower when the probe was at the distractor location than at the target and non-target location, p's < .01, with no difference between these two throughout all the SOAs. However, in the dilution condition, probe responses were significantly faster for the target location than for other locations at the 180-ms SOA, p's < .01. These results suggest that in the dilution condition, attention is solely focused on the target, decreasing distractor interference. By contrast, in the high load condition, rather than attentional focusing, the exhaustion of perceptual load seems to eliminate distractor interference.

33.347 **The effect of monetary reward on visual awareness**
Claudia Lunghi[1](clalunghi@gmail.com), Arezoo Pooresmaeili [2]; [1]Laboratoire des systèmes perceptifs, Département d'études cognitives, École normale supérieure, PSL University, CNRS, Paris, France., [2]Perception and Cognition Group, European Neuroscience Institute, Göttingen, Germany.

It is well known that monetary value enhances visual perception and attention (Pessoa 2015) and boosts activity in the primary visual cortex (Pooresmaeili et al, 2014), however, it is still unknown whether monetary reward can modulate visual awareness. To investigate this issue, we performed a psychophysical experiment using a breaking continuous flash suppression (b-CFS) paradigm. Suppression times of sinusoidal gratings (orientation ±45°, size 2°, SF: 2cpd) under CFS were measured in a group of 11 subjects (4 males, mean age: 26±6 years) before and after a short (100 trials) session of implicit learning in which each of the two possible grating orientations were associated either with high or low monetary reward. In a control condition during the training session the two orientations were associated with similar monetary rewards but had different contrasts (80-40%). We found that monetary reward modulated CFS by promoting dominance of the grating associated with high-reward over that associated with low reward (RM-ANOVA, $F(3,30)=5.42$, $p=0.004$). Specifically, suppression durations of the visual stimulus associated with high reward were on average 800 ms shorter after the training ($t(10)=4.31$, $p=0.006$) compared to baseline measurements, whereas the suppression duration of the stimulus associated with low reward did not change after training. Suppression durations did not change in the control experiment, indicating that the effect of monetary reward could not be attributable to low-level saliency of the visual stimulus. These results show that monetary reward modulates visual awareness by facilitating the access to awareness of visual stimuli associated with high monetary value, probably by boosting top-down modulation of activity in the early visual cortex. References Pessoa L. Multiple influences of reward on perception and attention. Vis cogn 2015;23(1–2):272–290. Pooresmaeili A, et al. Cross-modal effects of value on perceptual acuity and stimulus encoding. Proc. Natl. Acad. Sci. 2014;111(42):15244–15249.

33.348 **Task-dependent effects of volitional visuospatial orienting on perception**
Ralph S. Redden[1](rredden@dal.ca), Drake Mustafa[1], Raymond M. Klein[1]; [1]Dalhousie University

Titchener's fourth law of attention—the law of prior entry—states that the object of attention comes to consciousness more quickly than the objects which we are not attending to, or otherwise that attended stimuli are perceived prior to unattended stimuli. The phenomenon of prior entry is typically investigated in a temporal order judgment task (TOJ). When visuospatial orienting is elicited volitionally, the effect of the contingency manipulation—intended to engender the shift of attention—on perceptual tasks (i.e., TOJs, colour perception) is task-dependent (Shore, Spence & Klein, 2001; Redden, d'Entremont & Klein, 2017a/b). Our recent work has shown that, regardless of the type of TOJ task used to measure prior entry, there is a robust facilitatory effect on colour perception in an orthogonal task due to volitional visuospatial orienting. However, whether the colour perception benefit is for the probability or the resolution of encoding depends on the type of TOJ task being administered. Across experiments, whether individuals are required to make TOJs to moving, or onset, or both, types of stimuli has an effect on whether prior entry is observed—when presented alone we observe prior entry for onset but not motion stimuli, but when intermixed we observe prior entry for motion but not onset stimuli. The implications for task-dependent attentional control settings on the perceptual consequences of volitional visuospatial orienting will be discussed.

Acknowledgement: NSERC and KIllam Trusts

Attention

Sunday, May 19, 8:30 am - 12:30 pm, Banyan Breezeway

33.349 **Modeling task influences for saccade sequence and visual relevance prediction**
David Berga[1](dberga@cvc.uab.es), Calden Wloka[2,3], John K Tsotsos[2,3]; [1]Computer Vision Center, Universitat Autònoma de Barcelona, [2]Department of Electrical Engineering and Computer Science, York University, [3]Centre for Vision Research

Previous work from Wloka et al. (2017) presented the Selective Tuning Attentive Reference model Fixation Controller (STAR-FC), an active vision model for saccade prediction. Although the model is able to efficiently predict saccades during free-viewing, it is well known that stimulus and task instructions can strongly affect eye movement patterns (Yarbus, 1967). These factors are considered in previous Selective Tuning architectures (Tsotsos and Kruijne, 2014)(Tsotsos, Kotseruba and Wloka, 2016)(Rosenfeld, Biparva & Tsotsos 2017), proposing a way to combine bottom-up and top-down contributions to fixation and saccade programming. In particular, task priming has been shown to be crucial to the deployment of eye movements, involving interactions between brain areas related to goal-directed behavior, working and long-term memory in combination with stimulus-driven eye movement neuronal correlates. Initial theories and models of these influences include (Rao, Zelinsky, Hayhoe and Ballard, 2002)(Navalpakkam and Itti, 2005)(Huang and Pashler, 2007) and show distinct ways to process the task requirements in combination with bottom-up attention. In this study we extend the STAR-FC with novel computational definitions of Long-Term Memory, Visual Task Executive and a Task Relevance Map. With these modules we are able to use textual instructions in order to guide the model to attend to specific categories of objects and/or places in the scene. We have designed our memory model by processing a hierarchy of visual features learned from salient object detection datasets. The relationship between the executive task instructions and the memory representations has been specified using a tree of semantic similarities between the learned features and the object category labels. Results reveal that by using this model, the resulting relevance maps and predicted saccades have a higher probability to fall inside the salient regions depending on the distinct task instructions.

Acknowledgement: Office of Naval Research (ONR) (N00178-16-P-0087), Universitat Autònoma de Barcelona (UAB) (Estades Breus PIF 2018), Spanish Ministry of Economy and Competitivity (DPI2017-89867-C2-1-R), Agencia de Gestió d'Ajuts Universitaris i de Recerca (AGAUR) (2017-SGR-649), and CERCA Programme / Generalitat de Catalunya

33.350 **Precise localization in conflicting context requires feedback processing**
Sang-Ah Yoo[1, 4](sangahy@yorku.ca), John K. Tsotsos[2, 4], Mazyar Fallah[1, 3, 4]; [1]Dept. of Psychology, York University, [2]Dept. of Electrical Engineering and Computer Science, York University, [3]School of Kinesiology and Health Science, York University, [4]Centre for Vision Research, York University

People can rapidly perform simple visual tasks, such as object detection or categorization, suggesting the sufficiency of feed-forward visual processing for these tasks. However, more complex tasks, such as precise localization may require high-resolution information available at early areas in the visual hierarchy. Top-down feedback processing that traverses several stages in the visual hierarchy allows access to this information, but additional processing time is needed for this traversal (Tsotsos et al., 2008). Motivated by this, we hypothesized that a localization task which requires precise location information represented in early visual areas would need longer processing time than a simple categorization task. Each participant performed both categorization (animal detection) and feature localization tasks. We constrained

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stimulus presentation durations and compared processing time needed to perform each task. Performance would be asymptotic at shorter presentation duration if feed-forward processing suffices for a task, whereas performance would gradually improve as duration increases if the task employs feedback processing. In Experiment 1 where simple images were presented, both categorization and localization performance sharply improved until 100 ms then it leveled off. Feature localization mirrored the previously reported rapid categorization but did not support the involvement of feedback processing, indicating that the task could be performed based on coarse location information obtained via feed-forward processing. In Experiment 2, more attention-demanding and ecologically valid images were used as stimuli. We observed that categorization performance again plateaued after 100 ms as in Experiment 1. However, localization precision gradually improved as presentation duration increased as we hypothesized. A piecewise linear model explained these data better than a simple linear model, suggesting that both feed-forward and feedback processing contributed to localization but at different temporal ranges. To conclude, feedback processing is necessary for a visual task that requires high-resolution representation, including precise localization in conflicting context.

Acknowledgement: JKT: Air Force Office of Scientific Research (FA9550-18-1-0054), the Canada Research Chairs Program (950-219525), and the Natural Sciences and Engineering Research Council of Canada (RGPIN-2016-05352), MF: the Natural Sciences and Engineering Research Council of Canada Discovery Grants (RGPIN-2016-05296) and the Canadian Foundation for Innovation Leaders Opportunity Fund.

33.351 **Physical interaction makes invisible surfaces visible**
Patrick C Little[1](patlittle@jhu.edu), Chaz Firestone[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

Perhaps the most basic task faced by visual processing is to detect the presence of objects; before computing an object's color, shape, or orientation, we must first register that something is there. Detection may be fairly straightforward when an object is fully visible, but in many realistic viewing conditions the visual system can only infer the presence of objects using cues such as continuity behind occluders, coincidental clipping of multiple figures, or unified motion against a background. All such cues, however, concern fairly low-level aspects of visual processing, encompassing only basic geometric and kinetic factors. Might more sophisticated forms of input cue an object's presence? Here, we explore how a surprisingly high-level cue—physical interaction—can imply the presence of a hidden surface, in ways that directly facilitate later detection. Subjects saw an animation of a disk falling and then unexpectedly bouncing off of an 'invisible' surface. Sometimes, the disk bounced straight back up, implying a flat surface; other times, the disk's bounce implied an angled surface. Afterwards, a visible line appeared where the disk had just bounced, whose orientation either matched or didn't match the surface implied by the disk's exit trajectory; subjects' task was simply to report the orientation of this new, visible line, regardless of the physical events that came before it. Subjects were faster and more accurate at reporting the line's orientation when it matched the orientation of the physically implied surface vs. when it conflicted. Follow-up experiments extended this work to attentive search in multi-event displays; again, detection of a specific oriented line was facilitated by seeing physical interactions that implied surfaces with that orientation. This work shows how a process as basic and seemingly low-level as detecting the presence of an object or contour can be influenced by a surprisingly high-level cue: otherwise-unexplained physical interactions.

Acknowledgement: JHU Science of Learning Institute

33.352 **Modeling attention during visual search with hierarchical Bayesian inference**
Justin Theiss[1](theissjd@berkeley.edu), Michael Silver[1]; [1]University of California, Berkeley

The Bayesian brain hypothesis (Knill & Pouget, 2004) suggests that the visual cortex infers properties of a visual scene by computing conditional probabilities of underlying causes given a particular image. Within this framework, top-down spatial and feature-based attention have been modeled as feedback of prior probabilities over locations and features, respectively (Rao, 2004; Chikkerur et al., 2010). The present study investigated whether, given an image and top-down priors, the posterior probability of a feature map could be used to guide simulated eye movements in a computational model performing a visual search task. A two-layer hierarchical generative model (Lee et al., 2009) was trained on images of handwritten digits (MNIST; LeCun et al., 1998) using unsupervised learning. In this model, activity in the first layer represents the conditional probability of features (e.g., oriented lines), given the image, while feedback from the second layer represents the prior over first-layer features. In order to simulate eye movements, the model selected locations within the image based on the maximum posterior probability of the first-layer feature map, given the image and second-layer feedback. The model was tested using a visual search task for a digit (approximately 20x20 pixels) placed among non-digit distractors in a 60x60 pixel search array. For each trial, the model selected the most probable location of a single target digit placed randomly in the search array. In order to quantify the accuracy of the model, correct trials were defined as selecting a location within 10 pixels of the target center. Across 10,000 trials, the model was able to correctly locate the target on 70% of trials (chance: 11%). These results suggest that a visual system conforming to the Bayesian brain hypothesis could accurately perform visual search by using Bayes' rule to combine bottom-up sensory information with top-down priors.

33.353 **Playing nicely with your robot.**
Jeremy M Wolfe[1,2](jwolfe@bwh.harvard.edu), Makaela S Nartker[1]; [1]Surgery, Brigham & Womens' Hospital, [2]Radiology & Ophthalmology, Harvard Medical School

When humans and AI agents collaborate on visual decisions, it does not always go well. In breast cancer screening, for example, the combination of expert radiologists with expert AI does not produce as much benefit as signal detection theory might predict. We study this interaction with an artificial 2AFC task where observers classify textures as positive or negative based on average color. Signal and noise color mixtures are drawn from overlapping normal distributions (d'=2.2). Observers can be helped by a simulated AI (also d'=2.2). We tested three conditions. 1) AI acts as a "second reader". After the human response, AI states if it disagrees with the human decision. Humans can then choose to change or not change their response. 2) AI could "triage" trials before human response, showing humans only those stimuli that might plausibly contain signals. The criteria for making these AI decisions is a parameter that can be manipulated. For example, for triage, it makes sense to set a 'liberal' criterion so that AI makes very few "miss" errors. Method 3 combines 1 & 2 on the same trial. When these AI rules are used in a block of trials with 50% signal prevalence, AI helps the observer. However, when signal prevalence is 10%, second reader AI actually hurts performance and triage does little or nothing to help. Interestingly, if the same AI information is used both for triage and as a second reader on the same trial, performance is improved at both 10% and 50% prevalence. Asking your AI about its opinion in two different ways may be useful. This example comes from just one set of parameters. The method is flexible and can reveal rules of collaborative perceptual decision making. These experiments illuminate circumstances where intelligent algorithms can be helpful to human experts.

Acknowledgement: NIH EY017001, CA207490

33.354 **Cueing Effects in the Attentional Network Test: a Spotlight Diffusion Model Analysis**
Ryan A Curl[1](rcurl@syr.edu), Corey N White[2]; [1]Syracuse University, [2]Missouri Western State University

The attentional network test (ANT) uses flanker stimuli with different cue conditions to quantify differences in attentional processing. However, it is unclear precisely how the alerting and orienting cues in the task affect different decision processes. The present study leveraged computational modeling to identify the relationship between attentional cues and decision components. ANT data from a large sample of 156 participants were analyzed using the spotlight diffusion model, which quantifies decision components for response caution, motor/encoding time, perceptual processing, and attentional control. The spotlight analysis showed that the attentional cues had multiple effects on decision processing. Compared to the no cue condition, an alerting cue led to faster encoding/motor speed, improved perceptual processing, and increased attentional focusing. The orienting cue further led to a decrease in response caution and increased encoding/motor speed and attentional focusing to reduce interference from incompatible flankers. Improvements in RTs can stem from multiple factors, so it is important to have a method to delineate these factors and determine which ones are driving differences in behavior. This analysis demonstrates that alerting and orienting cues have complex effects on decision processes that are not captured by simple differences in RTs, and that model-based analyses can delineate such effects to allow researchers to identify precisely how attentional processing varies across individuals or conditions in tasks like the ANT. Future work investigating differences in cognitive processing can benefit from the incorporation of model-based analyses to provide greater insight into the underlying factors that drive task performance.

33.355 **Neural mechanisms underlying individual differences in attentional blink** Liqin Zhou[1](zhouliqin469@126.com), Zonglei Zhen[2], Jia Liu[2], Ke Zhou[2]; [1]College of Psychology and Sociology, Shenzhen University, [2]Beijing Key Laboratory of Applied Experimental Psychology, School of Psychology, Beijing Normal University

Attentional blink (AB) is a well-known phenomenon that detection of a first target (T1) results in reduced identification of a subsequent target (T2) presented within about 500ms in a rapid serial visual presentation (RSVP) stream. However, the neural bases of AB are still not well established. In the present study, we combined multimodal MRI and transcranial magnetic stimulation(TMS) to examine the brain structure and functional connectivity basis of AB. Based on multimodal MRI data from a large group of subjects, we used individual differences approach to search brain areas whose local gray-matter volume (GMV), and resting-state functional connectivity (RSFC) correlated with individuals' AB magnitude, which was measured by a classical AB paradigm. Further, triple-pulse TMS was used to verify the causal role of the discovered regions. We finally found that: (i) GMV in right temporo-parietal junction (rTPJ), which is essential for attentional reorienting, was positively correlated with AB magnitude; (ii) RSFC between left inferior frontal junction (lIFJ) and rTPJ was negatively correlated with AB magnitude; (iii) Both the correlation between lIFJ-rTPJ connectivity and AB magnitude, and the correlation between rTPJ GMV and AB magnitude were modulated by T1 performance: both lIFJ-rTPJ connectivity and rTPJ GMV predicted AB magnitude only for individuals with low T1 performance, not for those with high T1 performance; (iv) transient disruption of lIFJ by TMS after T1 onset attenuated theAB magnitude. Taken together, our findings revealed that differences in brain structure of rTPJ and its functional connectivity with lIFJ accounted for individual differences in AB magnitude, and that lIFJ also played a causal role in AB.

Acknowledgement: This work was supported by the National Nature Science Foundation of China grant (31671133, 31771251) and Shenzhen Science and Technology Research Funding Program (JCYJ20170412164413575).

33.356 **An attentional blink for ensemble representations** Sneha Suresh[1](sursn-19@rhodes.edu), John W Roberts [1], Jason Haberman [1]; [1]Department of Psychology, Rhodes College

The visual system averages similar features in our environment in a process known as ensemble perception. Substantial evidence suggests ensemble perception effectively operates even with limited attention, providing visual stability in a dynamic visual environment. Such findings raise the possibility that ensembles are robust to the attentional blink, a paradigm in which observers are unable to detect a second target in an RSVP stream after detection of a different, first target. In the current set of experiments, we explored whether ensemble representations are subject to an attentional blink. In our paradigm, observers viewed rapidly presented, cross-hatched patches, created by overlapping two orthogonally oriented gabors. Observers first had to detect a particular feature (T1), which varied across experiments (e.g., vertical or horizontal, red or blue, high or low spatial frequency), after which they had to adjust a test stimulus to match the average of the preceding set (either orientation or color; T2). The time between T1 and T2 varied among 400, 600, and 1800 ms. Adjustment performance improved at 1800 ms, but only when T1 and T2 came from different visual domains. This suggests that it is possible to at least partially blink ensemble information. When the T1 judgment came from the same visual domain as T2 (e.g., two orientation judgments), performance on the averaging task was consistently worse than when T1 came from a different domain (e.g., a color judgment followed by an orientation judgment), and did not vary as a function of ISI. Overall, these results suggest that, even though ensembles are extracted efficiently from the visual environment, they are nonetheless dependent on the availability of attentional resources.

33.357 **Attentional blink in preverbal infants** Shuma Tsurumi[1](perry.super178@gmail.com), So Kanazawa[2], Masami K Yamaguchi[1], Jun Kawahara[3]; [1]Department of Psychology, Chuo University, [2]Department of Psychology, Japan Women's University, [3]Department of Psychology, Hokkaido University

Cognitive models of visual attention propose that the visual perception is based on two processing stages; all visual stimuli would be rapidly processed as representation in the first stage, and then the limited stimuli attention directed would be encoded and consolidated in working memory. Although this model emphasizing the involvement of working memory has been tested in adults and children, it is not clear whether these principles apply to perception in preverbal infants. Specifically, we focused on the attentional blink effect, in which identification of the second of two brief targets is impaired when inter-target lags are short, and addressed this question by examining whether the effect could be observed in infants. This phenomenon has been attributed to the processing delay in working memory. We reasoned that finding a similar pattern of the attentional blink in preverbal infants as found in adults would imply a hallmark of working memory functioning similarly to adults. In the present study, we presented 7- to 8- month-old infants rapid serial visual streams including two female faces as targets, and examined whether infants could identify these two targets. The temporal separations between the first and the second target were 200 and 800 ms for Lag 2 and Lag 8 conditions, respectively. We predicted that infants could identify the first target regardless of the Lag conditions. More importantly, would fail to identify the second target only under Lag 2 condition (i.e., the attentional blink) if their working memory functions as adults. As expected, we found attentional blink in infants. They could identify both targets in Lag 8 condition, whereas they failed to identify the second target only under the Lag 2 condition. These results suggest that working memory in 7-to 8- month-olds functions with the same temporal parameters as adults.

33.358 **Individual differences in attention switching speeds predict the magnitude of the attentional blink.** Matthew S. Peterson[1,2](mpeters2@gmu.edu), Eric L Russell[1], Erika De Los Santos[1]; [1]Psychology, George Mason University, [2]Neuroscience, George Mason University

The attentional blink is a deficit in reporting the second of two targets, and peaks roughly 200-300 ms after the onset of the first target. Only a small proportion of individuals, sometimes known as non-blinkers, fail to show an attentional blink. One possible explanation for the attentional blink is that it is due to a delay in switching attention from processing the first target to processing the second. We used shifts of spatial attention as a proxy measure of attention switching speed. We based our task on that used by Peterson & Juola (2000), in which 3 RSVP streams are presented simultaneously, with precues indicating the likely spatial locations of T1 and T2. This allowed us to have separate measures of the attentional blink (both targets occurring in the same RSVP stream) and spatial shifting (targets occurring in separate streams). At the group level, our results are indistinguishable from the results of Peterson & Juola (2000), with accuracy for both tasks being nearly identical for every lag except for lag 1. However, individual differences tell a different story. We found that the magnitude of the attentional blink predicted spatial shifting speed, with low blinkers showing quicker shifts of spatial attention. In addition, blink magnitude predicted lag-1 sparing, with high-blinkers showing lag-1 sparing, and low-blinkers showing a lag-1 cost. In addition, switching speed predicted Lag-1 sparing, with fast-shifters showing little or no lag-1 sparing in the AB task. Taken as a whole, these results suggest that the attentional blink may be driven by the speed at which an individual can switch attention from one task to another.

33.359 **A compartmental model of feedback modulation in visual cortex** Christian Jarvers[1](christian.jarvers@uni-ulm.de), Heiko Neumann[1]; [1]Institute for Neural Information Processing, Ulm University

Problem: Cells at early stages of the visual processing hierarchy, as in cortical area V1, have small receptive fields and thus respond to items within a restricted region of the visual field. Perception, however, is influenced by global spatial and temporal effects, such as context, figure-ground interpretation, or working memory (van Kerkoerle et al., Nature Comm, 2017; Poort et al., Cerebral Cortex, 2016). The neural mechanisms underlying these processes are not yet understood. Method: We propose a computational model of visual cortex which is represented as an array of columns with granular (input), superficial, and deep compartments. Each compartment comprises excitatory, inhibitory, and dis-inhibitory units with continuous dynamics specified by first-order ordinary differential equations. The granular compartment receives bottom-up input and performs initial filtering. This activation is fed to cells in the superficial compartment to utilize lateral long-range interactions. The resulting activation is further progressed in an intra-cortical loop, activating cells in the deep compartment which subsequently modulate the input cells. Superficial and deep compartments additionally receive top-down modulating signals from other areas. Model simulations and theoretical analyses are performed for different stimulus and contextual conditions. Results and Conclusion: The model has been probed for stimulus conditions of figure-ground modulation and attentional target object selection. In particular, model parametrizations were fit to an attentional version of a curve-tracing task (Roelfsema & Houtkamp, Atten Percept Psychophys, 2011). It is demonstrated that the model dynamics successfully predict the multiunit activity in a working-memory version of the task. Our results suggest that a single mechanism, involving canonical cortical operations

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such as input filtering, modulating feedback, and normalization, implemented in different V1 compartments, can explain the laminar profile of activity in visual cortex across a wide variety of tasks.

33.360 **Selective Attention Desynchronizes Automatic Movements** Xilei Zhang[1,2,3](xilei_zhang@126.com), Wenming Zheng[1,2], Xiangyong Yuan[3]; [1]School of Biological Sciences and Medical Engineering, Southeast University, [2]Key Laboratory of Child Development and Learning Sciences of Ministry of Education, China, [3]Institute of Psychology, Chinese Academy of Sciences

Most daily acts, like sequential finger tapping and typewriting, are conducted with rare (if any) attentional or conscious guidance. Whereas, such automaticity must be available for revamp by deliberate attention in order to learn new skills. It yet remains elusive that attention may interact with automatic movements. Here we tackled this issue by quantifying the fast finger tapping movement to examine how selective attention interfere with automaticity. For Participants (N=16 for each experiment, all right-handed), tapping movements were recorded by 60HZ cameras and trajectories of the right-hand fingertips were extracted by DeepLabCut (Mathis et al., 2018), a video-based pose estimation toolbox. In Exp1 we used a dual-task paradigm to examine the effect of covert attention on automatic movement. While participants were watching the visual display and continuously tapping by four fingers, their covert attention were required to be allocated on the movement of the index finger (INDEX), the middle finger (MID), evenly distributed across all moving fingers (WHOLE) or exclusively on the letter counting task only (CTRL). Results reveal that 1) inter-finger synchrony was highest in CTRL, lowest in WHOLE, and intermediate in INDEX and MID. 2) inter-trial synchrony was reduced for all the attended fingers in INDEX, MID and WHOLE relative to the CTRL, and no significant changes were found for unattended fingers. All these effects have been well replicated in Exp2, in which we further examined the effect of overt attention by intentionally keeping eyes on the target finger(s) while neglecting the others. Exp3 further concluded that these effects cannot be artifacts of conceptual priming of targeted finger(s) since attending to the finger labels in the working memory instead of the movement while tapping made no attentional effects. Taken together, evidences here indicate intrinsic interactions between attentional allocation and automatic movements.

Perception and Action: Reaching and grasping

Sunday, May 19, 8:30 am - 12:30 pm, Banyan Breezeway

33.361 **Grasping 2-D Targets in Motion: The Influence of a Preferable Central Grasp Location on Eye-Hand Coordination** Ryan W. Langridge[1](langrirw@myumanitoba.ca), Jonathan J. Marotta[1]; [1]Psychology, University of Manitoba

When using a precision grip to grasp a rectangular object (index finger on top and thumb on the bottom of the object), digit placement is usually close to the object's horizontal center, ensuring stability.An object's position will also influence convenient digit placement (e.g. the left side of a rightward positioned object).This research investigated the direction of gaze and index finger placement while visually pursing and grasping moving targets that either allowed for or discouraged a central placement of the index finger and thumb when grasping.Right-handed participants' eye and hand movements were recorded while they reached for and 'grasped' 2-D computer generated targets translating horizontally across a computer screen. Reaches were cued at early, middle, and late stages of target travel. Control targets appeared as a 4 x 4 cm square.Experimental targets resembled Control targets, however the middle portion of the top and bottom edges were removed.At onset of target movement, gaze was directed toward its leading edge.During the reach itself, including at the time of contact, gaze and grasp positions shifted toward the trailing edge.This was especially true for grasps occurring at later stages of target travel, where deviations behind the midline were the largest.In general, gaze deviated further behind the Experimental targets' midline compared to the Control targets.Overall, horizontal gaze and index finger placement were closer to the target's midline when grasping Leftward moving targets.Though a misplaced grasp has no consequence when grasping 2-D targets, these results suggest participants favoured a safe, mechanically comfortable movement. In the absence of a preferable central grasp location, participants avoided the front of the object, potentially minimizing the risk of a collision with the leading edge.Increased accuracy when grasping leftward moving targets may reflect a compensatory strategy for cross-body reaching.

Acknowledgement: NSERC Discovery Grant, University of Manitoba Graduate Fellowship

33.362 **Eye-hand Coordination in Reaching and Grasping Vertically Translating Targets** Matsya R. Thulasiram[1](matsy.t@gmail.com), Ryan W. Langridge[1], Hana H. Abbas[1], Jonathan J. Marotta[1]; [1]Psychology, University of Manitoba

Previous research in our lab has revealed a strong visual bias toward the eventual index finger contact location when grasping stationary or horizontally moving targets. However, the unique properties of the thumb may have an increased role when grasping vertically moving targets.Using their index finger and thumb, right-handed individuals reached for and grasped 2-D rectangular targets moving upward or downward on a vertically oriented computer screen.It was expected that fixations would be directed toward the index finger when grasping upward moving targets, and to the thumb when grasping downward moving targets. In trials involving upward moving targets, initial fixations were positioned well above the target, in anticipation of the eventual movement, and remained above the target even after the target started to move. Gaze shifted to the leading (upper) edge of the target when participants initiated their reaching movement, suggesting that participants were primarily attending to the eventual contact location of the index finger. Initial fixations toward downward moving targets were positioned well below its bottom edge, once again anticipating eventual movement.When the targets started to move, gaze shifted upward to a position just below the target's centre of mass (COM) and remained there during reach onset.Final fixations for both upward and downward moving targets were positioned slightly above the target's COM, a location that would allow the monitoring of both index and thumb when grasping.These results suggest that while index finger placement is prioritized when grasping upward moving targets, visual attention is directed toward more central locations when grasping downward moving targets, thus allowing both contact points to be monitored simultaneously.This is suggestive of an increased importance of the thumb, in addition to the index finger placement, not shown previously when grasping stationary or horizontally translating targets.

Acknowledgement: NSERC Discovery Grant, NSERC Undergraduate Student Research Award

33.363 **Interaction of eye and hand movements during visual control of human reaching** Yan Yang[1,2](yyang@ibp.ac.cn), Dongbiao Sun[1,2]; [1]University of Chinese Academy of Sciences, Beijing 100049, China, [2]Institute of Biophysics, Chinese Academy of Sciences, Beijing, 100101, China

When we reach for an object, our eyes often guide toward the object as well. The behavioral pattern of both eye and hand movements directing to an object is well known as eye-hand coordination. We investigate interactions between eye and reaching movements in two types of behavioral tasks: 1) motor control, where human subjects were asked to do a memory-guided reaching task. A target was presented in one of 13 positions of a half circle (from -90o to 90o, by every 15o) for about 100ms. Behavioral results indicated that a systematic bias in both eye and hand movements correlated to reaching angles. 2) motor learning, where subjects were introduced scaled visual feedbacks of reaching endpoints. These visual instructions were scaled up or down by a function of angles. First, we have applied a single scaled feedback on one spot. Reaching movements to the spot have been adapted according to the instruction, while this learning effect can be generalized to all other positions. Second, we have applied double scaled feedbacks on two spots with an intersection angle of 90°, 60° or 30°. An adapted interference effect was found on these two spots. The learned response would be generalized to other positions differently based on intersection angles. Our data indicated that humans could be capable of learning a relationship between any two spatial instructions and generalize a learning effect in 2-D space.

Acknowledgement: CAS QYZDB-SSW-SMC019

33.364 **Grasping complex 3D shapes** Zoltan Derzsi[1](zd8@nyu.edu), Robert Volcic[1]; [1]New York University Abu Dhabi

Humans tend to effortlessly estimate the center of mass of objects before grasping them. It is known that minimum torque is required when the centroid of the contact points corresponds with or is near to the object's center of mass. This distance, when compared with respect to the dimensions of the grasped object, is inversely proportional to the quality of the grasping. In our experiment, we measured the distance between the center of mass and the grasping contact point centroid when participants grasped

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a sphere or three noisy objects. Noisy objects were created by displacing the surface of a sphere (radius = 30 mm) in the radial direction according to fractal Brownian motion noise (radius displacement of up to 20%, with a spatial bandwidth of 2 octaves). These 3D-printed objects were presented at table height, in various orientations. The task of our 18 right-handed adult participants was to use a two-digit precision grip to pick up these objects for a total of 1440 trials. The exact contact points on the object's surface were obtained by accurately tracking the positions of the fingertips with virtual markers (MOTOM toolbox: Derzsi & Volcic, 2018). We found that the distance between the center of mass and the grasping point centroid was 11.54 (95% C.I.: ±2.05) mm for the sphere, and for the three objects, the distances were 14.03 (95% C.I.: ±1.66), 13.67 (95% C.I.: ±2.08), and 14.15 (95% C.I.: ±1.95) mm, respectively. While we observed that the grasping of the sphere is more precise, we found that there are no differences between how well our participants grasped the noisy objects. We therefore suggest that, in our case, the grasping quality depends on the shape complexity, rather than the shape itself.

33.365 **Sensory feedback reduces scalar variability effects in perception and action tasks** Ailin Deng[1](dengailin@gmail.com), Evan Cesanek[1], Fulvio Domini[1]; [1]Cognitive, Linguistic, and Psychological Sciences, Brown University

According to Weber's law, the variability in a perceptual response scales with physical stimulus magnitude. Such scalar variability effects are widely observed in visual perception, but recent work shows that the kinematics of visually guided actions instead show equivalent variability across stimulus magnitudes. To account for this surprising violation of a supposedly lawful phenomenon, resistance to Weber's law has been touted as a feature of specialized vision-for-action processing, separate from perceptual processing. In this study, we investigated the alternative hypothesis that limited scalar variability is achieved by movement recalibration based on sensory feedback. In Experiment 1, participants performed a pantomime grasping block without any feedback and a feedback grasping block with visual and haptic feedback. These were alternated with three manual size estimation (MSE) blocks, counterbalancing for task order. Scalar variability affected the maximum grip apertures of pantomime grasps, but not normal grasps. More interestingly, a reduction in Weber's fraction was observed for MSEs following normal grasping, but not following pantomime grasping. When pantomime and normal grasping were intermixed (but with explicit cues to trial type), scalar variability was absent for both. Next, we investigated whether haptic feedback from grasping plays an irreplaceable role in reducing scalar variability, or if visual feedback in a perceptual task will also suffice. Experiment 2 consisted of three MSE blocks, with no feedback in the first and last blocks, but with visual feedback of the grip aperture relative to the target object in the middle block (two lines around the target displayed immediately upon entering the estimate). Visual feedback significantly enhanced accuracy and precision in the second block while also reducing scalar variability; these effects carried over into the third block. Clearly, sensory feedback plays a central role in the reduction of scalar variability, regardless of any functional distinction between perception and action tasks.

33.366 **Perceiving and grasping the equiluminant Ebbinghaus illusion** Sofia Lavrenteva[1](sofia@l.u-tokyo.ac.jp), Ikuya Murakami[1]; [1]Department of Psychology, the University of Tokyo

According to two streams hypothesis, (1) actions rely on the dorsal while perception on the ventral stream, (2) These streams process shapes within different frames of reference (egocentric vs. relative), and (3) the dorsal stream is less affected by the Ebbinghaus illusion, in which the perceived size of a central target is affected by the sizes of surrounding inducers. However, many studies indicate equivalent illusion strength between perception and action, supporting single shape representation used in both streams. We attempted to create inducer disks invisible to the dorsal stream, taking advantage of the tendency that it mainly gets its input through the magnocellular pathway insensitive to S-cone modulation. We measured how the illusion strength differed between perception and grasping in stimuli comprised of luminance defined and S-cone modulating equiluminant inducer disks. We used graspable disks (2-mm thick transparent plastic) of 3 different sizes as target disks. In each trial, the target disk was surrounded by either large or small inducer disks, defined either by luminance or by S axis in DKL color space. In a perception test, observers adjusted the size of a reference disk to match the apparent size. In an action test, they grasped the target disk with a precision grip. We only analyzed the data of the observers whose maximum grip aperture (MGA) was significantly affected by physical disk size. In the perception test, the Ebbinghaus illusion was similar in strength between the stimuli with luminance defined and equiluminant inducers. In the action test, however, the effect of the Ebbinghaus illusion on the MGA was stronger in the stimulus with the luminance inducers than in the stimulus with the equiluminant inducers. These results neither fully support different frames of reference in the two streams, nor a single shape representation. We discuss possible interactions between the two streams.

Acknowledgement: KAKENHI 15H01984

33.367 **Which brain areas are responsible for which aspects of grasping?** Lina K Klein[1](Lina.K.Klein@psychol.uni-giessen.de), Guido Maiello[1], Daria Proklova[2], Vivian C Paulun[1], Jody C Culham[2], Roland W Fleming[1]; [1]Department of Psychology, Justus-Liebig University Giessen, [2]Department of Psychology, Brain and Mind Institute, University of Western Ontario

Most neuroimaging studies of both grasping and object recognition have focused on simple objects made from homogenous materials. However, in behavioral experiments with complex objects, we have shown that participants can use visual object shape and material distribution to select optimal grasps based on a combination of factors: natural grasp axis, grasp aperture, the object's overall weight, and mass distribution. Given that visual perception of object shape and material distribution are putatively a ventral-stream function; whereas, grasping is putatively a dorsal-stream function, we used functional magnetic resonance imaging (fMRI) to characterize the role of brain regions in both streams during grasping of multi-material objects. We recorded brain activation while participants grasped and lifted objects made of wooden and brass cubes at preselected grasp points. To tease apart the different components of grasp selection, grasps were optimized for either torque, grasp aperture, grasp axis, or a combination of these. For example, some grasps were optimal with respect to minimizing torque, but suboptimal with respect to the aperture. Within visual and visuomotor regions of interest, we examined activation levels and patterns (with representational similarity analysis) to infer neural coding of grasp attributes. When participants grasped objects in configurations with high torque – that is when their grips had to counteract object rotation due to gravity – versus low torque, activation was observed in the grasp-selective anterior intraparietal sulcus, aIPS (in the lateral dorsal stream), the reach-selective superior parieto-occipital sulcus, SPOC (in the medial dorsal stream), and the object-selective lateral occipital cortex, LOC (in the ventral stream). These results suggest that when materials and their distribution are relevant for grasping, both visual streams are recruited.

Acknowledgement: This research was supported by the DFG (IRTG-1901: 'The Brain in Action' and SFB-TRR-135: 'Cardinal Mechanisms of Perception'), and an ERC Consolidator Award (ERC-2015-CoG-682859: 'SHAPE'), and by the 'Canada First Research Excellence Fund to BrainsCAN' Award which subsidized scan costs at Western's Centre for Functional and Metabolic Mapping. Guido Maiello was supported by a Marie-Skłodowska-Curie Actions Individual Fellowship (H2020-MSCA-IF-2017: 'VisualGrasping' Project ID: 793660).

33.368 **The timing of 'vision for action' and 'vision for perception' magnetoencephalography (MEG) responses during real and pantomimed grasps** Rosa M Sola Molina[1](r.solamolina@latrobe.edu.au), Laila Hugrass[1], Gemma Lamp[1], David P Crewther[2], Melvyn A Goodale[3], Sheila G Crewther[1]; [1]School of Psychology and Public Health, La Trobe University, [2]Centre for Human Psychopharmacology, Swinburne University, [3]The Brain and Mind Institute, The University of Western Ontario

'Vision for perception' and 'vision for action' are subserved by distinct, yet interacting, brain activity in the ventral and dorsal visual streams respectively (Goodale & Milner, 1992). fMRI studies have suggested that visual regions activated during real grasps are different to those activated during pantomimed grasps (Króliczak et al., 2007).However, little is known about the timing of visual responses during real and pantomimed actions. Here, we recorded magnetoencephalography (MEG) activity from 12 right-handed young adults (M = 29.08, SD = 5.37 years), during both the visual planning and motor execution of real and pantomimed grasps. Light stimuli cued participants to grasp a translucent rod in either the left or right target positions, both to the right of the participants' midline. For pantomimed grasps, the rods were removed from the target positions, but lights remained. Participants performed the cued action with their right (dominant) hand, and were instructed to act quickly and accurately. Separate source-localised MEG analyses, time-locked to the light onset, were performed for the left and right grasp and pantomime targets. Neither whole brain nor dorsal/ventral stream ROI analyses revealed significant differences between early visual responses during the grasp and pantomime trials. However, dorsal and ventral sources made different contributions to M170 visual responses to left

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and right targets. For both real and pantomimed grasps to the left target, the M170 response was strongest for right lateral occipital sources. For real and pantomimed grasps to the right target, the M170 response was dominated by parietal sources. For both targets, later visual responses (300- 500ms) were dominated by bilateral inferotemporal sources. Kinematic patterns reveal a more complex movement required to grasp the right object. These results highlight the value of using MEG to study both the timing and localisation of neural activity during visual planning of motor actions.

Acknowledgement: This research has been fully funded by the Australian Government, through an Australian Research Council grant as part of the Discovery Projects stream ID: DP170101035

33.369 **Investigating common coding of action execution and observation in the macaque monkey using cross-modal fMRI adaptation.** Saloni Sharma[1,2](saloni.sharma@kuleuven.be), Koen Nelissen[1,2]; [1]Laboratory for Neuro- and Psychophysiology, KU Leuven, Leuven, Belgium, [2]Leuven Brain Institute, Leuven, Belgium

Rather than demonstrating a simple overlap between action observation and execution fMRI responses, cross-modal fMRI adaptation has been proposed as a more suitable technique to confirm the presence or absence of mirror neurons in the human brain (Dinstein et al., 2007). Due to their multimodal properties and their proposed role in action simulation, it is suggested that regions containing mirror neurons should yield decreased responses when observing a particular action that was previously executed (or vice-versa), as opposed to executing and observing (or vice-versa) two different actions. However, the few studies that have employed this technique to study the possible presence of mirror neurons in the human brain have yielded conflicting results (Chong et al. 2008; Kilner et al., 2009; Lingnau et al., 2009; de la Rosa et al., 2016). Here we tested this proposal for the first time in monkeys using a motor-to-visual fMRI adaptation experiment. Two rhesus monkeys (male, 6-7 kg) were trained to perform in the scanner (Siemens 3 Tesla) either a number of consecutive grasping or reach-only movements, followed by observation of a video depicting either a similar grasping or reach-only motor act. Whole brain fMRI analysis did not reveal any voxels that showed a significant response reduction for same compared to different trials, even at a very low threshold. Moreover, detailed region-of-interest analysis of brain regions previously shown to house mirror neurons (premotor area F5, parietal areas AIP and PFG) also did not yield a significant reduction in fMRI signal for same compared to different trials. In line with a previous single cell study that failed to find repetition suppression effects in macaque F5 during action observation (Caggiano et al., 2013), our results suggest that care should be taken when using fMRI adaptation technique to confirm presence (or absence) of mirror neurons in the brain.

33.370 **What`s in the mirror? FMRI responses in the monkey action observation network while observing conspecific transitive and intransitive hand and tail actions.** Ding Cui[1,2](ding.cui@kuleuven.be), Mathias Vissers[1], Saloni Sharma[1,2], Koen Nelissen[1,2]; [1]Laboratory for Neuro- & Psychophysiology, Department of Neurosciences, KU Leuven, Leuven, 3000, Belgium., [2]Leuven Brain Institute, KU Leuven, Leuven, 3000, Belgium.

Observing others' actions is an important aspect of social behavior, especially in primates. Observation of other individuals in action elicits neural responses in the so-called 'Action Observation Network (AON)', which includes occipito-temporal brain regions as well as parietal and premotor portions of the sensorimotor system, the latter typically involved in planning and execution of these actions. A dominant view suggests that the parieto-frontal portion of the AON in monkeys responds in particular to observing goal-directed actions that are part of the monkey`s own motor repertoire. Contrary to this, much broader responses have been demonstrated in homologue regions of the human AON, including responses to both familiar and unfamiliar actions, transitive and intransitive actions, or even abstract sequences of events. Here we examined the effects of action transitivity and motor familiarity by measuring fMRI responses (Siemens 3 Tesla) in three adult rhesus monkeys while they observed an animated 3D monkey model (using open-source software Blender) performing either object-directed reach-and-grasp and reach-and-touch actions, or intransitive reach-only actions, executed with either the hand/forelimb or the tail. Both univariate whole-brain and region-of-interest (ROI) analyses in addition to ROI multivariate pattern analyses were performed. In line with previous electrophysiology and neuroimaging data, observing another individual performing a hand grasp yielded significant responses throughout the AON. Interestingly, also observing object touch or intransitive reach movements yielded robust responses throughout the AON, even when these actions were executed with a tail instead of a forelimb effector.Contrary to the suggestion that monkey sensorimotor regions only respond during observation of goal-directed motor actions which are part of the observer`s own motor repertoire, these results suggest that also intransitive and unfamiliar actions yield responses in visual and motor portions of the monkey AON, in line with human neuroimaging data and current predictive coding models of action observation.

33.371 **Monkey fMRI brain responses to different viewpoints of observed hand actions.** Koen Nelissen[1,2](koen.nelissen@med.kuleuven.be), Prosper A. Fiave[1,2]; [1]Lab for Neuro- & Psychophysiology, KU Leuven, 3000 Leuven, Belgium, [2]Leuven Brain Institute

The neuronal correlates of action observation in the primate brain have been studied mostly using third-person perspective visual stimuli, reflecting actions performed by others. Recently, several studies have suggested that neurons in the parieto-frontal portion of the monkey action observation network (AON) also display selectivity for first-person perspective, suggesting these motor regions might play a role in self-action monitoring (Maeda et al., 2015; Maranesi et al., 2015). Currently it is not known how different viewpoints of conspecific actions modulate brain responses throughout the monkey AON. Three rhesus monkeys were scanned (Siemens 3T) while fixating videos depicting a monkey hand performing either a reach-and-grasp or reach-and-touch action from three different viewpoints. Viewpoints included viewing angles resembling either a first-person perspective (0 degree), or third-person perspectives (90 degree or 180 degree). Both whole-brain univariate and region-of-interest (ROI) univariate and multi-voxel pattern analyses were performed to investigate the effect of action viewpoint on brain responses in the different sectors of the AON. In line with previous results investigating monkey brain responses during observation of human hand actions (Nelissen et al., 2011; Sharma et al., 2018, Fiave et al., 2018), observing a conspecific hand grasping or reaching yielded significant responses in temporal, parietal and frontal sectors of the AON. ROI analysis showed robust responses not only for third-person, but also for first-person perspective, in STS, parietal AIP and PFG, premotor F5 and ventrolateral prefrontal cortex. Action goals (grasping or reaching) for first-person and for third-person viewpoints could be decoded from both visual, motor and prefrontal regions. Distinct spatial patterns for different viewpoints of the same action were mostly observed in STS and prefrontal regions, with in particular STS showing a generalization of viewpoints across actions. Generalization of action goals across viewpoints was mainly observed in prefrontal cortex, parietal and STS regions.

Acknowledgement: This work was supported by Fonds Wetenschappelijk Onderzoek Vlaanderen (G.0.622.08, G.0.593.09), KU Leuven BOF-ZAP Startfinancing (14/10) and KU Leuven (C14/17/109).

33.372 **The deployment of spatial attention during goal-directed action alters audio-visual integration** Tristan Loria[1,3](tristan.defrancesco.loria@mail.utoronto.ca), Joëlle Hajj[1], Kanji Tanaka[2], Katsumi Watanabe[1,3], Luc Tremblay[1]; [1]Faculty of Kinesiology and Physical Education, University of Toronto, Toronto, Canada, [2]Waseda Institute for Advanced Study, Waseda University, Tokyo, Japan, [3]Faculty of Science and Engineering, Waseda University, Tokyo, Japan

The current study examined audio-visual integration processes as a function of spatial attention in the presence or absence of goal-directed aiming. Each trial began with the right index finger on a home position presented on a touch-screen monitor. Three target squares, arranged horizontally, were also displayed. On every trial, one visual flash (F) was presented while the number of auditory beeps (B) varied. The stimuli conditions were 1F (i.e., unimodal), 1F1B (i.e., bimodal congruent), and 1F2B (i.e., bimodal incongruent: fission illusion). These audio-visual cues occurred in the central target square on 70% of the trials, and in the non-target squares on 30% of the trials. After each trial, participants reported the perceived number of flashes. A response was considered correct when the reported number of flashes matched the number of actual flashes presented on that trial. In the no-movement condition, participants kept their finger on the home position for the entire trial. In the movement condition, participants performed a reaching movement to the center target square, with the stimuli presented at movement onset. When initiating a movement, deploying attention to the target's spatial location was expected to withdraw multisensory processing resources from the non-target locations, thus yielding better perceptual accuracy of the number of flashes at target compared to the non-target locations only for the bimodal stimuli. When unimodal stimuli were presented, perceptual accuracy was worse at the non-target compared to the target locations for both the no-movement and movement conditions. For the bimodal stimuli, perceptual accuracy was worse at the non-target than the target location in the movement condition only. These results indicate that at the onset of a reaching movement, inte-

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gration of congruent audio-visual cues is reduced at unattended vs. attended spatial locations, whereas integration of incongruent audio-visual cues at unattended locations enhances susceptibility to the fission illusion.

Acknowledgement: The Japan Society for the Promotion of Science, the Natural Sciences and Engineering Research Council of Canada, and University of Toronto Graduate Student Bursaries

33.373 **Prediction shapes visually-guided grasping and modulates somatosensory perception** Maximilian D. Broda[1](Maximilian.Broda@psychol.uni-giessen.de), Dimitris Voudouris[1], Katja Fiehler[1]; [1]Experimental psychology, Justus-Liebig-University Giessen

Somatosensory perception is hampered on a limb that is performing visually-guided goal-directed movements. This suppression has been attributed to a forward model that predicts future sensorimotor states based on the established motor command. Here we examine whether and how this suppression is modulated by the predictability of object features important for controlling a visually-guided grasping movement. Participants reached to grasp an object with a precision grip and then lifted it as straight as possible. Objects with symmetric or asymmetric mass distributions were presented either in a blocked or random manner, i.e. their mass distribution was predictable or not. At the moment of object contact, a brief vibrotactile stimulus was presented on the moving index finger and participants had to respond whether they detected it or not. Grasping control benefited when participants could predict the relevant object features: When the object's mass distribution was predictable, the chosen contact points resulted in minimized object roll during lifting. When the distribution was unpredictable, participants chose a 'default' grasping configuration that resulted in greater object roll for objects with asymmetric distributions. Participants also took longer to start lifting the object, presumably to allow enough time for processing afferent signals related to the object's mass distribution and for building up appropriate digit forces for lifting. Somatosensory perception was hampered during grasping compared to a baseline (no-movement) block. Importantly, suppression was stronger when participants could predict the object's mass distribution. We suggest that not only grasping characteristics but also the strength of somatosensory suppression depend on the predictability of movement-relevant object features.

33.374 **Object encoding but not action understanding in the the macaque medial reach-to-grasp network** Patrizia Fattori[1](-patrizia.fattori@unibo.it), Rossella Breveglieri[1], Francesco E Vaccari[1], Annalisa Bosco[1], Michela Gamberini[1], Claudio Galletti[1]; [1]Dept. Biomedical and Neuromotor Sciences, Univ. Bologna, Italy

The vision of an action evokes intriguing discharges in a rich network of cortical areas. Some cortical neurons, called 'mirror' neurons, discharge both during action execution and action observation (Rizzolatti et al. 1996, Cogn Brain Res). In the present study, we looked for mirror neurons in macaque medial parietal area V6A, an area of the reach-to-grasp network (Galletti and Fattori, 2018 Cortex) never explored to date in this regard. We recorded neural activity of 100 V6A neurons of two male Macaca fascicularis during grasping action and during observation of the same action performed by the experimenter. The overhealming majority of neurons (86/100) were modulated only when monkey executed the action. A minority (14%) showed mirror features, discharging also during observation of actions performed by experimenter. However, differently from classic mirror neurons, V6A mirror neurons responded also to passive object observation and showed dissimilar responses when monkey performed the action and when it observed the same action performed by experimenter. In other words, these neurons are able to encode the visual features of objects, but do not seem to be involved in action understanding, being the neural representations during execution and observation highly dissimilar, so excluding the possibility of creating an internal representation of other agent's actions. We have also found that in these neurons, the neural representation of the object changed according to whether grasping was allowed/performed or not, and whether object was or not target of another agent's grasp. In other words, rather than coding the agent's observed action, V6A neurons appear to encode the pragmatic relevance of the object. In summary, area V6A is well equipped to monitor own actions, but it is not able to build an internal representation of observed actions, while encoding the pragmatic relevance of object in the action to be performed.

Acknowledgement: MIUR-PRIN

Object Recognition: Neural mechanisms

Sunday, May 19, 8:30 am - 12:30 pm, Pavilion

33.401 **Mapping information accumulation and integration dynamics across ventral temporal cortex** Matthew J Boring[1,2,3](mjb200@pitt.edu), Michael J Ward[3], R. Mark Richardson[1,2,3], Avniel Singh Ghuman[1,2,3,4]; [1]Center for Neuroscience at the University of Pittsburgh, University of Pittsburgh, [2]Center for the Neural Basis of Cognition, University of Pittsburgh and Carnegie Mellon University, [3]Department of Neurological Surgery, University of Pittsburgh, [4]Department of Psychology, University of Pittsburgh

Studies examining spatial maps of where information is represented in ventral temporal cortex (VTC) have revealed critical organizational principles of the neural underpinnings of visual recognition. However, less is known about the fine spatiotemporal dynamics of information processing across VTC, which can also reveal critical details about the organizational and computational principles underpinning recognition. To fill this gap, we examined data recorded from 383 electrodes (electrocorticography, ECoG) in or on category-sensitive VTC of 38 participants. Temporally specific, multivariate information theoretic measures were used to assess how category-sensitive information evolved over time and space. At the group level and within individual subjects, the onset latency of this information was positively correlated with posterior to anterior VTC coordinate, consistent with fast-feedforward frameworks of the ventral visual stream. However, electrodes also demonstrated a decrease in the rate of information accumulation along the posterior to anterior VTC axis, with information accumulating more slowly and peaking later along a continuous gradient down VTC. We hypothesized that slower rates of information accumulation may be caused by increased diversity of sources that information is being integrated over in more anterior VTC regions. To test this, we examined the functional connectivity between each category-sensitive VTC electrode and all other electrodes implanted in the patients' brains. The results support our hypothesis, showing that the rate of information accumulation was negatively correlated with functional connectivity to non-visually responsive brain regions, but not connectivity to visually responsive brain regions. This study suggests a novel organizational and computational principle in VTC: the rate of category-sensitive information accumulation is shaped by the diversity of non-visual sources that a region integrates over, which correlates with a posterior-to-anterior gradient of VTC organization.

Acknowledgement: National Institute of Mental Health Award NIH R01MH107797 (to A.S.G), National Science Foundation Award 1734907 (to A.S.G.).

33.402 **Connectivity FIngerprints for the Visual Brain and Behavior** David E Osher[1](osher.6@osu.edu), Zeynep M Saygin[1]; [1]Dept. of Psychology, The Ohio State University

Since the advent of neuroimaging, there has been a considerable interest in mapping the visual system.This has led to exquisite maps of visual selectivity, but mapping is a purely descriptive approach to understanding the visual brain.In order to uncover mechanistic explanations, rather than descriptive maps of the visual system, neuroimagers will need to incorporate neural connectivity into their analyses.After all, connectivity is the principal constraint on the domain of information that a brain region can process, and thus should be highly predictive of neural selectivity.We previously showed that connectivity fingerprints can define a region so well that they can be used to predict the location of visual regions even in the absence of functional localizers, using only an individual's connectivity patterns (Osher et al. 2015; Osher et al. 2018). Here we present a suite of analytic tools that will allow researchers to derive the connectivity fingerprints that best define any specific visual region, offering answers to questions such as "what connectivity pattern does a region need to be highly selective to faces?"Our software suite is applicable to DWI as well as functional connectivity data, any set of brain regions as seeds and targets, any fMRI task, and any number of individuals. We also demonstrate how connectivity fingerprints can be used to predict behavioral data, in addition to neural activation in each subject. We present a few specific results from the application of connectivity fingerprints to predict neural activation in individual subjects and behavioral variation in various mental tasks

Acknowledgement: Sloan Foundation (ZMS)

 See page 3 for Abstract Numbering System

33.403 **Assessing Reproducibility of MEG and fMRI Data Fusion Method in Neural Dynamics of Object Vision** Benjamin Lahner[1,2](blahner@bu.edu), Yalda Mohsenzadeh[1], Caitlin Mullin[1], Radoslaw Cichy[3], Aude Oliva[1]; [1]Computer Science and Artificial Intelligence Lab., MIT, [2]Boston University, [3]Free University Berlin

Visual object recognition arises from a series of spatio-temporal activity patterns within the ventral and dorsal streams. To reveal human brain neural dynamics, Cichy et al. (2014, 2016) integrated measurements of functional magnetic resonance imaging (fMRI) with magnetoencephalography (MEG). Here, we assess the power of this fMRI-MEG fusion method in producing replicable results for visual recognition. First, we evaluated the reliability of the fusion method at capturing the spatiotemporal dynamics of representations by assessing the neural agreement of visually similar experiences within individuals. For this, we collected fMRI and MEG data while participants (N=15) viewed 156 natural images, performing an orthogonal vigilance task. The images were arranged in twin sets (two sets of 78 images each) with pair images sharing high similar verbal semantic description and with no significant difference in low level image statistics between each set. Fusion method revealed highly consistent spatiotemporal dynamics for the twin sets showing neural representations starting in the occipital pole (~70-90ms after stimulus onset), followed by neural representations in anterior direction along ventral stream and up to the inferior parietal cortex in dorsal pathway. Second, we tested the generalizability of the fusion method by replicating Cichy et al. (2016) and comparing the depicted spatiotemporal dynamics with the twins set temporal dynamics. Despite variations in stimulus set and participant groups, we again found highly overlapping spatio-temporal patterns starting in early visual cortex (~70-80ms) and extending to higher perceptual regions around 110-130ms with no significant difference between the two experimental settings. In sum, these results reveal the reliability and generalizability of fMRI-MEG fusion method and demonstrate that this method is an appropriate analytical tool to non-invasively evaluate the spatiotemporal mechanisms of perception.

Acknowledgement: This research was funded by NSF grant number 1532591, in Neural and Cognitive Systems as well as the Vannevar Bush Faculty Fellowship program funded by the ONR grant number N00014-16-1-3116 and the DFG Emmy Noether Grant CI 241/1-1. The experiments were conducted at the Athinoula A. Martinos Imaging Center at the McGovern Institute for Brain Research, Massachusetts Institute of Technology.

33.404 **Roles of animacy, shape, and spatial frequency in shaping category selectivity in the occipitotemporal cortex** Chenxi He[1](ch137@nyu.edu), Shao-Chin Hung[1], Olivia S. Cheung[1]; [1]Psychology, Science Division, New York University Abu Dhabi

Distinct concepts, such as animals and tools, often share vast and systematic differences in visual features. To what extent the neural representations in the category-selective regions in the occipitotemporal cortex contain visual vs. conceptual information? While it has been suggested that animacy, shape, and spatial frequency are three main factors to explain the lateral-to-medial activation patterns in the occipitotemporal cortex, these factors are often confounded (e.g., animals tend to have curvilinear shapes whereas tools are often elongated). To investigate the effects of these three factors on the representations in the animal- and tool-selective regions, we used low- or high-passed images of round or elongated animals and tools that shared comparable image statistics, as measured by GIST descriptors. Participants (n=20) performed a one-back task in the MRI scanner. Although the animal and tool images were indistinguishable based on image statistics, univariate analyses revealed robust category selectivity for such images in the animal-selective regions (bilateral lateral occipital complex and lateral fusiform) and tool-selective regions (left posterior middle temporal gyrus and medial fusiform), which were defined in a localizer with animal and tool images of naturally varied image statistics. Representational similarity analyses further revealed that the activation patterns in the animal-selective regions were most correlated with a model that represents only animal information, whereas the activation patterns in the tool-selective regions were most correlated with a model that represents only tool information. Moreover, shape or spatial frequency, compared with category information, appeared to contribute less significantly to the neural representations in these regions. Taken together, the distinction between animal and object representations in the occipitotemporal cortex is unlikely merely due to differences in low-level visual or shape properties. Instead, the involvement of higher-level conceptual influences may shape category selectivity and play a critical role for interpreting visual input during categorization.

33.405 **The spatio-temporal dynamics of personally-meaningful objects** Jasper JF van den Bosch[1,2](japsai@gmail.com), Ian Charest[1,2]; [1]School of Psychology, University of Birmingham, [2]Centre for Human Brain Health, University of Birmingham

Personally-meaningful visual objects, like our partner's face, are recognized faster (Ramon et al., 2011; Ramon & Gobbini, 2018) and evoke stronger activity in the brain (Herzmann, et al., 2004, Barense et al., 2011, Taylor et al., 2009; Trinkler et al., 2009, Castello et al. 2017). Activity patterns elicited by personally-meaningful objects also better predict semantic judgements about these objects (Charest et al., 2014). Despite evidence for larger brain activity, the impact of familiarity on the spatio-temporal dynamics of object recognition remains poorly understood. Here we set out to track neural representations of familiar and unfamiliar objects in the human brain as they evolve in space and time. Participants (n=20), saw personally-meaningful and unfamiliar objects matched in category (72 images, including faces, bodies, places, objects and pets) while we recorded electroencephalography (EEG) and functional Magnetic Resonance Imaging (fMRI) (in separate sessions). We constructed representational dissimilarity matrices (RDMs) for each EEG time-point, and for each fMRI voxel independently. We computed the RDMs' spatio-temporal similarity, combining the precise temporal resolution of EEG with the precise spatial resolution of fMRI (see also Cichy et al., 2014, 2016). We thereby mapped the spatio-temporal trajectories of personally-meaningful and unfamiliar object representations. These followed the typical cascade of visual processes bilaterally from primary visual cortex (V1; ~90ms) through to the ventral and dorsal streams (~130ms). Interestingly, unfamiliar representations reached V1 around 20ms later (~110ms). The cascade of neural representations for personally-meaningful objects rapidly involved additional regions in the MTL (~130ms), and dorsomedial and ventromedial prefrontal cortex (~165ms). Together, these results demonstrate for the first time, when and where prior experience and personal familiarity influence object recognition in the brain. Critically, our results strengthen our understanding of the interactions between the visual sensory system, the medial temporal lobes, and the prefrontal cortex in recognising visual objects.

Acknowledgement: European Research Council - START (759432)

33.406 **Alpha bursts in inferior parietal cortex underlie object individuation in dynamic scenes** Andreas Wutz[1,2](andreas.wutz@sbg.ac.at), Agnese Zazio[3], Nathan Weisz[1]; [1]University of Salzburg, Center for Cognitive Neuroscience, Salzburg, Austria, [2]MIT, Picower Institute for Learning and Memory, Cambridge, MA, USA, [3]IRCCS Saint John of God Clinical Research Centre, Brescia, Italy

Current theories suggest that alpha-frequency oscillations (9-13 Hz) reflect pulsed-inhibitory neural computations that structure visual perception into discrete time frames and sub-serve the individuation of spatiotemporal objects. Here, we investigated the impact of alpha oscillations on object individuation and its capacity limits in dynamic scenes. We recorded whole-head magneto-encephalography (MEG) while 24 participants performed a multiple-object tracking task (MOT). On each trial, the participants viewed 12 randomly moving objects and were required to track a subset of 2, 4 or 8 targets over a period of 2-3 seconds. In different blocks, they switched between different object processing tasks, which were previously reported to differ in their capacity limits (individuation, averaging). For individuation, participants had to indicate the spatial position of one object from the target pool (i.e. partial report). For averaging, they had to indicate the geometrical centroid position of the target pool. Behavioral performance declined from 2 to 4 objects in a similar way for both tasks. At 8 objects, however, averaging was significantly better than individuation performance confirming the previously found between-task differences in object capacity. In the MEG signal, we found a significant alpha power increase from pre-trial baseline in bilateral inferior parietal cortex during MOT, which was equally strong for both tasks. By contrast, we found stronger oscillatory bursting in the alpha band for individuation vs. averaging during MOT. Oscillatory bursting captures single-trial dynamics better compared to across-trial averaged power, because it measures time- and band-limited, high-signal periods above each trial's respective pre-trial mean. Critically, the alpha bursting effect was set-size specific and only reached significance for 2 and 4 but not for 8 target objects. Presumably, object capacity was exceeded and thus individuation failed at this high set size. Our results suggest that oscillatory alpha bursts underlie object individuation and its capacity limits during MOT.

Acknowledgement: FWF - the Austrian Science Fund

33.407 **The role of body partonomics and biological class in the representation of animacy in the ventral visual pathway**
J.Brendan W Ritchie[1](brendan.ritchie@kuleuven.be), Joyce Bosmans[1], Shuo Sun[1], Kirsten Verhaegen[1], Astrid Zeman[1], Hans Op de Beeck[1]; [1]Laboratory of Biological Psychology, Department of Brain and Cognition, KU Leuven, Belgium

A multitude of studies have shown that high-level regions of the ventral visual pathway differentially code for the animacy of objects. However, less clear are the organizing principles that structure the neural responses to images of "animate" exemplars. On the one hand, some studies have used images of human and animal faces and bodies (Kiani et al. 2007; Kriegeskorte et al. 2008, Cichy et al. 2014), which suggest that body partonomics may play a role. Such a possibility is reinforced by the well-known selectivity for body and face stimuli in circumscribed regions of lateral occipital and ventral temporal cortex. On the other, some studies suggest that intuitive hierarchies for biological class membership are represented in these more general regions (Connolly et al. 2012, 2016; Sha et al. 2015). We investigated the relative contribution of these two factors in accounting for the neural responses in multiple regions of the ventral pathway. Animate stimuli consisted of a single close-up face and full-body image of 24 animals from intuitive groupings of primates, mammals, birds, reptiles/amphibians, fish, and insects/invertebrates (48 images total). In behavioral and neural testing these were contrasted with (subsets) of 48 images of natural objects (flowers, fruits/vegetables, fungi).In total we collected data for seven behavioral tasks involving either similarity judgments (face, body, humanness, animacy) or categorization decisions (animate vs inanimate, face vs non-face, face vs body). The responses from these tasks were used to construct dissimilarity matrices (DM) to carry out representational similarity analysis, and compared with DMs constructed from neural responses from multiple ventral pathway regions selective for objects, faces, and bodies measured with human fMRI, as well as layers of a deep convolutional neural network. We found that both factors, body partonomics and biological class, are complementary predictors of neural responses across regions of the ventral pathway.

33.408 **Do responses in nonhuman primate inferior temporal cortex reflect external variables or internal dynamics?**
Marieke Mur[1,2,3](mmur@uwo.ca), Andrew Bell[4], Nicholas J Malecek[5], Elyse L Morin[5], John Duncan[1,4], Nikolaus Kriegeskorte[1,6,7]; [1]MRC Cognition and Brain Sciences Unit, University of Cambridge, [2]Department of Psychology, University of Western Ontario, [3]Brain and Mind Institute, University of Western Ontario, [4]Department of Experimental Psychology, University of Oxford, [5]National Institute of Mental Health, National Institutes of Health, [6]Department of Psychology, Columbia University, [7]Zuckerman Mind Brain Behavior Institute, Columbia University

Population responses to object images in inferior temporal cortex (IT) are dynamic. However, it is not well understood whether the dynamics of IT predominantly reflect encoding of external variables or internal population dynamics. Here we analyze single-unit recordings from monkey IT to investigate the predominant source of the time-varying population response. Single-unit activity was recorded from 989 neurons in the inferior bank of the superior temporal sulcus of two adult macaques passively viewing 100 grayscale object images from five categories (faces, body parts, fruit, objects, indoor scenes) presented for 300 ms at fixation at 5 degrees visual angle (Bell et al., 2011). We analyzed activity patterns across visually responsive neurons, from 100 ms before to 700 ms after stimulus onset, with population tensor analysis (Seely et al. 2016). Tensor analysis treats the population response as a third-order tensor indexed by neuron, condition, and time. The tensor is modeled as a linear combination of either condition-by-time components that are shared across neurons (basis neurons) or neuron-by-time components that are shared across conditions (basis conditions). If the tensor is reconstructed most accurately from the basis neurons (conditions), this indicates that population dynamics are predominantly driven by external variables (internal dynamics). For both monkeys, the IT population response was reconstructed most accurately from the basis neurons. The advantage of basis neurons over basis conditions increased with the number of leading components used for reconstruction (1-25). We matched the number of conditions and neurons before analysis by selecting random samples of 100 neurons. Results generalized to bootstrap resamplings of the condition set. These preliminary results suggest that, for passive viewing of isolated object images, responses in monkey IT predominantly reflect encoding of external variables (tuning). Internal population dynamics may play a larger role in challenging visual tasks that rely on recurrent processing.

Acknowledgement: National Institutes of Health, Medical Research Council

33.409 **Comparing novel object learning in humans, models, and monkeys**
Michael J Lee[1](mil@mit.edu), James J DiCarlo[1,2]; [1]Department of Brain and Cognitive Sciences, MIT, [2]McGovern Institute for Brain Research, MIT

Humans readily learn to identify novel objects, and it has been hypothesized that plasticity in visual cortex supports this behavior. Contributing to this view are reports of experience-driven changes in the properties of neurons at many levels of visual cortex, from V1 to inferotemporal cortex (IT).Here, we ask if object learning might instead be explained by a simple model in which a static set of IT-like visual features is followed by a perceptron learner. Specifically, we measured human (268 subjects; 170,000+ trials) and nonhuman primate (NHP; 2 subjects, 300,000+ trials) behavior across a battery of 29 visuomotor association tasks that each required the subject to learn to discriminate between a pair of synthetically-generated, never-before-seen 3D objects (58 distinct objects).Objects were rendered at varying scales, positions, and rotations; superimposed on naturalistic backgrounds; and presented for 200 msec. We then approximated the visual system's IT response to each image using models of ventral stream processing (i.e. specific deep neural networks trained on ImageNet categorization), and we applied a reward-based, perceptron learner to the static set of features produced at the penultimate layer of each model. We report that our model is sufficient to explain both human and NHP rates of learning on these tasks. Additionally, we show humans, NHPs, and this model share the same pattern of performance over objects, but that NHPs reach criterion performance ~10x as slowly as humans (human t = 139, NHP t = 1149), suggesting humans have similar but more rapid learning mechanisms than their NHP cousins in this domain. Taken together, these results suggest the possibility that object learning is mediated by plasticity in a small population of "readout" neurons that learn and execute weighted sums of activity across an upstream sensory population representation (IT) that is largely stable.

33.410 **Category-selective patterns of neural response to objects with similar image properties, but different semantic properties.**
Timothy J Andrews[1](timothy.andrews@york.ac.uk), Afrodite Giannkopoulou[1], Sanah Ali[1], Burcu Goz[1], David D Coggan[1]; [1]Department of Psychology, University of York, York UK

Neuroimaging studies have revealed strong selectivity for object categories in the ventral visual pathway. However, the extent to which this selectivity is based on high-level representations, or on the tuning for low-level or mid-level features that are common to images from a particular category remains unclear. To address this issue, we measured the neural response across the ventral visual pathway to five object categories (bottles, chairs, faces, houses, shoes) using fMRI.Using correlation-based MVPA, we found that each object category elicited a distinct pattern of neural response. To determine the extent to which these patterns of response might reflect more basic properties, we used a low-level image descriptor to measure the objects from each category. The average image descriptor for each category was then used to find five clusters of objects from a large database that had similar image properties, but were categorically and semantically different to the five object categories. We then measured the pattern of neural response to the five clusters of objects.We found that each object cluster elicited a distinct pattern of neural response. Critically, we found similar patterns of response to objects defined by either category or image.For example, the pattern of response to bottles was similar to the pattern of response to objects with similar image properties to bottles. Moreover, the similarity between patterns of response was dependent on the similarity in the image properties.These results suggest an important role for image properties in the neural representation of objects in the ventral visual pathway.

33.411 **Object Semantic Knowledge Can Bias Visual Processing Toward the Dorsal and Ventral Stream**
Dick Dubbelde[1](dubbelde@gwu.edu), Sarah Shomstein[1]; [1]George Washington University

Mounting evidence suggests that object semantic knowledge influences our perception. However, the mechanism of semantic influences on perception remains unclear. It has been shown that physical context biases perception of objects. For example, object processing can be biased to the dorsal (action related) or ventral (identification related) visual processing streams by manipulating hand location in relation to the object. If one's hands are proximal to the object, processing is biased toward the dorsal stream and if the hands are distal from the object, processing is biased toward the ventral stream. We investigated whether this perceptual bias becomes associated with object identity such that tools (e.g., hammer, wrench, saw), frequently perceived near the hands, bias the dorsal stream and non-tools (e.g., house, window, hydrant), infrequently seen near the hands, bias the ventral stream, regardless of the physical context. We used a detection task in which objects

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(controlled for low-level features such as clutter and luminance), were briefly presented near fixation. Participants performed one of two tasks, each designed to exploit sensitivity of the two streams: (i) detecting object flickering, because the dorsal stream has higher temporal resolution, and (ii) detecting a small gap in the object outline, because the ventral stream has higher spatial resolution. A significant interaction between object group and target type was observed, such that non-tools had lower RTs and higher accuracies for the spatial gap than the tools and this difference collapsed in the flickering condition. Importantly, inverting the objects, thereby reducing their semantic content, removes this interaction. This suggests that the differential processing in the two streams is driven by semantic knowledge of objects, rather than low-level differences. These results support the hypothesis that object semantic knowledge, derived from experiential hand proximity, biases visual processing to the dorsal or ventral stream.

Acknowledgement: NSF BCS-1534823 to S.S.

33.412 **Parahippocampal cortex represents the natural statistics of object context** Michael F Bonner[1](mfbonner@jhu.edu), Russell A Epstein[2]; [1]Department of Cognitive Science, Johns Hopkins University, [2]Department of Psychology, University of Pennsylvania

Many objects have a natural place in the world—a context where they and other objects are typically found. For example, tea kettles and stoves are often found together in kitchens, while fire hydrants and traffic lights are found on city sidewalks. This type of contextual knowledge about object co-occurrence can help people identify where they are in the world and what other objects they might encounter. Investigations of object perception have long sought to understand how contextual knowledge is represented in the brain (Bar, 2004), but conclusive evidence for such representations has remained elusive. Here we used fMRI and machine learning to test the hypothesis that object co-occurrence statistics are encoded in the human visual system and automatically elicited by the perception of individual objects. Using a statistical-learning technique from computational linguistics and a database of ~22,000 densely labeled scenes (ADE20K), we learned a set of 8-dimensional representations (object2vec) that captured the latent statistical structure of object co-occurrence in natural images. We mapped these statistical representations onto cortical responses through voxel-wise encoding models of fMRI data collected while four participants viewed images of isolated objects (81 categories, 10 exemplars per category) and performed a perceptual task by responding whenever the stimulus was a visually warped object. We found that an anterior portion of the scene-selective parahippocampal place area links objects with representations of the statistical ensembles in which they typically occur. In contrast, the semantic properties of objects that could be learned through language-based co-occurrence statistics (word2vec) engaged representations in the neighboring object-selective posterior fusiform gyrus. Together these findings reveal a mechanism for encoding statistical regularities of object co-occurrence, providing probabilistic information about the natural contexts in which objects are typically encountered.

Acknowledgement: NIH R01 EY022350

33.413 **Meta-analyses support the expertise hypothesis of the right fusiform face area** Edwin J Burns[1](eburns@richmond.edu), Cindy Bukach[1]; [1]Department of Psychology, University of Richmond

This year is the 20th anniversary of the first fMRI paper that reported non-face effects related to visual expertise in the right fusiform face area (FFA). This finding helped generate numerous conceptual replications over the next two decades, which lent support to the notion that the right FFA is responsible for the individuation of certain non-face objects. Despite this evidence, the expertise hypothesis has been repeatedly criticised for basing its assumptions upon studies that suffer from small participant numbers, small effects, and statistically significant p-values that are close to .05. An additional criticism is that these findings are difficult to replicate. A modern reader familiar with the replication crisis may therefore question whether the FFA's expertise effect is real. Recently developed meta-analytic techniques allow researchers to assess the evidential value for any given effect. We therefore put the literature to the test by running a series of meta-analyses on all eligible papers; from our search, we found 30 papers that showed non-face effects in the right FFA versus only six that did not. From the identified papers, 18 met the criteria to be included in our meta-analyses. Contrary to the aforementioned criticisms, our analyses confirmed that the right FFA's expertise effect is based upon evidential value, and thus, likely to be replicable. In summary, the literature supports a domain-general role for the right FFA, with our meta-analyses complementing recent neuropsychological work showing the FFA's functional contribution to object recognition.

Acknowledgement: The James S. McDonnell Foundation Scholars Award for Understanding Human Cognition and the MacEldin Trawick Endowed Professorship of Psychology

33.414 **Modeling voxel visual selectivities through convolutional neural network clustering** Daniel D Leeds[1](dleeds@fordham.edu), Amy Feng[1]; [1]Computer and Information Sciences, Fordham University

Visual properties used in cortical perception are subject to ongoing study, and features of intermediate complexity are particularly elusive. Recent works have used layers of convolutional neural networks (CNNs) to predict cortical activity in visual regions of the brain (e.g., Yamins 2014). Understanding the visual properties captured by CNN models can suggest similar structures represented in the brain. We use layers 2 through 5 of AlexNet (Krizhevsky 2012, trained on ImageNet) to identify candidate visual groupings. At each layer, we group image patches from ImageNet (Deng 2009) based on the corresponding pattern of CNN unit responses (Leeds 2017). We study the image patches in resulting clusters for similarity in unit responses and for intuitive visual/semantic consistency, based on labels from five subjects. We additionally assess the ability of clusters to improve the performance in predicting single voxel responses to visual stimuli measured from separate subjects from Kay (2008). For each CNN layer, we use each cluster's average unit response pattern as a candidate set of weights to predict voxel activity from activity of all CNN units. We correlate cluster-based stimulus responses with voxel responses across ventral temporal cortex. For all four CNN layers studied, cluster-based stimulus responses strongly correlate ($r>0.3$) with voxels in mid-level visual regions – V4, LO, and IT. Correlations are larger at higher CNN layers. Within each layer, there is significant correlation between cluster density (similarity of CNN responses to patches within the cluster) and voxel correlation magnitude. However, there is consistently less agreement on subject-reported image patch qualities for high-correlation clusters compared to patches from low-correlation clusters. Frequently occurring "properties" include texture, color, and full objects. In intermediate cortical vision, voxels may tune for complex mixtures of shade and texture properties less intuitive to human observers, but still uncovered through trained computer vision models.

Acknowledgement: Fordham University Faculty Research Grant to DDL in 2016 Clare Boothe Luce Scholarship to AF

Development: Lifespan, neural mechanisms

Sunday, May 19, 8:30 am - 12:30 pm, Pavilion

33.415 **Children's use of local and global visual features for material perception** Benjamin Balas[1](benjamin.balas@ndsu.edu), Amanda Auen[1], Josselyn Thrash[1], Shea Lammers[2]; [1]Psychology Department, North Dakota State University, [2]Human Development and Family Science Department, North Dakota State University

Adults can rapidly recognize material properties in natural images (Sharan, Rosenholtz & Adelson, 2009) and children's performance (Balas, 2017) in material categorization tasks suggests that this ability develops slowly during childhood. In the current study, we further examined the information children use to recognize materials during development by asking how the use of local vs. global visual features for material categorization changes in middle childhood. We recruited adults and 5-10 year-old children for three experiments that required participants to distinguish between shape-matched images of real and artificial food. Accurate performance in this task requires participants to distinguish between a wide range of material properties characteristic of each category, thus testing material perception abilities broadly. In two tasks, we applied distinct methods of image scrambling (block scrambling and diffeomorphic scrambling) to parametrically disrupt global appearance. In the third task, we used Gaussian blurring to parametrically disrupt local features visibility. In each task, we also measured baseline response latency differences between age groups using a simple 2AFC color-matching task. Our key question was whether or not participant age affected performance (correct response latency) differently when local vs. global appearance was disrupted. Parametric variation in each task strongly affected performance ($BF10 > 106$ in all tasks). Once baseline RT differences across age were regressed out, participant age affected performance when Gaussian blurring and block scrambling were applied ($BF10 > 80$ in each case), but not when diffeomorphic scrambling was applied ($BF10=1.2$). Finally, only block scrambling led to an interaction between parametric

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appearance variation and age (BF10=87.6). This pattern of results suggests that disrupting local and global visual features affects children's performance in much the same way as it affects adults, with the exception of block scrambling, which we argue differs due to the addition of high spatial frequency artifacts to manipulated images.

Acknowledgement: NSF DLS 1427427

33.416 **The innateness of visual number: A case study using children's counting books** Emily M Sanford[1](esanfor4@jhu.edu), Justin Halberda[1]; [1]Johns Hopkins University

A brief glance at an apple tree is enough to form a surprisingly accurate impression of the number of apples on its branches. What is the basis of this capacity? Can our abstract numerical representations be directly traced back to primitive early visual representations of number, or must we learn to construct them from low-level non-numerical features (such as surface area, density, or convex hull) over the course of development? If cognitive representations of number must be constructed from non-numerical visual features, then it must be the case that the visual evidence available to us sufficiently determines the number of items in a display. Here, we explore this assumption by making use of a surprisingly underutilized resource: the visual images that children look at when learning number from counting books. If the non-numerical visual cues in these images fail to capture number, then children could not rely on them to learn how many items are on a page. This implies that vision must rely on a more direct number signal. Much work suggests that the concept number must be constructed from early visual features, so we analyzed how well such features track cardinality across 50 children's counting books. We found that continuous features were at best weakly correlated with number (highest r2 = .32). A linear regression over the three most predictive features explained a modest amount of variability in the number of items, R2 = .33, p < .001. Further, a system of visual number that only uses evidence from non-numerical features will perform much worse than children do in typical number tasks. We show that children's number abilities go beyond that which could be provided by low-level visual features and therefore must involve either a more direct numerical extraction or an inference beyond the evidence of non-numerical features.

Acknowledgement: National Science Foundation

33.417 **An Objective and Sensitive Visual Acuity Assessment Method for Preverbal and Infantile Children Based on Steady-State Motion Visual Evoked Potentials** Xiaowei Zheng[1](hlydx2324@163.com), Guanghua Xu[1,2], Yunyun Wang[3], Sicong Zhang[1,2], Chenghang Du[1], Long Hao[1]; [1]School of Mechanical Engineering, Xi'an Jiaotong University, Xi'an, China, [2]State Key Laboratory for Manufacturing Systems Engineering, Xi'an Jiaotong University, Xi'an, China, [3]School of Software Engineering, Xi'an Jiaotong University, Xi'an, China

Abstract: Traditional evaluation of visual acuity, such as naming of Snellen letters, mainly depends on the subjective examiner's judgement, which can be easily affected by the impure motivational factors or intellectual abilities, so it may be more difficult for infants. By recording and analyzing electrophysiologic signals especially steady-state motion visual evoked potentials (SSMVEPs) from the human scalp, an objective, quantitative and sensitive method of evaluating objective visual acuity and monitoring the visual development of preverbal and infantile children can be provided. In this study, we designed a specific concentric ring SSMVEP paradigm with a given oscillating expansion-contraction frequency to assess the visual acuity. The canonical correlation analysis (CCA), signal-to-noise ratio (SNR) and some statistical methods were used to analyze the electroencephalography signals and extract visual acuity features in the test. We proposed a threshold determination method to define the corresponding objective visual acuity and established a representational model of the objective visual acuity. Each experiment was divided into 11 trails of different spatial frequencies corresponding to SSMVEP optotypes from 0.0 to 1.0 log minimum angle of resolution (logMAR), and the objective visual acuity of 22 eyes from 11 healthy adults had been tested using this paradigm with brain computer interface system. The CCA value at the target stimulus frequency of SSMVEP response had a decreasing trend from 1.0 logMAR to 0.0 logMAR SSMVEP optotype. The objective SSMVEP visual acuity and subjective psychophysical visual acuity were correlated significantly (P = 7.4708E-12, Pearson's r = 0.9532), and the difference between the two types of visual acuity of the same eye was within 0.1 logMAR range, except one eye with 0.2 logMAR difference. Our study proved that SSMVEP can be an objective and quantitative method to measure visual acuity, especially for evaluating and monitoring visual acuity of infants and preverbal children.

33.418 **Differences in Visual Search and Eye Movements Between Caesarean-Section and Vaginally-Delivered Infants and Adults** Maryam Rahimi[1](maryamra@yorku.ca), Scott A. Adler[1,2]; [1]Department of Psychology, York University, Toronto Canada, [2]Centre for Vision Research, York University, Toronto Canada

Search asymmetry occurs when feature-present targets are detected more easily than feature-absent targets, resulting in an efficient search (i.e. flat RT - set size function) for feature-present targets, but an inefficient search (i.e. increasing RT – set size function) for feature-absent targets. Both 3-month-old infants and adults have been found to exhibit a search asymmetry when assessed with saccade latencies (Adler & Gallego, 2014). Additionally, caesarean-section delivered infants exhibit slower attention and saccadic latencies than those born vaginally (Adler & Wong-Kee-You, 2015).This study is designed to determine the relative effects of different birth experiences on attention and search asymmetry performance and whether differences persist in adulthood. Two different visual circular arrays were presented: feature-present target among feature-absent distractors (R among Ps) or feature-absent target among feature-present distractors (P among Rs) with array set sizes of 1, 3, 5, 8. Results indicated that infants' and adults'saccadic latencies were unaffected by set size in feature-present arrays, suggesting an efficient search. Both caesarean-section born infants and adults had slower saccadic latencies when compared to the vaginal groups. Interestingly, infants born via planned caesarean-section were faster when compared to an emergency caesarean-section. There were no differences in saccadic latencies, however, between emergency and planned caesarean-section adults. For feature absent targets, both infants and adults exhibited increasing saccadic latencies with set size, suggesting an inefficient search. Infants born via planned caesarean-section had slower saccadic latencies than both vaginally born and emergency caesarean-section infants. Adults again, however, all preformed similarly regardless of birth experience, suggesting that any difference due to planned vs emergency caesarean-sections does not persist into adulthood.These findings suggest that any caesarean-section birth influences bottom-up attention and requires greater reliance on top-down processing even into adulthood. Thus, the development of attentional mechanisms can be influenced by early birth experiences that also impact adulthood.

Acknowledgement: Hallward Fund of Toronto Foundation

33.419 **Adults' Selective Attention and Eye Movements as a Function of Birth Experience** Scott A Adler[1, 2](adler@yorku.ca), Kyle J Comishen[1], Audrey M B Wong-Kee-You[3]; [1]Department of Psychology, York University, [2]Centre for Vision Research, York University, [3]Smith-Kettlewell Eye Research Institute

Selective attention filters available environmental information for which is further processed and the subject of subsequent cognitive or behavioral action.Spatial cueing studies, designed to measure the allocation of selective attention, have shown that adults produce saccadic eye movements with shorter latencies when they are cued indicating facilitation of attentional selection (Adler, Bala, & Krauzlis, 2002). A recent study with 3-month-old infants' has shown that their saccadic latencies in a similar spatial cueing task are sensitive to prior birth experience (Adler & Wong-Kee-You, 2015), with caesarean section delivered infants exhibiting slower latencies to localize the cued target than those born vaginally.The present study addressed whether the attentional effect of birth experience observed in infants was transient or more permanent.To this end, a peripheral cue was either presented or not at one of two possible locations 5.5° to the left or right of center for 150 msec, followed randomly between 500 to 1000 msec later by either a target at the cued location or a target and distractor for 1500 msec.Results indicated that adults delivered by caesarean section and vaginally exhibited the same overall pattern of saccadic performance across cueing conditions.Similar to infants, however, caesarean section delivered adults had slower latencies than those delivered vaginally. One possible explanation is that the caesarean section impacts bottom-up attention, requiring an over-reliance on the top-down system. Consistent with this possibility, caesarean section delivered adults also exhibit more incorrect anticipatory saccades than vaginally delivered adults.Neurally, the birth process is thought to lower serotonin levels leading to differentiation of the somatosensory cortex (Toda et al., 2013) – a cascade that might not occur during caesarean section.In sum, the findings indicate that the development of attentional mechanisms is not static, as generally proposed, but influenced by early experiences that persist into adulthood.

Acknowledgement: The Hallward Fund of the Toronto Foundation

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33.420 **Developmental changes in connectivity between the amygdala subnuclei and visual regions**
Heather A Hansen[1](hansen.508@osu.edu), Zeynep M Saygin[1]; [1]Department of Psychology, College of Arts and Sciences, The Ohio State University

The amygdala, a subcortical structure known for social and emotional processing, can be subdivided into multiple nuclei with unique functions and connectivity patterns. Tracer studies in adult macaques have shown that the lateral and basal amygdala subnuclei decrease in connectivity to visual cortical areas moving from anterior to posterior, and that infants have similar adult-like projections plus additional connections that are refined with development. Can we delineate the connectivity between the amygdala subnuclei and occipitotemporal cortex in humans, and will it show similar developmental differences as macaques? If so, what functional regions may be contributing to this pattern of connectivity? To address these questions, we anatomically defined the lateral and basal amygdala subnuclei in 20 adult subjects, 27 kids (aged 7-8), and 18 neonates. We then combined all Freesurfer anatomical regions in the temporal and occipital cortices in each individual's native anatomy, and split this entire region into five equal sections from anterior to posterior. We also defined visual functional parcellations in the occipitotemporal cortex (e.g. FFA, PPA) and anatomically defined primary visual cortical areas V1, V2, and V3. Using Diffusion Weighted Imaging data (b-value 700s/mm2, 60dir), we ran probabilistic tractography with FSL between the amygdala subnuclei as seeds and the occipitotemporal cortical parcellations as targets. Results showed that like macaques, the mean connectivity across subjects to the occipitotemporal cortex significantly decreased on a gradient from anterior to posterior, and that connectivity in kids and infants was adult-like but became more refined across development. Further, refinement of connectivity to mid- to posterior occipitotemporal cortex was largely driven by PPA, PFS, LO, and V1, with connectivity to higher order visual areas increasing with age. The functional maturation of these regions may contribute to the continued refinement of these connections, in line with Interactive Specialization hypotheses of brain development.

33.421 **Guided visual search in junior schoolchildren: Slow but sure**
Maria Falikman[1,2](maria.falikman@gmail.com), Igor Utochkin[1], Yury Markov[1], Natalia Tiurina[1], Olga Khasina[3]; [1]National Research University Higher School of Economics, [2]Russian Academy of National Economy and Public Affairs, [3]Moscow State University of Psychology and Education

Top-down guidance of visual search is an issue of continuous discussions (e.g. Wolfe, Horowitz, 2017). However, it's still unclear when guidance emerges in the course of individual development, and whether the fronto-parietal brain network, which underpins attentional control, is necessary for the attentional guidance. Although there were a number of experiments studying visual search in children, to our knowledge no study directly confronted conditions, under which adults do and do not demonstrate guided search, in younger populations. In our experiment, we compared feature search, guided conjunction search and unguided conjunction search in 20 young adults (university students, mean age 18.5) and 20 junior schoolchildren (7.5-9.5 years old, mean age 8.5). The two groups performed three randomized blocks of the standard visual search task, searching for a target "fox's house" among distractor houses and receiving feedback after each trial. The target house differed from distractors only in color (feature search), in color and shape (conjunction search), or was defined as a specific combination of two colors (conjunction search with no possibility of top-down guidance). Set sizes of 4, 7, and 10 stimuli were used, with only a half of the trials containing a target. Our hypothesis was that in adults we would observe top-down regulation of the conjunction search, whereas in children the search besides the feature search condition will be equally inefficient, because of the fronto-parietal network immaturity (e.g. Astle et al., 2015). Surprisingly, the overall pattern of results in all three conditions was the same in children and adults, with pronouncedly more efficient conjunction search as compared to the unguided search, although children were significantly (and proportionally) slower in all types of search. This allows concluding that top-down attentional guidance is already fully present in junior schoolchildren.

33.422 **Effects of age and target modality on spatial localization on the horizontal plane**
Douglas A Addleman[1,2](addle005@umn.edu), Yingzi Xiong[1,2], Gordon E Legge[1,2]; [1]Department of Psychology, University of Minnesota, [2]Center for Applied and Translational Sensory Science, University of Minnesota

We investigated spatial localization in younger and older adults as a function of target azimuth for visual and auditory stimuli. Thirteen younger subjects (21 to 33 years) and twelve older subjects (59 to 78 years) participated in a localization task. All subjects had normal vision and hearing. Stimuli were 200-millisecond auditory pink noise (0.2kHz- 8kHz) and/or visual white disks (subtending ~3°) presented at 17 locations along the horizontal plane (from 90° left to 90° right). For analyses, locations were collapsed across hemifields and categorized into central (0° to 30°) and peripheral (60° to 90°) space. Subjects verbally estimated azimuth (e.g., "left, 25 degrees") of targets in four conditions: multimodal (simultaneous visual and auditory cues); visual cue (with no auditory cues); auditory cue (with no visual cues); and auditory while blindfolded (no visual cues and no visual context). We measured accuracy (the unsigned difference between reported and actual target locations) and variability (the standard deviation of responses within each location). In central space, each group localized visual and multimodal cues better than those in either auditory condition; in peripheral space, each group showed comparable performance regardless of condition. Responses were less variable in central space than peripheral space in all four conditions in each group, with one exception: older participants, when wearing blindfolds, had similar performance regardless of target azimuth. Furthermore, performance between groups was statistically different only when localizing central auditory targets while blindfolded, in which case older participants were less precise than younger participants. This suggests that, while localizing auditory targets, older participants rely more on anchoring their responses to their visual environment than do younger participants, a strategy that may be more effective in high-acuity central space. Otherwise, our results reveal largely intact spatial localization in typical aging.

Acknowledgement: NIH grant EY002934, NSF DGE-1734815, University of Minnesota CATSS 5334800-UMF0021212

33.423 **Occipital alpha changes in response to label-learning during infancy**
Ryan A Barry-Anwar[1](rbarryanwar@ufl.edu), Gabriella Silva[1], Andreas Keil[1], Lisa S Scott[1]; [1]Department of Psychology, University of Florida

Occipital alpha has been found to desynchronize in infants during focused attention (Michel et al., 2015; Xie et al., 2018) and thus may be a useful measure for understanding attention changes associated with infant learning. Previous research suggests that exposing infants to individual-level labels for novel objects (e.g., "Harry") over the course of 3 months results in increased visual attention to those objects relative to category-level labels (e.g., "hitchel", Pickron et al., 2018). Here, 9-month-old infants (n=19) completed a brief in-lab learning session during which one group of novel objects was verbally labeled with individual names, and the other group was verbally labeled with a category name. Before and after label training, continuous EEG was recorded while infants watched objects and faces slowly moving down a screen for 10 seconds (see Figure 1). Infants saw 1) new exemplars from the individually labeled object group, 2) new exemplars from the category labeled object group, 3) exemplars from an untrained object group and 4) faces. The baseline relative amplitude at 7Hz was chosen for analysis, based on visual inspection of mean amplitude over the medial occipital area within the infant alpha range (6-9 Hz). Results revealed that alpha amplitude did not differ from baseline before the label training for any condition (see Figure 2). However, after training, significant alpha desynchronization was found when infants viewed faces (p=.001) and objects from the individually labeled group (p= .02). Alpha did not differ from baseline for objects labeled at the category-level (p= .46) or for the untrained objects (p= .43). Findings suggest similar patterns of alpha desynchronization for faces and individually-labeled objects and that labeling objects at the individual level, during infancy, results in increased visual attention.

33.424 **The Global Precedence Effect in Children With and Without the Use of Complex Instructions**
Emily C Blakley[1](eblakle1@binghamton.edu), Nicholas Duggan[1], Sarah Olsen[1], Alecia Moser[1], Peter Gerhardstein[1]; [1]Psychology, Binghamton University, SUNY

The Global Precedence Effect (GPE) describes a visual phenomenon in which adults are biased to perceive the global or holistic aspect of an image first before processing local information (Navon, 1977). Developmental research shows evidence of a local bias during early childhood (Poirel et al. 2014) that becomes global (Dukette & Stiles,1996; Kimchi et al. 2005) with age, through research disagrees on when this occurs (Hupp & Souther, 2014; Kramer et al.; Poirel et al., 2014; Scherf et al. 2009). Findings suggest that experimental factors such as task and stimuli manipulations may lead to these differing conclusions. The current study investigates the GPE in 4-year-olds, and investigates whether an instructional manipulation can influence the emergence of the effect. Four-year-olds were shown pairs of global shapes made up of local shapes. Pairs could be identical, or differ on either the global or local level. During Phase I, children were verbally asked if image pairs were "exactly the same in every way" or "different in any way". In Phase II, in addition to the verbal prompts, children were shown a visual instruc-

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tional sequence that explained what “exactly the same” or “different in any way” meant with regards to the local and global differences. Results show that 4-year-olds display a significant bias towards the local level, meaning that they were more likely to notice differences on the local level compared to the global level. After the instructional sequence, children showed less local bias and a higher global bias. This suggests that instructions, practice, and verbal manipulations may have an impact on the bias children show in GPE tests and that the switchover from local to global biases may occur earlier than the previously suggested age of 6 years.

33.425 **Aging and the perception of global structure** Alexia Higginbotham[1](alexia.higginbotham205@topper.wku.edu), Farley Norman[1]; [1]Department of Psychological Sciences, Ogden College of Science and Engineering, Western Kentucky University

The current study evaluated the ability of 17 younger (mean age = 20.4) and older adults (mean age = 76.7) to discriminate shapes depicted by Glass patterns (Glass, 1969). On any given trial, observers identified a particular pattern as either possessing a radial or concentric (i.e., circular) organization. Detecting a shape defined by a Glass pattern requires the successful detection of the orientations of its constituent local dipoles. In addition, long-range processes (e.g., the Boundary Contour System of Grossberg & Mingolla, 1985) are needed to integrate the spatially separated dipoles into perceivable contours that have a particular (e.g., radial or concentric) organization. In the current experiment, the shapes were defined by either 40 or 200 oriented dipoles spread over an area with a diameter of either 6 or 25 degrees visual angle. Three amounts of visual noise were added to the patterns to manipulate task difficulty: 1) no added noise points, 2) moderate amounts of noise (a 1:1 ratio of randomly-placed noise points and signal dipoles), and 3) large amounts of noise (a 5:1 ratio of randomly-placed noise points and signal dipoles). The results showed that the addition of noise greatly affected the observers’ ability to discriminate global shape ($F(2, 30) = 141.8$, $p < .000001$, partial eta squared = .90). Interestingly, there was no effect of the change in size of the pattern ($F(1, 15) = 1.35$, $p = .26$). Both younger and older adults were able to effectively discriminate shape even when the size of the pattern was increased more than 400 percent to 25 degrees visual angle (i.e., no age x size interaction: $F(1, 15) = 0.5$, $p = .49$). The current results demonstrate that older observers maintain an impressive ability to integrate local spatial information over large distances to perceive global shape.

33.426 **Development of Face Discrimination in Infancy: An Eye Tracking Study** Andrew T Marin[1](amarin@ucsd.edu), Karen Dobkins[1], Rain Bosworth[1]; [1]Psychology Department, University of California, San Diego

Introduction: Previous studies using habituation techniques have shown infants as young as three months can discriminate between different faces (Slater et al., 1998; Sangrigoli & De Schonen, 2004; Kelly et al., 2008; Slater et al., 2010). The current study expands upon this literature by tracking the development of face discrimination using an oddball visual stimuli method in conjunction with eye-tracking methods. Unlike previous studies, the current investigation contrasts the development of face discrimination with that of a comparable shape discrimination task using scrambled faces. Methods: Twenty-eight infants (M = 8.5m (±1.6); age-range (5.8-11m); 14 females) provided gaze metrics recorded with eye-tracking. The dependent measure was first-fixation latency (msec) toward an oddball target presented amongst three distractors. Each target, per stimuli type, were randomly positioned in one of the four corners of the monitor and each trial lasted five seconds. For the Face condition, the target was a different face than the distractors, and for the Shape condition, the oval target differed in aspect ratio from the distractors. To check for infant engagement, a high contrast circle was interleaved across trials, and only infants who reliably fixated this stimulus were retained for analysis. For both Face and Shape conditions, effects of age were examined using exploratory correlational analyses. Results: For Faces, a significant negative correlation was observed between first-fixation latency and age ($r(24) = -0.465$, $p = 0.016$). By contrast, for Shapes, there was no significant effect of age ($r(12) = 0.438$, $p = 0.154$). The correlation between first-fixation to Faces and age remained significant after Bonferroni correcting for multiple comparisons (p’s < .025). Conclusion: Using eye-tracking methods, developmental changes in face discrimination can be observed in the first year of life. The fact that this age-related effect was seen for faces, and not shapes, suggest different underlying mechanisms for face vs. non-face objects.

33.427 **The development of form and motion perception from school-age to adulthood:comparing sensitivity to luminance- and texture-defined stimuli.** Margarita Miseros[1](margarita.miseros@mail.mcgill.ca), Domenico Tullo[1], Jocelyn Faubert[2], Armando Bertone[1, 3]; [1]McGill University, [2]Université de Montréal, [3]Summit Center for Education, Research, and Training

Visual development has for the most part been assessed within the context of ventral- vs dorsal-stream functioning, underlying form and motion processing, respectively (Braddick et al., 2003; Atkinson, 2017). Few studies have assessed stream-specific visual development at different levels of processing within each stream during typical development (Bertone et al, 2009; Armstrong et al.,2009). The present study aimed to characterize visual development from school-age through adulthood by measuring the sensitivity to static and dynamic gratings defined by both luminance- and texture-defined attributes, presented before a dynamic noise background. One-hundred and fifty-eight (n=158) typically developing participants (Weschler IQ>80) were included in one of 5 age groups; 6-9 years (n=23), 10-13 years (n=34), 14-18 years (n=25), 19-22 years (n=30), and 23-30 years (n=46). Using a single interval, two-alternative, forced-choice paradigm, participants were asked to identify the orientation (vertical-horizontal) or direction (left-right) of a static (0 Hz) or moving (left to right at 2 Hz for 720 ms) grating defined by either luminance- or texture-contrast (1 cpd). An adaptive staircase procedure was used to measure sensitivity to stimuli in all four conditions. Age predicted sensitivity for luminance-defined stimuli (static and dynamic conditions; $R2=[0.25-0.38]$, $p< .001$) to a significantly greater extent than for texture-defined information($R2=[0.21-0.30]$, $p< .001$). Furthermore, sensitivity for both luminance-defined conditions, and the texture-defined, static condition was equal to that of the oldest group by 19 years of age; sensitivity of the texture-defined, dynamic condition reached that of the oldest group at 14 years. Findings demonstrate that visual development within each stream continues through adolescence, but is differentiated by the type of information, luminance- vs texture-defined, processed. We are assessing whether cognitive capacities (i.e. IQ and attention) mediate these findings, which are the first to compare static and dynamic information processing using luminance- and texture-defined stimuli from school-age through to adulthood.

33.428 **Development of human infants’ receptive field mechanisms in motion processing** Yusuke Nakashima[1](ynakashima214@gmail.com), So Kanazawa[2], Masami K Yamaguchi[3]; [1]The Research and Development Initiative, Chuo University, [2]Department of Psychology, Japan Women’s University, [3]Department of Psychology, Chuo University

Discrimination of motion direction is more difficult when the size of high-contrast motion stimuli is increased (Tadin et al., 2003). This is considered to be a perceptual phenomenon that reflects surround suppression in MT neurons. Using this effect, we examined the development of receptive field mechanisms of motion processing in human infants. To clarify when surround suppression in motion processing is acquired, we measured motion direction discrimination with small and large drifting gratings in 3- to 8-month-old infants using familiarization/novelty-preference procedure. During the familiarization phase, a grating moving leftward or rightward was presented repeatedly. In the test phase, gratings moving leftward and rightward were presented simultaneously. Small and large motion stimuli were used in separate sessions. If infants have surround suppression, higher novelty preference would be observed for the small stimulus than for the large stimulus. Our results showed that infants at 6-8 months exhibited higher novelty preference for the small stimulus. In contrast, infants at 3-5 months showed higher novelty preference for the large stimulus. These results suggest that surround suppression in motion processing emerges at around 6 months of age. To investigate developmental change in the size of the receptive field’s center region, we estimated the receptive field size in infants at 3-4 months and 7-8 months using a similar method. The results showed that the size of the receptive field center was larger in 3-4 month-old infants than in 7-8 month-old infants, suggesting that the excitatory center region of receptive fields shrinks with age. The present results are consistent with theories on the development of receptive fields in human infants derived from developmental changes of the contrast sensitivity function.

Acknowledgement: JSPS KAKENHI (17H06343)

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33.429 **Temporal contrast sensitivity is associated with retinal thickness** Nancy J Coletta[1](nancy.coletta@mcphs.edu); [1]School of Optometry, MCPHS University, Worcester, MA

Eyes with long axial lengths exhibit thinning of the inner retinal layers, which is associated with increased multi-focal ERG latencies. The goal was to determine if central and peripheral retinal thinning is associated with temporal contrast sensitivity (TCS) deficits. Measurements were made on 21 subjects with refractions from 0.25 D to -9.25 D and axial lengths from 22.65 to 27.51 mm. TCS for sinusoidal flicker was measured from 2 to 40 Hz at the fovea, and at 7° eccentricity in the superior and inferior retina. The stimulus was a 1° s.d. Gabor patch on a uniform white field. Retinal thickness in the fovea (central 1 mm) and perifovea (3-6 mm ring) was measured with a spectral domain OCT. Full retinal thickness is the thickness from the retinal pigment epithelium (RPE) to the inner limiting membrane (ILM); inner retinal thickness is the thickness from the inner plexiform layer (IPL) to the ILM. Foveal TCS at 5 to 40 Hz was significantly lower in subjects with central 1 mm full retinal thickness below 246 microns ($p< 0.05$ in t-tests) but was not significantly related to axial length. TCS at 30 Hz in the superior and inferior retina was significantly lower in eyes with smaller inner retinal layer thickness in the perifoveal ring ($p< 0.05$ in regressions); superior retina TCS was similarly correlated with superior hemifield and superior quadrant inner thickness ($p< 0.05$). Subjects with axial lengths longer than the mean of 24.29 mm exhibited significantly decreased TCS at 30 Hz ($p=0.025$) and 40 Hz ($p=0.03$) in the inferior retina and at 40 Hz ($p=0.016$) in the superior retina. Thinning of the fovea and inner perifoveal retina is associated with decreased temporal contrast sensitivity in the corresponding visual field region, which may indicate reduced function of retinal neurons where the retina is thinned.

Acknowledgement: MCPHS University

33.430 **Grouping of flankers is similar in children to adults and does not break crowding.** Sarah J Waugh[1](sarah.waugh@anglia.ac.uk), Monika A Formankiewicz[1]; [1]Anglia Vision Research, Department of Vision and Hearing Sciences, Anglia Ruskin University

Spatial interactions, including lateral masking and crowding, affect clinical visual acuity scores. Magnitude of interaction is determined by taking the difference in acuity (logMAR) between a flanked versus an isolated letter. It depends on target-flanker separation, target-flanker similarity and flanker grouping. Grouping of flankers, or ungrouping of flankers from the target, also contributes to visual scene perception and could be different in children and adults. We examined the impact of target-flanker similarity and flanker grouping on single letter acuity in normal healthy children aged 3 to 11 years (n=155) and adults (n=32). Visual acuity was measured for isolated letters (HOTV) and single letters (HOTV) surrounded by a box, bars, black letters or red letters (CLUA), placed 1 stroke-width away. No statistically significant effect of age was found on magnitude of spatial interaction when bars or a box surrounded the target letter.Threshold elevation was greater ($p< 0.001$) for bars (0.15±0.01 logMAR) than a box (0.11±0.01 logMAR).When letters surrounded a black letter, the magnitude of spatial interaction reduced with age ($p< 0.05$). It was greater for black, than red, surrounding letters ($p< 0.001$).From 3-5 years to adulthood, threshold elevation fell from 0.27±0.03 to 0.18±0.02 logMAR for black surrounding letters, and from 0.22±0.03 to 0.15±0.02 for red surrounding letters. Grouping of flankers by colour or continuity reduces the magnitude of spatial interaction similarly for healthy young children and adults.In children, target-flanker similarity heightens spatial interactions, demonstrating crowding. Grouping by colour bends but does not break crowding, so could be used to improve visual attention in children without losing diagnostic potency.

Acknowledgement: Anglia Ruskin University Quality Related Research Fund, NIH Grant 1R01EY027964–01A1

33.431 **Development of entorhinal grid-cell-like representations of visual space** Joshua B Julian[1](joshua.b.julian@ntnu.no), Matthias Nau[1], Christian F Doeller[1,2]; [1]Kavli Institute for Systems Neuroscience, NTNU, Trondheim, Norway, [2]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

It has been proposed that the hippocampal formation (HF) supports cognitive map-like representations of both navigational and visual spaces (i.e., where one is looking) (Nau, et al., 2018, TiCS), raising the question of whether the same neural mechanisms support both domains. If so, we would expect the HF visual mapping system to undergo a relatively protracted developmental trajectory, as it does in the navigational domain (Julian et al., 2018, Dev. Sci.). To address this question, we focused on grid cell-like representations of visual space in the entorhinal cortex (EC) in a large cohort of children (ages 5-18 years old). FMRI data were acquired while the children freely viewed a movie (Alexander et al. 2017, Sci. Data). We measured grid-cell-like fMRI responses as a function of gaze movement direction, using an analysis procedure previously used to identify this visual grid signal in adults (Nau et al., 2018, Nat. Neurosci; Julian et al., 2018, Nat. Neurosci.). There was significant reliable grid-cell-like modulation in EC as a function of gaze movement direction. Critically, the magnitude of EC visual grid coding increased with age, due to developmental changes in the temporal stability of visual grid-like representations. This change in visual grid coding across the early lifetime could not be explained by developmental changes in eye movement behavior. Our results support the idea that visual and navigable space are represented using the same neural mechanisms, and help to elucidate how cognitive maps emerge during development.

33.432 **Tactile influences on visual processing of bodily information in infant** Jiale Yang[1](jiale.yang.ac@gmail.com), Natasa Ganea[2], So Kanazawa[3], Masami K. Yamaguchi[1], Andrew Bremner[5]; [1]Chuo University, [2]Goldsmiths, University of London, [3]Japan Women's University, [4]University of Birmingham

Body representations are products of complex multisensory interactions and are closely related to motor control and the sense of self. A number of claims have been made that humans are born with an innate ability to perceive their own bodies (Rochat, 2010), with some evidence of visual tactile interactions present in the early months of life (Filippetti et al., 2013; Freier et al., 2016). However, only a little is known about how the multisensory body representations develop. In the present study, we used the steady-state visually evoked potentials (SSVEP) to investigate the development of tactile-visual cortical interactions underlying body representations in infants. In Experiment 1, twelve 4-month-old and twelve 8-month-old infants watched a visual presentation in which a hand was stroked with a metal tube. To elicit the SSVEP, the video flashed at 7.5 Hz. In the tactile-visual condition the infant's own hand was also stroked by a tube whilst they watched the movie. In the vision-only condition, no tactile stimulus was applied to the infant's hand. We found larger SSVEPs in the tactile-visual condition than the vision-only condition in 8-month-old infants, but no difference between the two conditions in the 4-month-olds. In Experiment 2, we presented an irrelevant video to 8-month-old infants rather than a hand. The enhancement of tactile stimuli on SSVEP was absent in this case, demonstrating that there was some degree of body-specific information was required to drive the tactile enhancements of visual cortical processing seen in Experiment 1. Taken together, our results indicate that tactile influences on visual processing of bodily information develops between 4 and 8 months of age.

33.433 **How mature are connectivity patterns in the neonate brain?** Jin Li[1](li.9361@buckeyemail.osu.edu), Athena L. Howell[1], Micah R. Rhodes[1], Zeynep M. Saygin[1]; [1]Department of Psychology & Center for Cognitive and Brain Sciences, The Ohio State University

Is the wiring pattern of high-level visual cortex innate, and if not, how does it develop with age? Previous research showed evidence for category selective responses in visual regions for 4 - 6-month-old infants (Deen et al., 2017). Moreover, the connectivity pattern of the VWFA exists even before a child learns to read, suggesting that wiring patterns may drive the development of specialized regions of cortex (Saygin et al., 2017). Here, we examined the connectivity patterns of putative high-level visual regions (i.e., faces, objects, scenes, visual word form areas (VWFA)), language, and speech regions in adults and in neonates. We analyzed data from the Human Connectome Project and developmental Human Connectome Project. We used functional parcels as defined in independent datasets of high-level visual regions, and other regions across the brain (including language, speech, and multiple-demand areas) and registered these parcels into each individual's brain, and calculated the resting-state functional connectivity between these areas in both adults and neonates. Although neonate connectivity was lower than adults overall, there were similar patterns of connectivity between high-level visual regions in neonates and adults. Neonates had stronger within network connectivity for high-level visual areas, just like adults. Further, we found that the VWFA was more connected with language areas than other regions, including nearby visual areas, in both neonates and adults. We also discuss similarities and differences between resting-state and diffusion-weighted imaging connectivity of these regions in neonates vs. adults. These results support the claim that many aspects of connectivity are innate and that the visual system, including regions that only become selective with experience (e.g. VWFA) is already set up for function, even before the relevant behavior exists (e.g. reading). Our study also provides neural evidence for how connectivity with language regions may facilitate high-level vision and vice-versa.

Acknowledgement: Alfred P. Sloan Research Fellow in Neuroscience (2018)

Sunday AM

33.434 **Predicting individual reading ability based on anatomical and functional neural connectivity** Carver B. Nabb[1](nabb.2@osu.edu), Heather A. Hansen[1], Stephen A. Petrill[1], Zeynep M. Saygin[1]; [1]Department of Psychology, College of Arts and Sciences, The Ohio State University

The ability to read is one of the most important skills that humans learn. There are vast individual differences in reading ability and this variation in reading ability can relate to neural differences, especially in white matter tracts (e.g. typical vs. dyslexic readers). Predicting reading disabilities is useful for early intervention, yet making reliable predictions is difficult.Here, we attempt to use diffusion weighted imaging (DWI) connectivity to improve the strength and accuracy of predictions at the individual subject level. We use machine learning algorithms, specifically support vector machine regressions (SVRs), to perform multivariate predictions of reading ability. Using DWI data, we ran probabilistic tractography using 86 pre-defined anatomical parcels as seeds and targets. We extracted the structural connectivity between seeds and targets in 220 subjects aged 14-16 years, and trained the SVR algorithms using a randomly selected subset of subjects (training dataset, N=120). These trained models were then tested on the remainder of the subjects (test dataset, N=100) in order to make predictions. Results showed that actual reading scores significantly correlated with predicted reading scores from the independent test dataset. We also tried the same approach but using group-average functional parcels instead of anatomical ones as seeds and targets. This model was also accurate in its predictions of reading ability. Both models outperformed control models and suggest that the connectivity of visual regions (e.g. VWFA) as well as possible language and attentional regions are predictive of reading ability. Our results demonstrate the feasibility of using DWI connectivity to predict individual reading ability. Due to the robust nature of these models, future applications may aid in the early identification of reading disabilities such as dyslexia.

33.435 **Investigating the influence of early life touchscreen use on screen-based attention control** Ana M Portugal[1](avazpo01@mail.bbk.ac.uk), Rachael Bedford[2], Celeste Cheung[1], Tim J. Smith[1,3]; [1]Centre for Brain and Cognitive Development, Birkbeck, University of London, [2]Biostatistics and Health Informatics Department, Institute of Psychiatry, Psychology & Neuroscience, King's College London, [3]Psychological Sciences, Birkbeck, University of London

The impact of the digital world on the developing mind is often debated but rarely evidenced. While TV viewing has previously been associated with attentional impairments, video gaming has been linked to enhanced visual attention. Touchscreen devices offer young children the potential for both watching videos and interactive use (i.e., playing games or educational apps) and the current study aims to test whether touchscreen use is associated with attention control differences during the pre-school years. In the current study, part of the Toddler Attentional Behaviours and LEarning with Touchscreens (TABLET) lab sample, we investigated longitudinally whether touchscreen use by toddlers at 12 months, 18 months and 3.5 years of age is associated with differences in a screen-based task of attention control – the Gap-Overlap Task (Johnson, Posner & Rothbart, 1991). Fifty-three infants were recruited based on their reported daily touchscreen use (High Users, >=10 minutes/day and Low Users, < 10 minutes/day minutes). Saccadic Reaction Times on baseline, gap, and overlap conditions were extracted offline using a set of trial gaze validation steps, and disengagement and facilitation were calculated by subtracting the baseline SRT to the overlap SRT and to the gap SRT, respectively. Generalised estimating equations showed a main effect of touchscreen usage group on disengagement (high users slower to disengage from stimuli, $p < 0.05$), which was followed up to reveal a group difference on the baseline condition (high users faster to orient to the peripheral target, $p < 0.05$. These effects suggest that early exposure to touchscreen devices may be associated with a quickening of attention to peripheral onsets with no concurrent detriment under conflict conditions. Future work should investigate whether performance in screen-based measures translates to real-world settings

33.436 **Test battery for daily self-assessment of visual abilities** Kenchi Hosokawa[1], Kazushi Maruya[1], Shin'ya Nishida[1], Satoshi Nakadomari[2]; [1]NTT Communication Science Laboratories, [2]Kobe City Eye Hospital

Visual ability tests are essential tools for Ophthalmologists and Optometrists and vision researchers to assess the status of basic visual abilities quantitatively for diagnose of the disease and monitoring its time course. Conventional tests require a help of professional assistance and often require time to measure (~several tens of minutes). From the view point of preventive health care, an easy test set which takes shorter measurement time and can be conducted by participants without professional assistance is expected. We, in this study, made a test battery consisting of with serious games for measuring visual abilities including fundamental visual function (perimetry, contrast sensitivity) and visual cognitive abilities (multiple-object tracking, visual crowding). The test is developed as a browser-based application using JavaScript and Web-GL libraries so that it runs on a wide range of tablet devices running iOS, Android OS and windows 10. Our priority for this test battery, which supposed to be used as a screening test, lies in the short measurement time and attractive graphical designs which aiming at increasing users' motivation, rather than in the measurement accuracy. Therefore, we adopted simplified measurement methods and/or limited range of stimulus parameters. The expected time to conduct each game is less than 3 minutes. In addition, we adopted a simple way for the measurements of contrast sensitivity functions (CSFs) by developing methods for tablet PCs proposed by Mulligan (2016). We compared the results of CSF measurements by our methods and those by conventional methods (QUEST methods with CRT display) and confirmed that the CSFs from our test have a peak at similar (~2cpd) spatial frequencies as CSFs measured by conventional methods. Those features of the test battery are suitable for preventive health care and daily assessment of visual abilities.

33.437 **Better statistical regularity with aging? Age-related difference in the neural processing of idioms** Su-Ling Yeh[1,3,6](suling@ntu.edu.tw), Shuo-Heng Li[1], Li Jingling[2], Joshua Oon Soo Goh[1,3,6], Yi-Ping Chao[4], Arthur C. Tsai[5]; [1]Department of Psychology, National Taiwan University, Taiwan, [2]Graduate Institute of Biomedical Sciences, China Medical University, Taiwan, [3]Graduate Institute of Brain and Mind Sciences, National Taiwan University, Taiwan, [4]Graduate Institute of Biomedical Engineering, Chang Gung University, Taiwan, [5]Institute of Statistical Science, Academia Sinica, Taiwan, [6]Center for Artificial Intelligence and Advanced Robotics, National Taiwan University, Taiwan

To process information efficiently, people extract regular/consistent patterns from the outside world to better predict upcoming events. Indeed, infant studies suggest that prior experience is necessary for such statistical regularity to be used. Yet, little work has been done to investigate if older adults—with their longer life experiences—would lead to greater influence of statistical regularity compared to their younger counterparts. We examined older and younger adults' processing of Chinese idioms—four-word phrases with semantic regularity acquired through experience. Thirty younger and 27 older neurologically-intact right-handed adults underwent an idiom recognition fMRI experiment. Participants viewed sequentially presented quartets of Chinese characters and, upon onset of the fourth characters, judged whether the quartets constituted idioms or not. Quartet sequences comprised frequent idioms, infrequent idioms, scrambled characters, and non-characters. Compared to younger adults, older adults had higher recognition hits for frequent idioms and higher false alarms for scrambled characters, with no difference in d', but smaller beta (more likely to make idioms judgment). fMRI results showed that older adults engaged higher neural responses to idioms relative to scrambled characters in left frontal, left parietal, and bilateral temporal areas, and to scrambled words relative to non-characters in left superior frontal gyrus. Critically, greater distinctive fronto-temporal engagement between idioms (either frequent or infrequent) and scrambled characters correlated with higher d' only in older but not younger adults. Our findings indicate that older adults were more prone to judging four-word phrases as idioms, with those who were more selective (greater d') for idiom judgment engaging more selective neural processing, possibly reflecting interaction of aging and experience. These findings suggest that different neural mechanisms are recruited for making the same idiom judgment in younger and older adults, reflecting the differential influence of statistical regularity extracted from the environment.

Acknowledgement: MOST 106-2420-H-002-010-MY3

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Spatial Vision: Low-level coding, natural image statistics

Sunday, May 19, 8:30 am - 12:30 pm, Pavilion

33.438 **What surface in the world is in best focus for the human eye?** Vivek Labhishetty[1](vlabhish@berkeley.edu), Agostino Gibaldi[1], Larry N Thibos[2], Martin S Banks[1]; [1]School of Optometry, University of California Berkeley, [2]School of Optometry, Indiana University

The retinal conjugate surface is the surface in the environment that is in best focus on the retina. We measured the shape of that surface in emmetropic and myopic eyes as those eyes accommodated to different distances. Using the Indiana Scanning Wavefront Aberrometer (Liu et al., 2016), we measured wavefront-aberration data in 16 emmetropic and 18 myopic eyes in the central 30º of the visual field across 37 retinal locations (including fovea). We did so for eight accommodative stimulus distances. At each retinal location, we defined a ray from that location through the eye's optical center and into the world. We moved a virtual object along that ray to find the distance at which the object would create the sharpest retinal image. To define sharpness, we used different image-quality metrics: Strehl ratio, equivalent width, and encircled energy. The results were very similar for all three metrics. In all eyes and accommodative states, there is significant astigmatism in the periphery with tangential axes. In emmetropes, the retinal conjugate surface is concave and consistently pitched top-back and rotated slightly nasal-back. The top-back and nasal-back effects are consistent with natural-scene statistics and the empirical binocular horopter. In myopes, the surface is less concave (consistent with a prolate or elongated eye shape) and is not consistently rotated top-back or nasal-back. Thus, the best-focus surface for emmetropes is reasonably well suited for the environment we usually experience. It is less well suited in myopes. These observations have important implications for the design of display screens and for the prevention of myopia.

Acknowledgement: NSF

33.439 **Measuring the field of contrast sensitivity via saccadic foraging.** Concetta F Alberti[1](conce.alberti@gmail.com), Anna Kosovicheva[1], Peter J Bex[1]; [1]Department Of Psychology, College of Sciences, Northeastern University

The visual system's response to complex stimuli can be estimated from the contrast sensitivity function (CSF), which varies across the visual field. Measuring this field of contrast sensitivity (Watson, 2018) has significant value, but requires too many measurements for practical applications. However, simplification may be possible via a spatial scaling factor (Strasburger et al, 2011). We measured detection thresholds in 6 normally-sighted observers with Laplacian of Gaussian (LoG) stimuli at 3 eccentricities (4°, 9°, 19°) and 8 angular locations in two 8AFC tasks. In a behavioral task, observers reported the location of the target via button press; in a continuous- eye movement task, observers foraged for targets and each saccade landing point was scored as a directional response and became the fixation for the next trial. For faster evaluation, two points on the CSF were measured and then the contrast sensitivity function was fit with an asymmetric log-parabola (Watson & Ahumada, 2005) with upper and lower bandwidths fixed (Chung & Legge, 2016). First, visual acuity was measured at each location, then contrast sensitivity was measured 1.16 log10 units below the measured acuity.There were no significant differences between thresholds measured with behavioral and eye-movement methods, suggesting that these methods are interchangeable and the ease of comprehension of the eye movement task may favor its use in naive populations. Log Acuity decreased linearly with eccentricity ($p < 0.001$). Peak contrast sensitivity was constant as a function of eccentricity ($p>0.05$), which we attribute to the scaled nature of the LoG stimuli. The CSF in healthy eyes was therefore determined by visual acuity. Therefore, in healthy visual systems and scaled visual stimuli, the field of contrast sensitivity function can be estimated from the field of acuity resolution and this may provide a simple reference to rapidly detect visual field deficits in visually impaired populations.

Acknowledgement: CFA: NIH K99 EY026130 AK: NIH F32 EY028814 PJB: NIH R01 EY029713

33.440 **Quick contrast sensitivity assessment in primates using an exploratory search task** Mariana Cardoso[1](mc7055@nyu.edu), Najib J. Majaj[1], Gerick M. Lee[1], Krysten Garcia[1], Lynne Kiorpes[1]; [1]Center for Neural Science, New York University

Collecting high-quality psychophysical data to estimate contrast sensitivity in human and animal subjects is typically time-intensive and requires extensive training. New tasks requiring continuous tracking of targets are fairly intuitive, require little training and are a much faster way to collect a large amount of data. By design, these tasks assess behavioral performance at the center of gaze. In order to test both foveal and peripheral vision we used a visual search task to obtain quick and reliable estimates of contrast sensitivity. We presented targets of variable spatial frequency and contrast at a variable distance from the center of gaze, and required the subject to acquire the target. This task requires virtually no training, granted that the subject is accustomed to orienting towards a monitor and is able to perform well-controlled eye movements. To evaluate the effectiveness of our task at measuring visual function for a variety of cases, we collected data from adult humans and macaque monkeys in different stages of visual development. We also collected data monocularly from an adult amblyopic macaque monkey. We compared contrast sensitivities as a function of age, amblyopia, or distance from the center of gaze. For the human subjects we compared the resulting sensitivities with ones obtained with a two alternative forced choice task (2AFC). Qualitatively, our findings suggest that the visual search task produces reasonable results. We confirmed that contrast sensitivity increases throughout development, the amblyopic eye is less sensitive than the fellow eye, and sensitivity in the periphery is poorer than near the center of gaze. We propose that this visual search task can be used to quickly estimate contrast sensitivity. This is particularly useful for testing challenging populations such as young children or young animals.

33.441 **The extent of the vertical meridian asymmetry in spatial frequency sensitivity** Shutian Xue[1](vivianxuest@outlook.com), Antoine Barbot[1,2], Marisa Carrasco[1,2]; [1]Department of Psychology, [2]Center for Neural Science, New York University

Goal: Human visual performance is heterogeneous across the visual field. At a fixed eccentricity, performance is better along the horizontal than the vertical meridian and along the lower than the upper vertical meridian. These performance fields are found in numerous tasks, including contrast sensitivity and spatial resolution. However, it is unknown whether the spatial resolution asymmetry is confined to the vertical meridian or whether and how far it extends into the upper and lower hemifields. Here, we measure the extent of this vertical meridian asymmetry by assessing spatial frequency (SF) sensitivity. Method: Spatial frequency sensitivity was measured using suprathreshold (100% contrast) gratings presented at isoeccentric locations (10º). In each trial, stimuli appeared at 4 locations separated by 90º polar angle. Participants were asked to discriminate the orientation (±45º) of the stimulus at the location indicated by a response cue. Auditory feedback was provided. In each block, the axes of the four isoeccentric locations were rotated clockwise from the vertical meridian by 0, 15, 30, 45, 60, 75 or 90º polar angle. The extent of the vertical meridian asymmetry was assessed by comparing 75%-correct SF thresholds for upper and lower visual field locations as a function of polar angle. Results: At constant eccentricity, SF sensitivity was higher in the lower than the upper visual hemifield, and was similar in the left and right hemifields. Moreover, we found that the vertical asymmetry in SF sensitivity decreased as the angular distance from the horizontal meridian increased, and was no longer significant by ~45º from the vertical axis. Conclusion: Our results imply that vertical asymmetry in SF sensitivity is most pronounced at the vertical axis and decreases gradually, being no longer significant by the secondary meridian. These results advance our understanding of performance fields and visual information processing, and constrain models of visual perception.

Acknowledgement: NIH NEI RO1-EY027401 to MC

33.442 **Temporal property of the density-size adaptation effect** Rumi Hisakata[1](rumi.hisakata@icloud.com), Hirohiko Kaneko[1]; [1]Dept. of Information and Communications Engineering, Tokyo Tech.

How the visual system encodes metric properties such as size and separation is still unclear. Regarding this, Hisakata, Nishida & Johnston (2016) reported a new adaptation effect in which the perceived separation of two dots or size of ring shrank after adaptation to a dense texture (density-size aftereffect). They proposed that the estimated separation (size) be coded relative to an adaptable spatial metric, which will be based on internal density representation. In many studies about visual adaptation, it is well known that the prolonged exposure to adaptation stimuli induces the larger aftereffect, whereas Aagten-Murphy & Burr (2016) reported that numer-

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osity adaptation required a repetitive presentation, not long exposure of adaptation stimulus. According to a theory of magnitude (Walsh, 2003), the estimation of numerosity and size share a common metric, and it is likely that the density-size adaptation has the same temporal properties as the numerosity adaptation. Here, we investigated the time course of the density-size adaptation and the effects of both the frequency of the refresh of the adaptation stimulus and the adaptation duration. We used the staircase method to measure the time course. Adaptation had 60 trials. The adaptation duration in one trial was 1000ms or 5000ms and the total duration was 60s or 300s respectively. The position and polarity of the adaptation texture were refreshed every 100ms, 300ms, or 0ms (no-refresh). As the results, the perceived size after the 5000ms adaptation more shrank than 1000ms in all conditions. However, in the 5000ms adaptation condition, the refresh every 100ms and 300ms induced the greater aftereffects than the no-refresh situation, indicating that the repetitive presentation of adaptation texture enhanced the density-size aftereffect only when the adaptation duration was enough. We will discuss the relationship between a theory of magnitude and the density-size aftereffect from the temporal property of it.

Acknowledgement: KAKENHI Grant-in-Aid for Young Scientists 18K18341

33.443 **Eccentricity-dependent differences in cross-orientation adaptation** Yi Gao[1](yi.gao0525@outlook.com), Fang Jiang[1], Michael A. Webster[1]; [1]University of Nevada, Reno

Recently we found that both the strength and dynamics of contrast adaptation differ between the fovea and near periphery when adapting and testing at the same orientation. In the present study we compared adaptation at the two loci when the adapt and test orientations were orthogonal. Participants adapted to horizontal or vertical Gabor patches (90% contrast, 1.5 cycle/degree, diameter of 5°, counterphase flickering at 5Hz) viewed centrally or in the periphery (10 degree eccentricity). Contrast thresholds were tracked using a yes/no detection task before, during, and after a 5 min adaptation block. In the fovea, cross-orientation aftereffects were only exhibited after adapting to vertical Gabor patches, showing an orientation asymmetry. Specifically, vertical adaptors produced larger sensitivity losses on horizontal tests than vice versa, despite no consistent differences in threshold changes at each adapting orientation. This asymmetry may be related to other evidence for anisotropies in orientation coding such as the "horizontal effect" (Essock et al. 2003), and to differences in the cross-axis effects in other domains such as luminance vs. chromatic contrast (Webster and Mollon, 1994). However, these cross-orientation asymmetries were much less evident in the visual periphery. Our results suggest that the effects of contrast adaptation on the orthogonal orientation is both orientation and eccentricity dependent, and point to further differences either in the properties of adaptation or the adapted mechanisms in the fovea and periphery. EY023268 to Fang Jiang, EY10834 to Michael A. Webster

Acknowledgement: EY023268 to Fang Jiang, EY10834 to Michael A. Webster

33.444 **Fixation-Related Potentials and Oculomotor Dynamics reveal Contrast Response and Adaptation in Free Viewing** Oren S Kadosh[1](okadoshx@gmail.com), Yoram Bonneh[1]; [1]School of Optometry and Vision Sciences, The Mina and Everard Goodman Faculty of Life Sciences, Bar-Ilan University, Ramat-Gan, Israel

Background: Event Related Potentials (ERPs) and the Oculomotor Inhibition (OMI) in response to transient visual stimuli are known to be sensitive to stimulus saliency, repetition and attention. Eye movements, which were traditionally considered as artifacts in the EEG signal are now being set as the event potential onset, timed locked to saccade offset creating Fixation Related Potentials (FRPs). Here we combined EEG and eye tracking, using free viewing techniques, to simultaneously asses the brain and OMI responses to incoming visual information after eye movement occurrence. The result of this movement is assumed to be equivalent to flashed stimuli with additional parafoveal preview. Methods: Participants moved their gaze freely in 10 sec. trials over full-screen images of random orientation Gabor patches texture, differing in contrast or spatial frequency between experimental conditions ("free viewing", exp1). In a second experiment, participants moved their gaze sequentially between four Gabor patches ("guided viewing", exp2) to investigate adaptation over time. We computed the FRP triggered by saccades of 1-6 deg., and the microsaccade Reaction Time (RT) as the time of the first microsaccade released from inhibition following these triggers (in a 200-700ms window). Results: In exp1, the FRP for O1-O2 occipital electrodes showed monotonic increase in P1 (Lambda response) amplitudes and decrease in peak latency with stimulus saliency (higher contrast and lower spatial-frequency). Microsaccade RT showed a similar decrease with saliency, but with much longer latencies and therefore microsaccades could not have affected the P1 response at ~100ms. In exp2, preliminary FRP results indicate that the P1 magnitude decreases over time of few seconds, presumably due to contrast adaptation, and this effect appears to depend on stimulus uniformity. Conclusion: The FRP and OMI analyses are applicable tools for the study of low-level visual processing, including saliency and adaptation in free viewing.

33.445 **A continuum in the retinal modulations resulting from eye movements** Michele Rucci[1](mrucci@bu.edu), Janis Intoy[1,2], Zhetuo Zhao[1], Jonathan D Victor[3]; [1]Center for Visual Science and Dept. of Brain & Cognitive Sciences, University of Rochester, [2]Graduate Program in Neuroscience, Boston University, [3]Feil Family Brain and Mind Research Institute and Dept. of Neurology, Weill Cornell Medical College, New York

Much work has been dedicated to the spatial consequences of eye movements, i.e., how gaze shifts position the stimulus on the retina.In contrast, considerably less attention has been paid to the temporal consequences of oculomotor activity, i.e., the possible impact of the luminance changes that eye movements produce on the retina.A growing body of evidence supports the notion that oculomotor modulations are functionally important, and that the visual system use them to establish a temporal scheme of spatial encoding.Here we focus on the commonalities in the modulations resulting from different types of eye movements.Can a single framework characterize modulations from eye movements as diverse as the fast and rapid saccades and the slow and small eye drifts of visual fixation? To investigate this question, we recorded the human eye movements at high-resolution, reconstructed the spatiotemporal input signals impinging onto retinal receptors, and examined how different types of eye movements transform the spatial power of the scene into temporal modulations on the retina. We show that very different types of eye movements yield luminance flows on the retina with qualitatively similar spectral distributions.The power redistribution can always be decomposed into two regimes:a whitening regime below a critical spatial frequency, in which the amount of stimulus power transformed into temporal modulation grows proportionally to spatial frequency; and a saturation regime, above this critical frequency, in which the temporal power available is a constant fraction of the stimulus' spatial power, independent of spatial frequency.The critical spatial frequency varies across eye movements: it is highest for drift, lower for saccades, and decreases with saccade amplitude.These results reveal a continuum in the modulations given by different eye movements.Transitions across eye movements primarily act by shifting the boundaries between whitening and saturation regimes on the retina.

Acknowledgement: NIH grants EY018363 and EY07977 NSF grants BCS-1457238 and 1420212

33.446 **A Comparison of Receptive Field Structures of Hierarchical Models of V2** Joshua Bowren[1](jbowren@miami.edu), Luis Sanchez Giraldo[1], Odelia Schwartz[1]; [1]Department of Computer Science, College of Arts and Sciences, University of Miami

Neurophysiology experiments as well as computational models provide a compelling explanation for the receptive field structures of Primary Visual Cortex (V1). However, a comprehensive explanation of the receptive fields of the Secondary Visual Cortex (V2) still remains far from complete. Recent hierarchical models of V2 provide an appealing avenue for progress. By fixing the computations of lower better-understood visual areas in hierarchical models, as demonstrated for instance by Hosoya and Hyvärinen (2015), the computations and receptive field structures of V2 models can be learned from an ensemble of images and studied independently. In this work, we compared the receptive field representations obtained from two candidate V2 models. First, we implemented a modified version of the model of Hosoya and Hyvärinen (2015) (model M1), in which the first layer model complex cells undergo a significant dimensionality reduction with PCA, followed by an expansive sparse coding (in place of independent component analysis). Second, we modified this pipeline by first incorporating learning of a ubiquitous cortical nonlinearity, namely divisive normalization by the contextual surround, and then followed by pooling, PCA (Coen-Cagli and Schwartz, 2013), and an expansive sparse coding (model M2). Both models were trained on 4 million randomly sampled 48x48 image patches from the ImageNet database distributed for ILSVRC12 (Russakovsky et al., 2015). The learned receptive field structures of M1 included some of the patterns found in Hosoya and Hyvärinen (2015) (e.g. iso-oriented excitation with broad inhibition units) along with circular structure. The incorporation of the contextual divisive normalization further resulted in corner and curvature selective units. We quantified the similarity of the representations by finding for each given

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unit in one model the highest correlated unit in the other (34.6% of M1 units had matching M2 units with correlation above 0.3). We also qualitatively compared the models with the t-SNE visualization.

Acknowledgement: NSF Award Number: 1715475, NSF GRFP. This material is based upon work supported by the National Science Foundation Graduate Research Fellowship Program under Grant No. 1451511. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

33.447 **The critical reliance of early visual cortex on the fractal structure of natural scenes** Zoey J Isherwood[1](zoey.isherwood@gmail.com), Colin WG Clifford[2], Mark M Schira[1,3], Branka Spehar[2]; [1]School of Psychology, University of Wollongong, Wollongong NSW 2522, Australia, [2]School of Psychology, UNSW Sydney, Sydney NSW 2052, Australia, [3]Neuroscience Research Australia, Randwick, NSW 2031, Australia

Despite considerable variability in the visual appearance of natural scenes, they share many statistical regularities. Firstly, natural scenes are similar in their photometric properties as they share a unique distribution of luminance intensity variations known as the $1/f\alpha$ amplitude spectrum ($\alpha \approx 1$). Secondly, natural scenes are similar in their geometric properties as they each contain a similar density of structure across spatial scales—a property that makes them fractal (e.g. in how the branching pattern of a tree is similar irrespective of scale). Since the visual system has evolved in a natural environment, it is likely that it is tuned to both its photometric and geometric properties—but to what extent? Is it critically reliant on photometric characteristics which can change dramatically depending on the illumination of a scene? Or is it preferentially tuned to geometry which remains stable irrespective of illumination? Here we use both psychophysics and fMRI to measure perceptual sensitivity (4AFC "odd one out" task) and BOLD responses in visual areas V1-V4 (N = 10) to three different stimulus image types—greyscale, thresholded, and edges. While each image type shares the same geometric properties, their photometric properties differ dramatically. If the visual system is preferentially tuned to natural geometry, we should observe virtually no difference in the pattern of activity across image type conditions—which is exactly what we find. Both sensitivity and BOLD activity show a characteristic dependency on the geometric properties of an image, peaking for stimuli which had the most natural geometry across all image types despite large differences in their photometric properties. This suggests that both behaviourally and physiologically, the visual system is critically reliant on the geometrical, fractal, structure of natural scenes—a property of which remains stable irrespective of scene illumination.

33.448 **Comparing population receptive fields in human and macaque visual cortex** Edward H Silson[1](ed.silson@nih.gov), Susheel Kumar[1], Benjamin Jung[1], Elissa Koele[1], Clarissa James[1], Adam Messinger[1], Chris I Baker[1], Jessica Taubert[1]; [1]NIH/NIMH

The population receptive field (pRF) modelling approach has been applied widely in human fMRI to inform the organization of both early and late stages of the cortical visual hierarchy. Recently, a pRF implementation was developed that allows for oriented and elliptical pRFs and demonstrated that dorsal and ventral divisions of early visual cortex (EVC) differentially sample visual space. Thus, differences between the larger dorsal and ventral visual processing streams may be set early on in the visual hierarchy. However, despite its common use, we do not yet understand how pRFs relate to the receptive fields of single neurons. Therefore, cross-species validation by means of comparative fMRI would go a long way to bridging the gap between single-unit recordings in monkeys and fMRI in humans. Here, we compare pRFs from dorsal and ventral divisions of EVC in both humans (n=12) and macaques (Macaca mulatta; n=2). Participants (both humans and macaques) fixated centrally while a bar aperture traversed gradually across the visual field revealing brief scene fragments. Data from both study populations were analyzed in AFNI using both standard (circular) and elliptical pRF models. Cross-validation analyses revealed that, similar to the human, the elliptical pRF model captured more variance in the time-course of macaque data than a circular pRF implementation. Further, pRF eccentricity was positively correlated with both pRF aspect ratio and pRF area, with the strength of correlation increasing generally as a function of position in the visual hierarchy. Also consistent with our human data, the average pRF angles of dorsal and ventral divisions of EVC are oriented differentially. Finally, we found that on average pRF size estimates in macaques tended to be larger than in humans, despite the overall similarity. Overall, these results reveal a very similar pattern of pRF properties between macaque and human visual cortex

Acknowledgement: Intramural research program NIH/NIMH

33.449 **Visual evoked potentials elicited by complex scenes are regulated by high spatial frequency content** Andrew M Haun[1](haun2@wisc.edu), Bruce C Hansen[2]; [1]Center for Sleep and Consciousness, University of Wisconsin-Madison, [2]Department of Psychological and Brain Sciences, Neuroscience Program, Colgate University

The early cortical response to a natural scene is composed of signals from many overlapping neural populations tuned to narrow bands of image content. Psychophysical studies equate these populations with perceptual channels that undergo numerous forms of cross-channel interaction. In particular, psychophysical data suggest that cross-channel suppression is biased toward lower spatial frequencies (SFs). The neural bases of such interactions are largely unknown. In this study, we sought a neural picture of this cross-SF suppression through the lens of visual evoked potentials (VEPs). The stimuli were derived from 64 source natural scene images that were each divided into four SF bands (centered at 8, 16, 32, and 64 cycles per image) and then recombined into all 16 possible permutations (including the 'blank image' permutation, four 'single-band' permutations, six 'two-band' permutations, etc.). While undergoing 128-channel EEG, participants (n = 18) viewed the resulting 1024 unique stimuli (subtending 18.5deg diameter at fixation) for 500ms at their original contrast, and gave a perceived-contrast estimation response for each trial. Within a sliding window, we modeled the multi-band stimulus VEPs by combining the single-band VEPs according to a family of related rules, including some expressed as divisive gain control models with variable input and output weights. According to the gain control rules, responses to higher-SF image content contribute disproportionately more to cross-frequency suppression, while responses to lower-SF content are disproportionately subject to suppression. The SF-dependence of suppression was pronounced during earlier epochs (50-150ms post-stimulus); after 200ms, suppression appeared evenly weighted across SF. In sum, the modeling results suggest a high-to-low-SF flow of cross-frequency response suppression in the early VEP response to natural scene stimuli. The known pattern of perceptual suppression therefore seems to be shaped very early in the visual response to complex scenes, possibly serving to bias perception towards higher SF content.

Acknowledgement: Templeton Foundation grant to the CSC, James S McDonnell Foundation (220020439) grant to BCH

33.450 **Image-statistics correlates of visual evoked potentials to natural texture images** Taiki Orima[1](apple.lemon.melon000@gmail.com), Isamu Motoyoshi[2]; [1]Department of Integrated Sciences, The University of Tokyo, [2]Department of Life Sciences, The University of Tokyo

Recent psychophysical and neurophysiological evidence shows that primate early visual cortex computes statistical structure of natural images, which may underlie rapid and efficient perception and recognition of complex scenes and surfaces. In order to understand the temporal dynamics of neural encoding of these statistical information, the present study analyzed the correlation between visual evoked potentials (VEPs) to natural texture images and simple image statistics. In our procedure, 8 observers viewed 111 achromatic images of various natural textures (mean luminance of 54 cd/m2) each of which was successively presented for 500 ms in random order. Each image was repeatedly shown for 30 times in separate blocks. During the experiment, EEG signals were recoded from 19 electrodes. Following preprocessing of EEG signals, the average VEPs for each image was calculated across repeated presentations and observers. We then computed single correlation coefficient between occipital VEP amplitudes for 111 images with image statistics as used in Portilla-Simoncelli texture analysis, which has been suggested to be encoded in V1 and V2. The analysis revealed dynamic changes in correlated image statistics. For example, VEPs at 250, 300, and 350 ms showed high correlations with SDs and kurtosis at low, mid, and high spatial frequencies, respectively. Particular periods (250-400 ms) of VEPs were also correlated with higher-order image statistics such as cross-orientation and cross-frequency linear/energy correlations. These results seem to suggest that the early visual cortex encodes image statistics in textures with different temporal dynamics.

Acknowledgement: The Commissioned Research of National Institute of Information and Communications Technology, JSPS KAKENHI JP15H05916, JSPS KAKENHI JP18H04935

Sunday AM

33.451 **Sensitivity of inferotemporal cortex to naturalistic image statistics in developing macaques**
Gerick M. Lee[1](gerick@cns.nyu.edu), Darren A. Seibert[2], Najib J. Majaj[1], J. Anthony Movshon[1], Lynne Kiorpes[1]; [1]Center for Neural Science, New York University, [2]Department of Brain and Cognitive Sciences and McGovern Institute for Brain Research, Massachusetts Institute of Technology

Neurons in macaque infero-temporal cortex (IT) are selectively sensitive to images of natural objects, and this sensitivity develops over the first months of life. We wanted to know whether IT neurons – like neurons in V2 and V4 but not V1 – were also sensitive to natural image statistics in texture images, and how that sensitivity might develop. We used the 2000 Portilla and Simoncelli model to generate two kinds of textures – all were matched in spatial frequency and orientation content – they differed only in the presence or absence of naturalistic image correlations. We recorded single- and multiple-unit neuronal responses to these textures in fixating macaque monkeys ranging from 6 to 24 months of age, using 96-channel "Utah" arrays. IT neurons responded better on average to the textures containing naturalistic image correlations at all ages; discriminability analysis supported this finding. We also measured latencies for the onset of the visual response and also for the onset of the differential response to naturalistic texture. Both measures of latency decreased and became less dispersed with age. In addition, we compared IT latencies with those from concurrent recordings in V1 and V2, and at each age we found the shortest latencies in V2. Our results demonstrate the sensitivity of IT neurons for naturalistic image content. Furthermore, they suggest that the likely origin of this sensitivity is in V2, across all ages tested.

33.452 **The role of local image statistics in separating figure from ground**
Jonathan Victor[1](jdvicto@med.cornell.edu), Mary M Conte[1]; [1]Brain and Mind Research Institute, Weill Cornell Medical College

Separating figure from ground is a crucial step in early visual processing. In complex textured images, local analysis of image statistics can provide several kinds of cues: the statistics within the figure, the statistics within the ground, and the differences between them.Here, we attempt to separate these roles. To address the high dimensionality and inter-relatedness of image statistics, we work in a domain of binary (black-and-white) images, and statistics that describe configurations within 2x2 neighborhoods. This domain has 10 dimensions, encompassing luminance, contrast, orientation, and corners; previous work (Vision Res. 2015 and eLife 2014) showed that perceptual distances in this domain corresponded to the informative aspects of natural images.Moreover, the perceptual distances in this space are simple: sensitivities to positive and negative changes in image statistics are nearly identical and isodiscrimination contours are elliptical, and approximately homogeneous throughout the space.We ask how figure-ground separation depends on perceptual distances in this space. Stimuli consisted of five randomly-positioned circular regions containing a "figure" texture, superimposed on a distinct "ground" texture. Figures constituted 25% of the total area. In a 2-AFC task, subjects were asked to distinguish this target stimulus from a non-target stimulus, consisting of a uniform texture whose statistics matched the area-pooled statistics of figure and ground in the target.Trials were grouped in blocks, in which the subject knew the composition of figure and ground. We found (N=3) that perceptual distance between figure and ground textures was an important factor in determining threshold, but not the only factor. Specifically, when the ground texture was negatively correlated, thresholds were 40 to 50% higher than when the ground texture was positively correlated, even when the figure-ground difference was held constant.Thus, ground composition, as well as figure-ground texture contrast, influences thresholds for separation of figure and ground.

Acknowledgement: NIH EY07977

33.453 **Deep neural network features predict perceptual sensitivity and cortical responses to visual textures**
Akshay V Jagadeesh[1](akshayj@stanford.edu), Justin L Gardner[1,2]; [1]Department of Psychology, Stanford University, [2]Wu-Tsai Neuroscience Institute, Stanford University

Textures with similar visual features, scrambled locally, can be obviously distinguishable when viewed directly, but metameric (i.e. perceptually indistinguishable) when viewed in the periphery (Freeman & Simoncelli, 2011). This suggests that the visual system pools complex features over small regions of space. Prior studies of texture perception have utilized textures synthesized by iteratively updating random noise images to match handcrafted features derived from a linear filter bank (Portilla & Simoncelli, 2001). Extending this approach, we generated textures by matching complex features extracted from various layers of the VGG-19 convolutional neural network (Gatys et al., 2011), pooled over uniform-sized subregions of a naturalistic image. We asked five human observers to distinguish original images from feature-matched textures, presented at 10 degrees eccentricity. Feature-matched textures were less distinguishable from original images when features from later layers (e.g. pool4) (F=346.42, p< 0.001) or within smaller pooling regions (F=68.59, p< 0.001) were matched. We modeled behavioral performance as a function of the distance between the features of the original image and texture on each trial. Comparing 12 different observer models, we found that a model using pool4 features computed within 2-degree pooling regions best predicts human performance on held-out trials. Furthermore, to assess the neural basis of texture perception, we measured BOLD activity in the visual cortex as five human subjects viewed texture images during ten 6 minute runs. Following published procedures (Freeman et al., 2013), images were flashed at 5Hz within 9 second blocks alternating between textures and phase-scrambles. We found that sensitivity to pool2 and pool4 textures relative to phase-scrambled images emerges in V2 and increases from V2 to V3 to V4. In sum, these results suggest that both feature complexity and pooling region size contribute to visual metamerism and that cortical representations in areas V2-V4 may support these perceptual effects.

33.454 **Contrast Sensitivity in Naturalistic Images Measured Using Generative Adversarial Nets**
Elee D Stalker[1](elee.stalker@gmail.com), Jaykithan Y Patel[1], Ingo Fruend[1]; [1]Department of Psychology and Centre of Vision Research, York University, Toronto, ON

Contrast is one of the most important dimensions of the human visual experience. Although defining contrast is relatively straightforward for simple stimuli such as gratings or lines, it is much more difficult for naturalistic scenes with complex and often nonlinear structure. Generative image models based on deep neural networks, known as Generative Adversarial Nets (GANs), represent an image as a high dimensional vector of nonlinear latent features. Here, we explore how contrast is represented in these nonlinear latent dimensions. Based on previous observations, we hypothesized that contrast is related to the length of the latent feature vectors. We measured "contrast" sensitivity functions from four observers along this hypothesized contrast dimension. In a two-alternative forced-choice task, observers selected the image that appeared higher in contrast, between pedestal and target images. As the length of the pedestal stimulus' feature vector increased, just noticeable differences increased approximately linearly with an average slope of 0.012+/-0.0023 (mean+/-sem) units per unit pedestal increment (R-square of 0.61+/-0.071). This indicates that perceived contrast is related to vector length in a GAN's latent space through a Weber's law. A logistic regression model using the full latent space vectors did not predict single trials better than a model that only had access to the lengths of the latent vectors. This confirmed that the feature vectors' length was the main determinant of observer responses in our task. We conclude that contrast in complex and naturalistic scenes can be approximated by image representations based on deep neural networks.

33.455 **Invariance of Human Image Recognition Measured Using Generative Adversarial Nets**
Jaykishan Y Patel[1](jay96@my.yorku.ca), Elee D Stalker[1], Ingo Fruend[1]; [1]Department of Psychology and Centre for Vision Research, York University, Toronto, ON

Humans can perform fine discriminations between different natural images. Previous studies for identifying visual discrimination mechanisms have often used grating stimuli. However, gratings often look different from real world images, which have complex and nonlinear structure. Quantitative characterization of discrimination performance requires precise manipulation of stimuli. Yet, the required precision can be difficult to achieve for naturalistic images without distorting the image. Generative image models based on deep neural networks, known as Generative Adversarial Nets (GANs), represent an image as a vector of highly nonlinear latent image features. Here, we attempted to generalize classical oblique masking experiments to this highly nonlinear feature space. We have found previously that rotations of these latent feature vectors corresponds to changes in the images' content, while length of the feature vectors seems to correspond to the images' contrast. In a 2-alternatives forced-choice task, 4 observers were asked to match one of two probe stimuli to a target stimulus. Crucially, one of the probes was rotated in feature space towards the target, making its features slightly more similar to the target's features. This allowed us to measure thresholds for rotations in the latent feature space. Thresholds were on average 29.24+/-1.99 (mean+/-sem) degrees and did not significantly change with our overall measure of global contrast. An analysis of trial-by-trial responses showed that sensitivity to these feature space rotations was approximately independent of the length and exact identity of the feature vectors corresponding to the presented stimuli. This further indicates that selectivity to image content

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was not only independent of global contrast but in fact selectivity did not change throughout the entire space of natural images captured by our model.

33.456 **Partial awareness based on the parallel processing of spatial frequency** Cheongil Kim[1](kimcheongil@gmail.com), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

Studies have attempted to explain ambiguous states between complete awareness and unawareness by the notion of partial awareness (Kouider et al., 2010). This account proposes that access to some levels of representations in a hierarchy is independent of access to other levels, and that such access causes partial awareness. However, the account considering only the hierarchical access cannot explain partial awareness experienced in each level, especially gradually occurring phenomenal experiences in low levels. Here, we tested a hypothesis based on the parallel processing of spatial frequency (SF). Specifically, independent access to some SF information could cause gradual phenomenal experience in low levels. In two experiments we used a novel method in which a state of phenomenal experiences gradually changed for a long time. Stimulus displays were presented very briefly (about 12 ms per frame) and repeatedly with an inter-stimulus interval (ISI), ranging from 0 to 20 frames. As the ISIs increased, the probability of stimulus detection was lowered. Experiment 1a showed two superimposed sinusoidal gratings, each of which had a specific SF and orientation. Participants were asked to keep reporting the orientation of the gratings and showed that the duration of orientation detection over that of the stimulus presentation decreased with the ISIs but that the decrease was smaller for lower SF stimuli. Experiments 1b and 2 used more natural stimuli having broad SF spectrums, such as letters (a large E made of small Es) and scenes (dog, cat, car and truck pictures), respectively. We again found that participants detected poorly as the ISIs increased. However, this poor detection was lessened when the large Es and superordinate categories (animal vs. vehicle), requiring lower SF analysis, were reported. These results suggest that some SF information can be independently accessed, which may cause gradual phenomenal experiences in low levels of hierarchical representations.

Acknowledgement: This research was supported by the Brain Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (NRF-2017M3C7A1029658).

Eye Movements: Cognition

Sunday, May 19, 8:30 am - 12:30 pm, Pavilion

33.457 **Re-re-considering Yarbus: Predicting observer "taskiness" from eye movement patterns** Dylan Rose[1](rose.dy@husky.neu.edu), Peter Bex[1]; [1]Northeastern University

Greene, Liu and Wolfe reported a negative result for identifying task using eye movements (2012). Others have challenged this finding, often by substituting dynamic for static features (Boisvert & Bruce, 2016). We propose instead mapping eye movements onto a latent dynamic manifold with connected, overlapping regions of related task effects. This manifold's structure is defined using features extracted from a variational auto-encoder trained on multi-dimensional time-series of values for two different salience maps at observer fixation locations (GBVS: Harel et al., 2007; modified semantic similarity: Rose & Bex, 2018). This approach helps reconcile Greene's findings with others' by treating eye movement as less "task driven" than "tasky": affected by current task while remaining influenced by those performed in the past. We therefore hypothesized that observers' sequential performance of different tasks–as in Greene and colleagues' study–may deflect behavior across manifold regions, decreasing classifiability. Performing the same task should result in more regular trajectories within a manifold, increasing classifiability. We tested this hypothesis on three datasets first by comparing classification accuracy per task/trial using twenty-five manifold features and a SVM classifier. Second, we compared sequential determinism and entropy in trial-to-trial sequences of feature distances to separating hyperplanes using multidimensional recurrence quantification analysis (Wallot, 2016). For two sets (Koehler et al.,2014; Borji&Itti, 2014,Expt.2), subjects always performed the same task. In the third (created in-lab), tasks were randomized across trials. Classification performance was significantly above chance and equivalent to that reported elsewhere for random order studies (Borji & Itti, 2014:24.2%, ours:24.6%, chance:14.2%; Boisvert & Bruce,2016:53.4%; ours:51%, chance:33.3%) but not the third (ours:39.5%, chance:33.3%). Determinism was also significantly higher and entropy significantly lower for the random task order experiment than for the others (Kruskal-Wallis, p< 0.001). Our method therefore both retains high discrete classification peformance while connecting task effects to other efforts concerning serial dependencies (Fischer & Whitney,2014).

33.458 **Investigating volitional attentional control during film viewing** Taylor L Simonson[1](tlsimons@ksu.edu), John P Hutson[2], Shunsuke Kumakiri[3], Ryoh Takamori[3], Ella Mcleod[1], Hudson Treyu[1], Yuhang Ma[1], Anna Cook[1], Katherine Kolze[1], Kenzi Kriss[1], Ost Nicholas[1], Yoshiyuki Uehara[3], Jun Saiki[3], Lester C Loschky[1]; [1]Psychological Sciences, Kansas State University, [2]Psychology Department, College of Wooster, [3]Human and Environmental Studies, Kyoto University

Film viewers' eye movements seem largely disconnected from their comprehension. Viewers' eye-movements rarely deviate from focal narrative elements, regardless of differences in their comprehension (Loschky et al., 2015; Hutson et al., 2017), suggesting bottom-up film features overwhelm top-down attentional control. However, viewers' eye-movements did deviate from focal narrative elements when given a task irrelevant to film comprehension. This suggests viewers used volitional attentional control. However, do people commonly use volitional attention during film viewing? Volitional attention is cognitively demanding, as shown by anti-saccade task failure under executive working-memory (E-WM) load (Mitchell et al., 2002). Thus: 1) Is volitional attention during film viewing cognitively demanding? 2) Is this demand moderated by E-WM capacity? Participants viewed film clips with different task goals and levels of attentional demand while they were eye-tracked. Participants had a primary task of either watching a film clip for comprehension (Comprehension Condition) or drawing a map of the film space from memory (Map Condition). Participants had a secondary task (cognitive load) on half the trials to increase attentional demand. We then assessed their E-WM capacity. We measured viewers' eye-movement deviation from screen center and used multilevel modeling techniques. We entered film, participant, and their interaction as random effects, and factorially combined cognitive load and condition as fixed effects. The Map Condition had significantly more deviation, showing volitional attention. The cognitive load trials had significantly less deviation, showing less volitional attention control. However, cognitive-load task performance showed two distinct groups of participants, high and low. When accounting for E-WM capacity we expect to find an interaction: specifically, high E-WM viewers may have higher deviation regardless of load, but low E-WM viewers may only achieve high deviation if they ignore the load task. If so, E-WM may moderate the relationship between volitional attention and task during film viewing.

33.459 **Gaze bias during preference-based decision making** James P Wilmott[1,2](jpwilmott3@gmail.com), Rachel Souza[4,5], Carolina Haas-Koffler[3,4,5], Joo-Hyun Song[1,2,6]; [1]Brown University, [2]Department of Cognitive, Linguistic and Psychological Sciences, [3]Department of Psychiatry and Human Behavior, [4]Department of Behavioral and Social Sciences, [5]Center for Alcohol and Addiction Studies, [6]Carney Institute for Brain Science

Previous research has shown that gaze closely reflects attentional bias as well as preference during preference-based decision making. For example, prior studies employing a two alternative choice task (e.g., choose between two faces) found that participants initially distribute gaze evenly between both options, but then gradually shifted toward the stimulus that they eventually chose. So far, most studies have examined how participants bias their gaze while presenting choices that are not associated with a strong prior preference. Here, we were instead interested in whether and how gaze biases can represent individuals' varying degree of prior preferences during a choice task. To address this question, we recruited participants with an alcohol dependence who also smoked cigarettes, because they have already established different degrees of craving between these two substances. First, we identified their most preferred alcohol (e.g., Budweiser) and cigarette items (e.g., Marlboro). Then, participants were exposed to these two preferred items and self-reported cravings for each. Finally, in an eye-tracking task, we presented one each picture of an alcohol, a cigarette, and a water item on a computer screen. We randomly manipulated the relative preference of each item across trials by presenting a most preferred (e.g., Marlboro) or less preferred item (e.g., Newport cigarettes) along with a neural item (e.g., water bottle). We asked participants to select which of the three items they preferred the most by keypress while tracking their gaze. We demonstrated that the relative proportion of time spent looking at alcohol and cigarettes was correlated with self-reported relative craving. Furthermore, we demonstrated that participants fixated at the eventually chosen item for a greater proportion of time, regardless of the relative preference. Taken together, these results reveal a relationship between internal craving, gaze bias and choice during decision making.

Acknowledgement: NSF (BCS 1555006) awarded to J.-H. S.

33.460 **The effect of eye movements in preferential decision**

Dan Uemura[1](dan_barcelona_lupin@yahoo.co.jp), Shouta Katayama[1], Kenji Yokoi[1]; [1]National Defense Academy of Japan

The gaze cascade effect, in which the gaze leans to the eventually chosen stimulus prior to the decision, was found by Shimojo et al. (2003). They also demonstrated that the manipulation of the eye movement biased the preferential decision toward a face with a longer duration and concluded that eye movements should give a positive feedback to preferential formation. The recent study, however, claimed that the preferential bias can be replicated without eye movements by considering the masking effect, thus the eye movement is not involved in decision making (Bird et al., 2012). To clarify this issue directly, we examined the influence of eye movements by using the gaze-contingent method. Similar to the previous studies, two faces were displayed side by side alternately for 300ms and 900ms respectively, then participants selected a more attractive face. In the central view condition, participants shifted their gaze to the presented face repeatedly. The probability of choosing the longer presented face was 58.3%. In the peripheral view condition, participants viewed two faces in the periphery while fixating the central cross. The bias (51.7%) was not significant. In the gaze-contingent condition, participants were instructed to view the presented face. But the whole stimulus was shifted according to the gaze position, so that the retinal image was identical to that in the peripheral view condition except eye movements. Interestingly, the bias to the longer presented face was significantly decreased to 42.5%. Prior to this condition, participants were trained to inhibit multiple saccades especially toward the longer presented face due to the limited width of the screen. This suppressive gaze shift might affect the decision making in the opposite way. Our findings suggest not only the occurrence of the eye movement but also the intention of the gaze may affect preferential decision.

33.461 **Examining whether eye movement behavior contributes to in-group bias in memory**

Mengzhu Fu[1](mengzhu.fu@huskers.unl.edu), Matthew G Rhodes[2], Michael D Dodd[1]; [1]University of Nebraska - Lincoln, [2]Colorado State University

Extensive research has shown that individuals often exhibit enhanced attention to—and memory for—in-group members relative to outgroup members, even in cases where group membership is randomly defined.There is mixed evidence, however, regarding whether differences in eye movement patterns and visual processing contribute to these behavioral differences.Eye movement patterns have been shown to influence memory for other race-faces (McDonnell et al., 2014) and perception of ambiguous emotions (Neta et al., 2017) but it is unclear whether similar pattern contribute to other types of in-group bias.In the present study, we examined eye movements differences for in-group and out-group members as a function of political affiliation (E1) and age (E2).Participants (college students) encoded images of individuals who were college-aged or elderly, with the background color of each image (red or blue) denoting the target's political temperament.Eye movements were recorded during both encoding and recognition and participants later completed a series of questionnaires assessing their own political temperament.Behaviorally, there is evidence of in-group bias as participants exhibit better memory for those in their in-group.There were only minor differences, however, in visual behavior that linked to memory performance as scanpaths and kinematic measures were highly similar.These results suggest that while eye movement patterns may help to differentiate between when behavioral differences occur, overall, visual processing stays relative stable and does not necessarily change as a function of in-group bias.

Acknowledgement: NSF/EPSCoR grant #1632849

33.462 **Examining the relationship between eye movement kinematics and schizotypy in the normal population**

Lauren N Bandel[1](lauren.bandel@gmail.com), Marian E Berryhill[2], Michael D Dodd[1]; [1]University of Nebraska-Lincoln, [2]University of Nevada-Reno

Individuals continually make eye movements when performing tasks to extract meaningful information from objects and regions of interest. Compared to neurotypical individuals, those with schizophrenia spectrum disorders (SSD) exhibit impairments in oculomotor function, including impairments in smooth pursuit, motion-processing, and attention-based tasks. These deficits indicate that individuals with SSD may be unable to extract visual information in a neurotypical manner, potentially contributing to the cognitive deficits often associated with SSD. Schizotypy represents a broad range of characteristics associated with SSD that occur in the general population, with schizotypy occurring at a higher frequency than clinically significant schizophrenia. In the present study, we sought to examine whether there are differences in oculomotor kinematics and visual scanning behavior between those low and high in schizotypy. To the degree that schizotypy influences eye movement behavior, oculomotor function could be a useful additional diagnostic mechanism for related disorders. In the present study, participants viewed scenes while performing one of three tasks (visual search, memorization, pleasantness rating) while their eye movements were monitored. Following the visual tasks, participants completed the Schizotypal Personality Questionnaire-Brief Revised Updated (SPQ-BRU). Trial analyses confirm differences in saccade amplitude and fixation duration for those low vs. high in schizotypy but the effects are moderated by task type (saccade amplitudes impacted during search/rating, fixation durations impacted during memory). Schizotypy also influenced scanning time within regions of interest, such that those high in schizotypy processed each region for considerably less time during initial processing. Collectively these results indicate differences in oculomotor behavior as a function of schizotypy in basic visual tasks with additional pilot data seeking to characterize whether scanning behavior can be subsequently improved in this population via gaze-contingent manipulations.

Acknowledgement: NSF/EPSCoR grant #1632849

33.463 **Distinct pupil features correlate with between-participant and across-session performance variability in a 16-week, longitudinal data set**

Russell A Cohen Hoffing[1](russell.cohenh@gmail.com), Steven M Thurman[1], Nina Lauharatanahirun[1,2], Daniel E Forster[1], Javier O Garcia[1, 4], Nick Wasylyshyn[1], Barry Giesbrecht[3], Scott T Grafton[3], Jean M Vettel[1, 3, 4]; [1]Human and Research Engineering Directorate, US Army Research Laboratory, [2]Annenberg School of Communication, University of Pennsylvania, [3]Department of Psychological and Brain Sciences, University of California, Santa Barbara, [4]Department of Biomedical Engineering, University of Pennsylvania

Pupillary response provides a rich and accessible source of insight into cognitive processes due to its link with neural circuits in the brain. However, the relationships between pupil diameter and specific cognitive constructs are not yet dissociable because of the complex temporal dynamics of cognitive processes and individual variability. While extant research has identified a number of features that correlate with cognition, group-level analyses are typically used, making it unclear whether these relationships would hold between participants and upon repeated measurements. To gain insight into the robustness of pupil features and cognition, we analyzed a longitudinal pupillometry data set, characterizing relationships between standard pupil features and cognitive performance between participants (subject-level), across sessions (session-level) and within sessions (trial-level). Participants (N=26) completed 8 bi-weekly sessions of a mental arithmetic task in which participants indicated whether modular arithmetic statements were true or false under easy and difficult conditions. In the present analysis, we focused on the relationship between response speed and three pupil features typically studied in the literature: pre-stimulus baseline, peak amplitude, and peak latency. Mixed-effects model results indicated that the pre-stimulus baseline was associated with response speed at the subject-level, whereas peak amplitude was associated with the trial-level type (i.e. easy vs. difficult trials), but not trial-level performance. Peak latency was robustly associated with response speed at the group-, subject-, and trial-levels. We show that distinct pupil features correlate with performance at dissociable levels of analysis and may also reflect distinct influences of underlying cognitive processes.

33.464 **Ocular Motor Function and Information Processing in Young and Older Adults**

Sheila Crewther[1](s.crewther@latrobe.edu.au), Deena Ebaid [1]; [1]School of Psychology and Public Health, La Trobe University, Melbourne, Australia 3086

Although the visual system is reported to undergo profound changes across the lifespan, oculomotor function during measures of perceptual speed have seldom been compared in samples of healthy, educated, young and older adults. Thus, the current study aimed to examine and correlate patterns of eye movements and consequent shifts in attention during text-reading and during Rapid Automatized Naming (RAN) tasks (alphanumeric and objects conditions), with time needed for accurate performance on visually driven-cognitive tasks including Inspection Time (IT) and Change Detection (CD) tasks) in both groups. Results demonstrate that older adults took longer (i.e., named less stimuli in the same time period) on the objects condition but not on the alphanumberic version of the RAN. Significant age-group differences in fixation and saccade durations patterns were also demonstrated, with younger adults fixating on the stimuli for significantly longer than older adults, while older adults demonstrated longer saccade durations between stimuli. No significant differences between age-groups were seen during the text-reading condition. Significant correlations between oculomotor measures and performance on the CD cognitive tasks, and the alphanumeric condition of the RAN was seen for older but not younger participants. Our results provide preliminary understanding of eye gaze patterns and oculomotor function with age, and demonstrate that eye movements become significantly slower with age especially during unpractised rapid automatic naming of familiar objects but not during text reading.

33.465 Congruency Effects in the Attention Network Task: The Influence of Stimulus Onset Asynchrony and Eye Movements

Anthony J Ries[1,2](anthony.ries@us.army.mil), David Slayback[1], Erika Fulbright[2], Marisa Sligh[2], Kaliyah Gorman[2], Jon Touryan[1]; [1]U.S. Army Research Laboratory, Human Research and Engineering Directorate, Aberdeen Proving Ground MD, [2]Dept. of Behavioral Sciences and Leadership, Warfighter Effectiveness Research Center, U.S. Air Force Academy CO

Prior research using the Attention Network Test (ANT) has shown larger reaction time differences between incongruent and congruent targets (i.e., congruency effect) on alert with respect to non-alert trials. The ANT typically requires participants to maintain central eye fixation while targets are presented at a discrete cue-to-target interval. However, it is unclear if congruency effects are modulated by eye movements and if the magnitude of the congruency effect changes over time. To address these issues, we had participants perform a gaze-contingent variant of the ANT, with targets presented at central fixation (eye fixed trials) or at a peripheral location after an eye movement (saccade trials). Each trial began with an alert cue indicating whether to maintain central fixation or immediately make a saccade to one of four peripheral locations (small circle at NE, NW, SW, SE quadrants). On saccade trials, participants were instructed to hold fixation at the peripheral location until the target array appeared. Target arrow arrays (congruent and incongruent) were presented at one of three intervals (50, 350, 750ms) with respect to the offset of the alert cue, in eye fixed trials, or fixation onset in the saccade trials. The results revealed that congruent targets produced faster reaction times and higher accuracy with respect to incongruent trials. The magnitude of the congruency effect was largest at the 700ms interval for eye fixed trials whereas saccade trials produced the largest congruency effect at the 50ms interval. These results suggest the magnitude of conflict on incongruent trials changes over time and the nature of this change is modulated by saccade related processes.

Acknowledgement: ARL-74A-HR53

33.466 Eye-movement analysis of training effectiveness for microexpression recognition

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Microexpression is a fleeting expression which appears when people try hard to suppress their true felt emotions. The ability to recognize microexpression is important for detecting deception. Can we improve the ability to recognize microexpression? If so, what happens during the recognition process? To answer the questions, we trained our participants (12 college students, mean age = 21.4, SD = 0.67, 6 females) on how to recognize microexpression (happiness, anger, sadness, fear, surprise, disgust) following the paradigm used by Ekman (Microexpression training tool, Paul Ekman Group), the gain scores were calculated for each participant. The participants were asked to recognize the same spontaneous microexpressions and sandwiched expressions (artificial microexpressions) twice before and after the training. Meanwhile, an eye tracker from SMI (RED 250) recorded eye-movements of participants at 250 Hz. The results found that the training was effective (the gain score was significantly greater than zero), and the duration of fixation of the correct answers after training was significantly greater than that before training. Post training, participants showed changes in attention to the key features of emotional facial expressions (e.g., the mouth of happiness), which suggested that the improved emotion recognition is associated with changes in the way participants viewed facial expressions of emotion. In addition, the evidence showed that gender of participants has an effect on the recognition (recognition accuracy for females was 0.66, and 0.59 for males) and training outcomes (gain score of females was 23.8%, and 17.1% for males).

Acknowledgement: National Natural Science Foundation of China (No.31460251) Project of Social Sciences in Jiangxi Province (No. 18JY24)

33.467 Predicting Mental States from Eye Movements During Reading

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The pattern of eye movements made during reading is one of the most stereotyped high-level behaviors made by humans. As the readers of a language, we all agree to move our eyes in about the same way. Yet might there be hidden within all this self-similar behavior subtle clues as to how a reader is engaging the material being read? Here we attempt to decode a reader's eye movements to reveal their level of text comprehension and their mental state, with the states considered being the dimensions of: interested/bored, awake/sleepy, anxious/relaxed, and confused/clear. Eye movements were recorded from participants reading five published SAT passages. After each the corresponding SAT question was asked, followed by a questionnaire about the reader's mental state while reading the passage. A sequence of fixation location (x,y), fixation duration, and pupil size features were extracted from the reading behavior and input to a deep neural network (CNN/RNN), which was used to predict the reader's comprehension (e.g., accurate or inaccurate answer) and their questionnaire scores. Specifically, classifiers were trained on labeled reading data (80%) for a given passage, then evaluated in their ability to predict scores from the unlabeled reading eye movements (20%). We also compared our model to an SVM model that used hand-coded features, such as average forward speed and angularity of eye movement, to predict the same comprehension and questionnaire scores. We found that our models successfully predicted most of the scores, in some cases highly above chance (classification accuracy >80%), and that the deep network model generally outperformed the SVM model. By learning and using features that code the seriality and nonlinearity of fixations made during reading, we conclude that a CNN/RNN can decode reading behavior to reveal a reader's level of comprehension and mental state.

33.468 iMap4D: an Open Source Toolbox for Statistical Fixation Mapping of Eye-Tracking Data in Virtual Reality

Valentina Ticcinelli[1](valentina.ticcinelli@unifr.ch), Peter De Lissa[1], Denis Lalanne[2], Sebastien Miellet [3], Roberto Caldara[1]; [1]Eye and Brain Mapping Laboratory (iBMLab), Department of Psychology, University of Fribourg, Switzerland, [2] Human-IST Institute & Department of Informatics, University of Fribourg, Switzerland, [3]Active Vision Lab, School of Psychology, University of Wollongong, Australia

In the current days, virtual reality (VR) has become a widespread, easily accessible technology. The intrinsic advantage of generating experiments in fully controlled, realistic and engaging scenarios opens up endless possibilities in modern eye-movement research and in visual sciences. However, the readiness of this technology clashes with the unavailability of any user-friendly tool to analyze the highly multidimensional VR eye-movement data. In our previous work with iMap4 (Lao et al., 2017), we provided the possibility to turn 2D sparse fixation data (x, y eye-movement coordinates weighted by the fixation duration) in continuous statistical maps, and isolate significant differences between groups and conditions with linear mixed modeling. Here, we developed iMap4D, which allows to perform the same robust data-driven statistical evaluation as iMap4, while also handling two further VR dimensions (the z-coordinate and time), with smooth pursuits on moving objects also included in the map. To estimate average individual fixation maps on the model mesh, for every condition we perform a space convolution between the sparse fixation points and a 3D Gaussian kernel. The size of the kernel is scaled to account for objects' apparent size due to their position in the 3D space. We then consider the continuous hypersurface resulting from the statistical fixation intensity on each vertices of the mesh. Similar to iMap4, we apply for each vertex a univariate linear mixed model with subject as a random effect. All the possible linear contrasts can be performed, which statistical significance can be assessed by a spatial cluster test based on bootstrapping. To the best of our knowledge, iMap4D is the first free MATLAB open source toolbox for the statistical fixation mapping of 4D eye-movement data, and we believe that this toolbox could pave the way in boosting the number of vision science studies exploiting the groundbreaking VR technologies.

Acknowledgement: This study was supported by the Swiss National Science Foundation (100019_156541).

SUNDAY AFTERNOON TALKS

Objects and Scenes: Shape categorization, scene perception

Sunday, May 19, 2:30 - 4:15 pm, Talk Room 1

Moderator: Michelle Greene

34.11, 2:30 pm **Perceiving Sets and Categories** Noam Khayat[1](Noam.Khayat@mail.huji.ac.il), Shaul Hochstein[1]; [1]ELSC Brain Research Center & Life Sciences Institute, Hebrew University, Jerusalem

The visual system is constantly bombarded with too much information. Two cognitive processes are exploited to compensate for perceptual, cognitive and memory limits: object categorization and set summary statistics perception. We naturally relate objects to their category, assume they share relevant category properties, often disregarding irrelevant characteristics. Similarly, spreading attention over a set of objects with some similarity, we form an ensemble representation of the group: Without encoding detailed information of individuals, observers absorb set summary data. We now relate these processes and suggest they depend on similar mechanisms. Just as categorization may include/depend on prototype and inter-category boundaries, so set perception includes property mean and range. We find common features of these processes. We test summary perception of low-level features with a Rapid Serial Visual Presentation (RSVP) paradigm and find that participants perceive both the mean and range extremes of stimulus sets, automatically, implicitly, and on-the-fly, for each RSVP sequence, independently. We now use the same experimental paradigm to test category representation of high-level objects. We find participants perceive categorical characteristics better than they code individual elements. We relate category prototype to set mean and same/different category to in/out-of-range elements, defining a direct parallel between low-level set perception and high-level categorization. The implicit effects of mean or prototype and set or category boundaries are very similar. We suggest that object categorization may share perceptual-computational mechanisms with set summary statistics perception.

Acknowledgement: Israel Science Foundation (ISF)

34.12, 2:45 pm **Shape similarity and shape categorization using Bayesian shape skeletons** Nathan R J Destler[1](ndestler@psych.rutgers.edu), Manish Singh[1], Jacob Feldman[1]; [1]Rutgers University, Department of Psychology

What makes two shapes similar? Given two shapes, is there a mathematically principled way to predict human similarity judgments as they're used to classify both 2D and 3D shapes? In previous work, we proposed a shape similarity measure based on shape skeletons in a Bayesian framework. This measure posits that shape similarity is a function of the probability that the two shapes were generated from a common skeletal model. A key term in this probability is a probabilistic cost of transforming one shape into the other using the skeleton-based shape generation process. In current work, we expand on our previous validation of this model, comparing it to other successful models in a pair of shape classification experiments. We then use the model to test whether humans tend to infer prototype-like process (which estimates a common model from multiple examples) or exemplar-like process (which does not). We ran two experiments to test human shape categorization. Exp. 1 uses 2D shape silhouettes, while Exp. 2 uses images of 3D shapes. In both experiments, subjects are shown examples from a novel category of unfamiliar shapes, and (in some conditions) a negative example of a shape not from that category. Subjects are then asked to select shapes from a 6x6 grid of shapes that they judge as belonging to the novel category. We then use our model's similarity metric to predict the classification judgments from the experiments, and compare our model's performance to that of deep learning models on the same data. Finally, we use two variations on our model, in conjunction with the human classification patterns, to test whether humans infer prototype-like or exemplar-like shape category structures. Here, we find that our prototype-like model provides a better fit to human data than does our exemplar-like model.

Acknowledgement: NIH (NEI) Grant EY021494

34.13, 3:00 pm **Fast Periodic Visual Stimulation EEG as an implicit measure for perceptual discrimination and categorization of mid-level objects.** Jaana Van Overwalle[1,3](jaana.vanoverwalle@kuleuven.be), Stephanie Van der Donck[2,3], Sander Van de Cruys[1,3], Bart Boets[2,3], Johan Wagemans[1,3]; [1]Brain & Cognition Unit, KU Leuven, Belgium, [2]Center for Developmental Psychiatry, KU Leuven, Belgium, [3]Leuven Autism Research (LAuRes), KU Leuven, Belgiuim

How do we organize and process incoming visual information on a daily basis? Perceptual categorization and discrimination are essential to interact efficiently with the surrounding world. However, these implicit and automatic processes are typically investigated explicitly, allowing for decisional or motivational biases. The present project investigates whether Fast Periodic Visual Stimulation (FPVS) during scalp EEG can provide an implicit neural marker of perceptual categorization and discrimination. In FPVS, visual stimulation of the brain at a constant frequency rate leads to an EEG response at that exact frequency. The detection of periodically introduced oddball images in a series of base images will be signaled by an EEG response at the oddball frequency, which makes it an objective and implicit measure for change detection. FPVS paradigms have been validated in the context of low-level (e.g. contrast sensitivity) as well as higher-level (face) processing, but not yet for perceptual discrimination and categorization of mid-level objects. In a first experiment (n=8), we showed that the FPVS base-oddball paradigm offers a reliable neural signature of categorical perception while systematically "sweeping" through morph series of visual objects (e.g. peacock-truck and church-duck). In a second experiment (n=8), we confirmed that the FPVS base-oddball paradigm can implicitly measure reduced discrimination for exemplars within a category and enhanced discrimination across the category boundary in the same morph series.Both experiments suggest that FPVS EEG can provide reliable neural measures for categorization and discrimination, and correlations with behavioral measures suggest an association with behavioral sensitivity. Next, we will collect data on 14 participants performing both the discrimination and categorization experiment implicitly and explicitly and look at correlations between these measures. Furthermore, we will investigate whether the combination of these measures can shed more light on individual differences in perceptual processing along particular personality traits, e.g. autism-quotient.

34.14, 3:15 pm **What is a scene? Concavity as an intrinsic property of a scene** Annie Cheng[1](rcheng6@emory.edu), Dirk B Walther[2], Soojin Park[3], Daniel D Dilks[1]; [1]Psychology, Emory University, [2]Psychology, University of Toronto, [3]Psychology, Yonsei University

While over two decades of research has investigated the neural mechanisms underlying human visual place or "scene" processing, a fundamental question remains unanswered: What exactly is a scene? Intuitively, we are always inside a scene (while interacting with the outside of objects); hence, one intrinsic property of a scene may be concavity. Here, using two functional magnetic resonance imaging (fMRI) studies in humans, we directly tested the strongest predictions of this hypothesis: 1) if a scene-selective region tracks the concavity of a scene, then it will be sensitive to changes in concavity but not convexity of spatial boundary cues, and 2) if concavity is a diagnostic property of a scene, then a scene-selective region will respond not only to images of scenes, but also to non-scene images that depict concavity, such as the inside of objects. Consistent with our predictions, we found that a scene-selective cortical region (the parahippocampal place area, PPA) shows an increasing response to images of spatial boundary cues parametrically changing in concavity but not convexity, and to the inside of objects over the outside of objects. By contrast, an object-selective region (the lateral occipital complex, LOC) shows a greater response to convexity than concavity, and to the outside of buildings over the inside of buildings. Taken together, these results provide converging evidence that concavity is an intrinsic property of a scene, and raise the intriguing hypothesis that concavity versus convexity may be a diagnostic visual feature enabling the human brain to differentiate scenes from objects.

Acknowledgement: Emory College, Emory University (DDD), National Eye Institute grant R01EY026042 (SJP)

See page 3 for Abstract Numbering System

34.15, 3:30 pm **Perceptual grouping aids recognition of line drawings of scenes by CNNs** Morteza Rezanejad[1](morteza@cim.mcgill.ca), Gabriel Downs[1], John Wilder[2, 3], Dirk B. Walther[3], Allan Jepson[2], Sven Dickinson[2], Kaleem Siddiqi[1]; [1]School of Computer Science and Centre for Intelligent Machines, McGill University, [2]Department of Computer Science, University of Toronto, [3]Department of Psychology, University of Toronto

Humans can accurately categorize natural scenes from both photographs and line drawings. Gestalt grouping principles, such as proximity, parallelism and symmetry, are known to aid human performance in such complex perceptual tasks. Convolutional Neural Networks (CNNs) for categorizing scenes, on the other hand, rely heavily on color, texture and shading cues in color photographs. These cues are largely absent in line drawings, which convey contour-based shape information. We here show in computational experiments that CNNs pre-trained on color photographs are able to recognize line drawings of scenes, and that explicitly adding mid-level grouping cues, such as parallelism, symmetry and proximity, can improve CNN performance. Our contributions are threefold: (1) In addition to artist-drawn line drawings, we introduce computer generated line drawings extracted from two large scene databases, MIT67 and Places365, using a fast edge detection algorithm, followed by post-processing. We demonstrate that off-the-shelf pre-trained CNNs perform contour-based scene classification at performance levels well above chance on these datasets. (2) We evaluate computational methods for computing local measures of contour grouping based on medial axis representations of the scenes. Specifically, we compute salience measures for contour separation (corresponding to the proximity Gestalt rule), ribbon symmetry (parallelism), and taper symmetry (mirror symmetry). We show that these grouping cues prioritize contour pixels according to how informative they are for scene categorization. The observed variations in CNN classification performance for subsets of these measures qualitatively match those in scene categorization by human observers.
(3) Explicitly adding these salience measures to the line drawings boosts CNN performance over the use of line drawings alone. Overall, our results indicate an important role for perceptually motivated Gestalt grouping cues for contour-based scene classification by state-of-the-art computer vision systems, as demonstrated on datasets of complexity not yet considered in human vision studies.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC)

34.16, 3:45 pm **High-def memories of low-def scenes: A new phenomenon of "vividness extension"** Jose Rivera-Aparicio[1](-jriver36@jhu.edu), Chaz Firestone[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

Memories fade over time: A crisp hike on a wooded trail becomes harder to vividly recall as it moves further into the past. As the quality of a memory wanes, what happens to that memory's content? For example, as one's memory of a hike fades and loses clarity, might one also recall the day itself as literally being dimmer or more faded? Or might the opposite occur: Might we recall the experience as having been clearer and more detailed than it really was, even as our ability to recall those details is diminished? Here, four experiments demonstrate a surprising bias to remember visual scenes as having been more vivid and higher quality than they really were. Subjects saw images of natural scenes that had been blurred to varying degrees. A brief delay followed each scene, after which a new instance of the same scene appeared; subjects adjusted the blur of the new image to match the blur of the scene they had just viewed. Surprisingly, a powerful bias emerged wherein subjects misremembered scenes as being sharper and more vivid (i.e., less blurry) than they had truly appeared moments earlier. Follow-up experiments extended this phenomenon to saturation (with a bias to remember scenes as more colorful) and pixelation (with a bias to remember scenes as appearing at a higher resolution), while ruling out various response biases (e.g., a preference to look at sharper scenes, or to give extreme responses). The strength and pervasiveness of this bias suggests that, just as the mind fills in the details surrounding scenes in phenomena such as boundary extension, a similar process occurs within a scene itself: A phenomenon of "vividness extension", whereby scenes are remembered as being more vivid than they really were.

Acknowledgement: JHU Science of Learning Institute

34.17, 4:00 pm **The role of recurrent processing in visual scene categorization** Jamie L Siegart[1](jsiegart@bates.edu), Wuyue Zhou[1], Enton Lam[1], Munashe Machoko[1], Michelle R Greene[1]; [1]Program in Neuroscience, Bates College

The core of visual scene understanding can be accomplished with a single fixation (Fei-Fei et al., 2007; Greene & Oliva, 2009). This speed has implied that core visual processing can be accomplished in a feedforward manner (Serre et al, 2007). Deep convolutional neural networks (dCNNs), themselves exclusively feedforward, have achieved categorization abilities rivaling those of human observers (Russakovsky et al., 2015). However, these networks fail to explain critical neural and behavioral responses (Geirhos et al., 2017), and cannot explain the massive feedback connections in primate visual systems (Felleman & Van Essen, 1991). Work in monkey physiology has demonstrated that images that are easy for humans to recognize, but difficult for dCNNs take longer to decode from IT cortex (Kar et al., 2018), suggesting a role for recurrent processing for difficult images. However, these images are not meaningful to the monkeys and consist of photoshopped objects on arbitrary backgrounds. To what extent does this pattern hold for humans viewing familiar images? We identified 25 scene categories from the SUN database whose images led to a range of categorization accuracies in three dCNNs. We isolated 20 images with high- and 20 images with low- dCNN performance per category. Observers viewed these images in random order while performing 2AFC categorization. We recorded 64-channel EEG and submitted the raw waveforms to a linear decoder to assess category information. Observers were on average 50 ms faster to categorize images that were easy for the dCNNs. Although both easy and hard images could be decoded at an above-chance level, decodable information for the easy images was available by 57 ms post-image onset and peaked after 85 ms, but information about hard images was not available until 72 ms, peaking at 192 ms. Together, this pattern is suggestive of the role of recurrent processing in human scene categorization.

Acknowledgement: National Science Foundation (1736274) grant to MRG

Binocular Vision

Sunday, May 19, 2:30 - 4:15 pm, Talk Room 2

Moderator: Alexander Maier

34.21, 2:30 pm **Monovision and the misperception of motion** Johannes Burge[1,2,3](jburge@sas.upenn.edu), Victor Rodriguez-Lopz[1,4], Carlos Dorronsoro[4]; [1]Department of Psychology, University of Pennsylvania, [2]Neuroscience Graduate Group, University of Pennsylvania, [3]Bioengineering Graduate Group, University of Pennsylvania, [4]Institute of Optics, Spanish National Research Council (IO-CSIC)

Monovision corrections are a popular treatment for presbyopia. Each eye is fit with a lens that sharply focuses light from a different distance, causing differential blur in the two eyes' images. Approximately 12.5 million people in the United States have a monovision correction, but little is known about how differential blur affects motion perception. Accurate motion perception is critical for many daily tasks. We investigated by measuring the Pulfrich effect, a stereo-motion phenomenon first reported nearly 100 years ago. When a target oscillating in the frontoparallel plane is viewed with unequal retinal illuminance or contrast in the two eyes, the target appears to follow an elliptical trajectory in depth. The effect occurs because the image with lower illuminance or contrast is processed more slowly. The mismatch in processing speed causes a neural disparity, which results in the illusory motion in depth. What happens with differential blur? To investigate, we used trial lenses to induce interocular blur differences up to 1.0D, and a haploscope for dichoptic presentation of targets undergoing sinusoidal motion. Then, as a function of onscreen interocular delay, we measured how frequently human observers perceived 'front right' motion. Remarkably, the results show that differential blur causes a reverse Pulfrich effect, an apparent paradox. Blur reduces contrast and should therefore cause processing delays. But the reverse Pulfrich effect implies that the blurry image is processed more quickly. The paradox is resolved by recognizing i) that blur reduces the contrast of high-frequency image components more than low-frequency image components, and ii) that high spatial frequencies are processed more slowly than low spatial frequencies, all else equal. Thus, this new version of a 100-year-old illusion is explained by known properties of the early visual system. Implications for the spatial frequency binding problem and for public safety will be discussed.

Acknowledgement: NIH: R01-EY028571

34.22, 2:45 pm **Nasotemporal Division of Retina is Well Suited for Disparities of Natural Scenes** Agostino Gibaldi[1](agostino.gibaldi@berkeley.edu), Martin S Banks[1]; [1]School of Optometry, University of California at Berkeley

In most primates, neurons from nasal retina project to the brain's contralateral hemisphere, and those from temporal retina to the ipsilateral hemisphere. If contralateral and ipsilateral projections were precisely split along the vertical meridians, objects near the midsagittal plane would send signals to opposite hemispheres, making disparity estimation difficult. But anatomical studies of macaque reveal overlapping projections near the vertical meridians (Fukuda et al., 1989). The overlap expands with eccentricity and is biased toward crossed disparities in the lower visual field (not known in the upper field). We asked whether the overlap is well suited to ensure that common disparities project to the same hemisphere thereby aiding precise stereopsis. To answer this, we must know the distribution of disparities near the vertical meridians. We measured natural retinal disparities in humans using a custom device. Participants performed everyday tasks at close, medium, and far range. The resulting database has ~880,000 video frames. The disparity distributions are peaked with long tails. The most likely disparity depends on position near the vertical meridian: uncrossed in the upper field and crossed in the lower. Variance increases with eccentricity. From those data, we calculated the percentage of disparities that would projection to opposite hemispheres if human contralateral and ipsilateral projections were the same as those in macaque. The macaque overlap would encompass 75-85% of natural disparities if it was symmetric in the two eyes. It would encompass 85-90% if it were biased toward uncrossed disparity in the upper field and crossed in the lower. Because of the long tails of the disparity distribution, wider overlap would not provide significantly better coverage. The pattern of nasal-temporal overlap in retinal-cortical projections is well suited for ensuring that common disparities produce direct projections to the same hemisphere thereby aiding precise stereopsis.

Acknowledgement: NSF Research Grant BCS-1734677, Corporate University Research, Intel Labs, and the Center for Innovation in Vision and Optics

34.23, 3:00 pm **Playing 3-dimensional (3D), but not 2D video games can improve stereoacuity in neurotypical observers.** Dennis Levi[1,2](dlevi@berkeley.edu), Roger W Li[1]; [1]School of Optometry, University of California, Berkeley., [2]Helen Wills Neuroscience Institute, University of California, Berkeley.

Bruce Bridgeman, who had been stereo-deficient due to strabismus all of his life, recovered stereoscopic vision after viewing the 3D movie Hugo (Bridgeman, 2014). He hypothesized that "sustained attention to varying high-disparity stereoscopic challenges in an engaging immersive environment" may have resulted in this remarkable improvement. Here we ask whether playing immersive 3D video games containing exaggerated binocular disparities, results in improved depth perception in observers with normal binocular vision. To address this question neurotypical young adults with limited video game experience were randomized into two groups. Group 1 (3DVG, n=12) played stereoscopic 3D first-person shooter video games for a total of 40 hours, 2 hours per session. Group 2 (2DVG, n=12) participants played the same video games but in 2D mode (no binocular disparity) over the same time course. Before and after 40 hours of video game play we measured the participants' stereoacuity with static random dot stereograms (Patel et al., 2003) using the method of constant stimuli. The observers' task was to determine whether a central square was in front or behind an outer reference square. Stereoacuity was defined as the disparity at the 84% correct response rate, obtained by fitting a Probit function. There was a significant improvement in stereoacuity for the 3DVG group (mean Pre:Post ratio = 1.5; $p = 0.004$), but not the 2DVG control group (mean Pre:Post ratio = 1; $p = 0.92$). Nine of the twelve participants in the 3DVG group showed improved stereoacuity, up to more than a factor of two. We conclude that playing immersive 3D videogames that contain disparities much larger than those generally encountered in natural scenes (Sprague et al., 2015), can result in improved stereoacuity. Notably, our most recent experiments (Li et al., 2018) have shown that 3D video games may also enhance stereoacuity in patients with amblyopia.

Acknowledgement: NEI Grant RO1EY020976

34.24, 3:15 pm **Can human stereopsis improve by making the eyes optically perfect?** Cherlyn J Ng[1,2](cherlyn.j.ng@rochester.edu), Martin S Banks[3], Duje Tadin[2,1], Randolph Blake[4], Geunyoung Yoon[1,2]; [1]Flaum Eye Institute, University of Rochester, Rochester, NY, United States, [2]Center of Visual Science, University of Rochester, Rochester, NY, United States, [3]School of Optometry, UC Berkeley, CA, United States, [4]Department of Psychology, Vanderbilt University, TN, United States

Higher-order ocular aberrations (HOAs) limit visual acuity even when spherical and cylindrical errors are well corrected. We investigated how such aberrations affect stereoacuity. Four stereo-normal adults were tested psychophysically in a binocular adaptive-optics vision simulator. With this simulator, we can correct sphero-cylindrical and higher-order aberrations in real time. High-contrast visual acuity was measured with the "Tumbling E" method. Stereoacuity was measured with random-dot stereograms that portray sinusoidal depth corrugations (1, 2, or 3cpd). On average participants had $0.27\pm0.15\mu m$ RMS wavefront error for higher-order aberrations (HOAs). Full correction decreased this error to $< 0.05\mu m$, and significantly improved visual acuity in all participants ($p< 0.01$). The improvement in visual acuity was particularly large for a participant with large HOAs (0.54 RMS error; 0.218 vs 0.142 ± 0.07logMAR). Stereo thresholds increased significantly and had greater variation between participants with increasing corrugation frequency ($p< 0.01$), but were significantly lower after HOA correction (27.30 ± 17.16arcsec vs. 45.86 ± 33.26; $p=0.05$). There were larger improvements at high frequencies that tended towards significance (1cpd: 1.8-, 2cpd: 2.5- and 2.3-fold improvement; $p>0.1$, $p=0.1$, $p=0.07$ respectively). There was no significant correlation between stereoacuity and the amount of correction for HOAs. Correcting higher-order aberrations produces consistent improvement in visual acuity, but stereo acuity was not correlated with HOAs. The lack of correlation suggests factors beyond optics that further limit performance to ceiling after correction. We suggest neural factors play a role, at least in part, with the smaller improvement on stereopsis at low frequencies being attributable to reliance on relatively large receptive fields required for computing binocular disparity.

Acknowledgement: EY014999

34.25, 3:30 pm **Binocular Modulation of Monocular Neurons in the Primary Visual Pathway** Kacie Dougherty[1](kacie.dougherty@vanderbilt.edu), Michele A Cox[1,2], Jacob A Westerberg[1], Alexander Maier[1]; [1]Department of Psychology, Vanderbilt University, [2]Center for Visual Science, University of Rochester

Our brains reliably transform the patterns of light on the two retinae into a singular view. Retinal projections from each eye target mutually exclusive groups of neurons in the lateral geniculate nucleus (LGN) of the thalamus. Congruent with this pattern of innervation, almost all LGN neurons respond to one eye and not the other (monocular neurons). In V1, some neurons, especially in the primary LGN input layer, respond to only one eye as well. However, most V1 neurons respond to either eye (binocular neurons), though stimulation of one eye (the dominant eye of the neuron) often leads to a greater response than stimulation of the other. These findings suggest that the two eyes' signals are combined into a binocular response before they leave V1. However, we do not know exactly where this happens as even monocular neurons might be sensitive to both eyes. For example, monocular neurons could significantly alter, or modulate, their responses during binocular stimulation compared to stimulation of their dominant eye alone. To test for this possibility, we used linear multicontact electrode arrays to record LGN and V1 spiking responses to visual stimuli presented to one or both eyes at varying contrast levels. While the majority of LGN neurons did not modulate during binocular stimulation, approximately one-fifth of LGN units showed a significant difference between monocular and binocular stimulation, consistent with earlier reports in anaesthetized animals. In stark contrast, most monocular V1 neurons, including those in the primary LGN input layer, significantly modulated their responses during binocular viewing. Most of this binocular modulation occurred several milliseconds following the onset of the visual response, suggesting that the bulk of binocular modulation involves intracortical processing.

Acknowledgement: R01EY027402-02,5T32 EY007135-23, P30-EY008126

 See page 3 for Abstract Numbering System

34.26, 3:45 pm **Interocular Conflict Predicts Individual Differences in Binocular Rivalry** Janine D Mendola[1](janine.mendola@mcgill.ca), Elizabeth A Bock[2], Jeremy D Fesi[1], Sylvain Baillet[2]; [1]Department of Ophthalmology, McGill University, [2]Department of Neurology and Neurosurgery, Brain Imaging Centre, MNI

Introduction: Binocular rivalry (BR) is a dynamic visual illusion that provides insight into the cortical mechanisms of visual awareness, stimulus selection, and object identification.When dissimilar binocular images cannot be fused, perception switches every few seconds between the left and right eye images.The speed at which individuals switch between alternatives is a stable, partially heritable trait. In order to isolate the monocular and binocular processes that determine the speed of rivalry, we presented dichoptic stimuli tagged with a different flicker frequency in each eye and applied stimulus-phase locked magnetoenphalography (MEG) source imaging. We hypothesized that the strength of the evoked fundamental or intermodulation frequencies would vary when comparing Fast and Slow Switchers.Methods: Ten subjects participated in the experiment with three stimulus conditions: BR, a pattern rivalry control, and a nonrivalrous control condition. Subjects reported perceptual alternations with mean dominance durations between 1.2–4.0 sec. Results: During BR, event-related monocular input in V1, and broadly in higher-tier ventral temporal cortex, waxed and waned with the periods of left or right eye dominance/suppression. In addition, we show that Slow Switchers produce greater evoked intermodulation frequency responses in a cortical network composed of V1, lateral occipital, posterior STS, retrosplenial & superior parietal cortices. Importantly, these dominance durations were not predictable from the brain responses to either of the fundamental tagging frequencies in isolation, nor from any responses to a pattern rivalry control condition, or a non-rivalrous control. Conclusions: The novel cortical network isolated, which overlaps with the default-mode network, may contain neurons that compute the level of endogenous monocular difference, and monitor accumulation of this conflict over extended periods of time.These findings are the first to relate the speed of rivalry across observers to the 'efficient coding' theory of computing binocular differences that may apply to binocular vision generally.

Acknowledgement: National Science and Engineering Research Council of Canada

34.27, 4:00 pm **The Attentional Modulation of Binocular Rivalry: an OKN Approach** Stella C Qian[1](qianche5@msu.edu), Jan W Brascamp[1,2]; [1]Department of Psychology, Michigan State University, [2]Neuroscience Program, Michigan State University

Binocular rivalry (BR) is observed when the two eyes receive conflicting information, leading to perceptual switches between the eyes' images. Evidence indicates that rivalry ceases, and the two images are processed equally, when attention is fully withdrawn. Consistent with this, computational models of BR typically have a region in the parameter space where both competing representations reach an equilibrium, and recent model work suggests that strong attention withdrawal drives the system into such a region (Li et al., 2017). But there is an unresolved issue: in existing models those parameter changes that move the system toward, but not into, the equilibrium region (e.g. modest attention withdrawal) increase the perceptual switch frequency, yet experiments (Paffen et al., 2006; Alais et al., 2010) indicate that modest attention withdrawal has the opposite effect of reducing switch frequency. Due to the key position of this latter result as an obstacle to reconciling empirical results and models, we aimed to verify the result. Moreover, the original work raises a potential methodological concern because observers reported BR dominance while also performing a secondary attention task, which may have invited a strategy of shifting attention back and forth between tasks. To avoid this potential concern, we used optokinetic nystagmus to track perceptual switches of a task-irrelevant rivalry stimulus (foveally presented dot fields moving in opposite directions in the two eyes), while observers performed an auditory attention task. Our results show that switch frequency decreases as the auditory attention task becomes more challenging, thus confirming the existing finding with our new method that does not share the original method's potential shortcomings. Because computational model predictions are inconsistent with this finding, our work indicates that modifications to existing models are needed.

Visual Search: Models, neural mechanisms

Sunday, May 19, 5:15 - 7:15 pm, Talk Room 1

Moderator: Stefanie Becker

35.11, 5:15 pm **Selection and Enhancement: Modeling Attentional Capture during Visual Search** Andrew Lovett[1](andrew.lovett.ctr@nrl.navy.mil), Will Bridewell[1], Paul Bello[1]; [1]U.S. Naval Research Laboratory

Our goal is to explore the concrete mechanisms underlying visual attention. Previously, we developed a computational model of multiple-object tracking that relies on two attentional mechanisms: selection, which enables an object in the visual field to receive further processing, resulting in representations stored in visual short-term memory (VSTM); and enhancement, which improves sensitivity to stimuli in the spatial regions around recently selected objects, increasing the likelihood that those stimuli will be selected. Here, we generalize selection and enhancement to visual search. Recent work suggests three factors govern attentional capture during search: bottom-up salience; top-down goals, possibly provided by verbal cues that describe the search target; and selection history, as in intertrial priming, where a target similar to the previous trial's target is easier to find. Although there are important distinctions between these factors, verbal cueing and intertrial priming may both be supported by featural enhancement. Similar to spatial enhancement during object tracking, featural enhancement increases the likelihood that stimuli with visual properties similar to a recently selected item will be selected. We developed a computational model that relies on three key components: segmentation, which divides the visual input into candidate objects for selection; salience, which scores each candidate based on its contrast to local and global surroundings; and enhancement, which scores each candidate based on featural similarity to recently selected objects represented in VSTM. Scores from salience and enhancement are combined to determine which candidate is selected. To support top-down goals, previously selected objects are represented in long-term memory (LTM). A verbal cue (e.g., "orange") causes the model to retrieve an LTM representation matching that cue and add it to VSTM, so that its features will be enhanced. Preliminary findings suggest the model accounts for the contributions of all three factors governing attentional capture during search.

Acknowledgement: Office of Naval Research

35.12, 5:30 pm **The psychophysics of visual search with heterogeneous distractors: effects ofset size, task, temporal order and stimulus spacing** Andra L Mihali[1,2](alm652@nyu.edu), Wei Ji Ma[1,2]; [1]Center for Neural Science, New York University, [2]Department of Psychology, New York University

Visual search with homogeneous distractors has been extensively characterized within a modeling framework, both with signal detection theory (Palmer et al, 2000), and optimal-observer models (Mazyar et al, 2012). Visual search with heterogeneous distractors has also been investigated, starting with Duncan and Humphreys (1989), but a much smaller proportion of this work used simple parametric stimuli, making modeling and dissociation of component processes more difficult. Here, we performed a detailed characterization of the factors that influence performance in visual search with heterogenous distractors: set size, task (detection vs localization), temporal order of revealing target identity and search array (perception vs memory conditions) and stimulus spacing (distant vs nearby stimuli). We captured this data with optimal-observer models and quantified the influence of these factors on model parameters. In both tasks and conditions, performance decreased with set size, and also as the most similar distractor was closer in orientation distance to the target. In contrast, increased proximity in orientation distance to the mean of the distractors did not decrease performance and neither did increases in the heterogeneity of the distractors. These patterns of results were captured by an optimal-observer model with a variable precision encoding stage. The fitted mean precision parameters decreased with the set size of the array and were higher in perception than in memory in both tasks. Adding a decision noise parameter improved the model fits on the detection data, but not on the localization data. Additionally, we were able to capture both the localization and detection data with a model with joint encoding parameters, suggesting that observers might be using the same encoding processes across both tasks. We replicated our results in a separate experiment with reduced stimulus spacing. These results futher demonstrate the value of using parametric stimuli and optimal-observer modeling to better understand visual search.

Acknowledgement: R01EY020958

35.13, 5:45 pm **Computational strategies used during hybrid visual search** Farahnaz A. Wick[1,2,4](farahnaz@gmail.com)**,** Gabriel Kreiman[1,3,4]**,** Jeremy M. Wolfe[1,2]; [1]Harvard Medical School, [2]Brigham & Women's Hospital, [3]Boston Children's Hospital, [4]Center for Brains, Minds & Machines

Biologically-inspired deep computational models like the Invariant Visual Search Network (Zhang et al., 2018) can effectively search for a single target in an image. We modified the IVSN model to perform hybrid search, i.e. searching a visual display for any one of several targets held in memory. In this case, the features from multiple targets must be utilized to guide search. This raises the question: what strategies best model human behavior? The model was given an input image consisting of eight grayscale objects on each trial. Either 1, 2 or 4 targets were held in memory. The search image included a single target in each trial. The model generated a separate priority map from the search image for each target held in memory. These priority maps were either combined or selected at random with replacement (randomly cycled) and the output guided fixation. The model generated fixations until the target was found or all locations were visited. Each fixated location was inhibited such that the model never revisited a location. We compared model performance to data from a psychophysics experiment where human observers performed the same task with the same stimuli. Using human target-present data, we assessed human and model performance for the number of fixations needed to find the target and the sequence of locations visited during a trial. Averaging model priority maps across targets in memory produced a poor fit to human performance. Cycling priority maps to guide each successive fixation produced performance similar to humans as if observers might be prioritizing a different member of the memory set on each fixation. Combining priority maps by taking the maximum across maps at each location also produced performance similar to humans. These computational strategies reveal possible mechanisms used by humans during hybrid search when multiple target templates are held in memory.

Acknowledgement: NSF, NIH-NEI EY017001, Harvard Mind, Brain & Behavior Faculty Award to Kreiman & Wolfe

35.14, 6:00 pm **Scene context does not necessarily limit processing to target-consistent regions in visual search.** Gavin JP Ng[1](jng17@illinois.edu)**,** Jiahao Zhou[1]**,** Simona Buetti[1]**,** Alejandro Lleras[1]; [1]University of Illinois

Recent research suggests that processing in visual search begins with an accumulation of evidence across all locations in the display. This accumulation towards a non-target threshold involves the computation of a contrast signal between each item and the target template. In efficient search tasks, this results in a logarithmic increase in reaction times (RTs) as a function of set size. On the other hand, visual search in scenes can benefit from contextual information by limiting selective attention to target-consistent regions. For example, when looking for a mug, observers limit attention to target-consistent regions (e.g. countertops) while ignoring target-inconsistent regions (e.g. ceilings). Is the evidence accumulation process mandatory for the entire scene in efficient search, or can contextual information exclude target-inconsistent regions from processing? In a series of experiments, we manipulated set size in an efficient search task in scenes. Observers searched for a uniquely-colored target item that always appeared in a target-consistent region (e.g. fish in the sea and not the sky. Consistent with previous studies, we found that the evidence accumulation process is restricted to the set size of the target-consistent region; set size of the target-consistent region did not contribute to RTs. In a subsequent experiment, we changed the predictability of the target-consistent region by making its location random instead of always appearing in a specific area of the display. Thus, observers had to locate the target-consistent region instead of relying on previous experience. Interestingly, all distractors now contributed to RTs. However, observers were not ignoring scene context: logarithmic slopes for distractors in the target-inconsistent region were shallower, indicating that these distractors were rejected more quickly. Thus, evidence accumulation in efficient search is mandatory and takes places across the entire display when scene context is unpredictable but can be speeded up for distractors in target-inconsistent regions.

35.15, 6:15 pm **At what stage of the visual processing hierarchy is visual search relational and context-dependent vs. feature-specific?** Stefanie I. Becker[1](s.becker@psy.uq.edu.au)**,** Aimee Martin[1]**,** Nonie J Finlayson[1]; [1]School of Psychology, The University of Queensland, Brisbane, Australia

Previous studies showed that attention, eye movements and visual short-term memory operate on (partly) context-dependent representations of stimuli. Specifically: When observers have to search for a target with particular features (e.g., medium orange), attention is usually tuned to the relative size and colour (e.g., largest, reddest; 'relational search') rather than the physical features (e.g., medium, orange). Attention can also be tuned to the specific features of the target, but feature-specific search is more effortful and slower. Importantly, it is currently unknown whether information about relative features is derived from lower-level neurons that respond to specific features, or whether visual inputs are first encoded relationally, with feature-specific codes extracted later. The present study addressed this question using functional magnetic resonance imaging (fMRI) in a colour search task in which we enforced relational vs. feature-specific search. Our current findings support the first possibility, with inputs being first processed in a feature-specific manner, and later relationally: In V1, repetition suppression was most pronounced in the feature-specific condition, indicating that these neurons respond to specific feature values. In V2, repetition suppression was equally strong for both conditions, but in later areas (V3, parietal and frontal areas), the result reversed, with stronger repetition suppression for relational search. Surprisingly, these results were obtained even when both the target and nontarget colours changed on a trial-by-trial-basis in relational search, and only the nontarget colour in feature-specific search. These findings show that repetition suppression is not always tightly linked to repetitions of the stimulus input, but can depend on top-down search goals, especially during later processing stages. Moreover, while V1 seems to respond to specific features, relational information is apparently derived as early as V3, and dominates throughout the visual processing hierarchy. This dominance may explain why relational search is more efficient and generally preferred to feature-specific search.

Acknowledgement: Australian Research Council (ARC)

35.16, 6:30 pm **Induction of Shape Selectivity in Macaque Frontal Eye Field Dissociates Perceptual and Motor Processing Stages of Visual Search** Kaleb A Lowe[1,2,3](kaleb.a.lowe@vanderbilt.edu)**,** Jeffrey D Schall[1,2,3]; [1]Department of Psychology, Vanderbilt University, [2]Center for Integrative and Cognitive Neuroscience, Vanderbilt University, [3]Vanderbilt Vision Research Center, Vanderbilt University

Neurons in frontal eye field (FEF) respond to visual stimulation, before eye movements, and both. These responses differentiate whether or not a stimulus is a saccade target. This differentiation, or target selection, is stimulus-locked for many neurons. Importantly, this target selection does not usually depend on the features that define a target as such, because most neurons in FEF do not exhibit intrinsic feature selectivity. However, consistent mapping of a stimulus feature and reward can elicit feature selectivity. Whether this feature selectivity is similarly stimulus-locked or if it is related to the selection of a saccade endpoint is unknown. We developed a search pro-/anti-saccade task in which shape varies among stimuli but does not define the saccade target. One monkey tested in this task developed a strategy that exploits an incidental shape-response association as opposed to the intended rule. We identified visual neurons in FEF that exhibited shape selectivity. The timing of this selectivity followed visual onset but was coincident with saccade target selection. Further, we found that these neurons showed an additional increase in firing rate when a stimulus of the preferred shape was also chosen via saccade. This occurred after feature selection and was coincident with additional temporal measures of saccade endpoint selection. These findings together suggest that feature selectivity, when induced, is tantamount to target selection which is then followed by saccade endpoint selection. In this way, we can exploit feature selectivity in FEF neurons to dissociate the perceptual and motor stages of a complex visual search task.

Acknowledgement: R01-EY08890, P30-EY08126, U54-HD-083211, and Robin and Richard Patton through the E. Bronson Ingram Chair in Neuroscience

 See page 3 for Abstract Numbering System

35.17, 6:45 pm **Inhibitory tagging of previously-foveated locations in the superior colliculus during visual search**
Rakesh K Nanjappa[1](rnanjappa@sunyopt.edu), Robert M McPeek[1]; [1]Graduate Center for Vision Research, SUNY College of Optometry

Efficient visual search involves exploring novel regions of a scene and ignoring previously analysed ones. Computational models of search incorporate this through an activity map in which regions of space that have been previously foveated are tagged with an inhibitory signal. We trained a rhesus monkey to search for green targets among red distractors in a grid-like array while we recorded activity from the superior colliculus (SC), a midbrain structure causally involved in saccade target selection. In a dynamic search condition, each target changed color to the distractor color upon being foveated, such that the monkey had to 'extinguish' all the targets by fixating each one. In contrast, in the memory search condition, targets did not change color upon fixation. This required the monkey to remember the locations that had already been foveated in order to search efficiently. Overall, search was more efficient in the dynamic than the memory search condition, as measured by the number of saccades per trial and the proportion of saccades to targets. SC visual activity for a given stimulus was reduced during a 100-150 ms period following fixation onset when the stimulus had been previously foveated, even after controlling for the target-distractor identity of the RF stimulus. At the individual cell level, visual cells showed more suppression than visuomotor and motor cells. We also observed a sinusoidal modulation of the cells' mean activity in the suppression period based on the time since the distractor was last foveated. These findings point to a role for the SC in mediating inhibitory tagging during visual search, similar to what has been observed in area LIP.

Acknowledgement: NIH EY014885

35.18, 7:00 pm **Laminar organization of the superior colliculus priority map**
Brian J White[1](brian.white@queensu.ca), Janis Y Kan[1], Laurent Itti[2], Douglas P Munoz[1]; [1]Centre for Neuroscience Studies, Queen's University, Kingston, Canada, [2]Computer Science Dept., University of Southern California, Los Angeles, USA

The superior colliculus (SC) is a multilayered midbrain structure with depth-dependent cortical/subcortical connectivity, and a longstanding role in the control of attention/gaze. While the superficial layers (SCs) have been associated with a bottom-up saliency map, the intermediate layers (SCi) have been described as a priority map, where neuronal signals related to visual salience and behavioral relevance combine to determine attention/gaze. However, the use of single electrodes to understand SC laminar function has been a major limitation due to inaccurate depth estimates. Here, we examined depth-dependent processing of stimuli of different salience/relevance across the intermediate and deeper SC layers using a linear microelectrode (LMA; 16ch, 200µm inter-contact spacing). Rhesus monkeys were presented with an array of oriented color stimuli (~200 items) with two salient but feature-distinct oddballs. One oddball was goal-relevant (salient/relevant), the other goal-irrelevant (salient/non-relevant), and both were embedded in a feature-homogenous array of 'distractors' (non-salient/non-relevant). Following array onset, the animals maintained fixation for 0.5-0.7s allowing temporal separation between visual- and saccade- processes. The fixation stimulus then disappeared, instructing the animal to saccade to the goal-relevant oddball for a reward. We examined multiunit activity (MUA), local field potential activity (LFP), and current source density (CSD). We observed a depth-specific change from net inward-to-outward current flow in the saccade-evoked LFP, and corresponding CSD, indicating a depth-dependent functional distinction. We also observed depth-dependent oddball selectivity corresponding roughly to the upper window (~1600µm) defined by the CSD cutoff, consistent with SCi. This oddball response was maximal at the center of the window and systematically attenuated dorsal and ventral from this. The deepest sites showed visual and saccadic responses, yet were not oddball selective. These results are consistent with a depth-dependent priority map in the SCi that combines information about stimulus saliency and relevancy to systematically rank order map locations for attention/gaze control.

Acknowledgement: Canadian Institutes of Health Research (Grant# MOP-FDN-148418)

Visual Memory: Working memory

Sunday, May 19, 5:15 - 7:15 pm, Talk Room 2

Moderator: Keisuke Fukuda

35.21, 5:15 pm **Human gaze tracks the focusing of attention within the internal space of visual working memory**
Freek van Ede[1](frederik.vanede@ohba.ox.ac.uk), Sammi R Chekroud[1,2], Anna C Nobre[1,2]; [1]Oxford Centre for Human Brain Activity, Wellcome Centre for Integrative Neuroimaging, Department of Psychiatry, University of Oxford, [2]Department of Experimental Psychology, University of Oxford

There is considerable overlap in the brain areas that control overt shifts of gaze and covert shifts of attention. In visual perception, these two functions are naturally linked because information sampled at covertly attended locations often informs where to look next. We ask whether the brain's oculomotor system also participates in attentional focusing when there is no incentive for overt shifts of gaze: when attention is voluntarily directed to one out of multiple visual items held internally within the spatial layout of visual working memory. Paradoxically, we showcase this participation through gaze behaviour itself. We demonstrate that selecting an item from visual working memory leads to an increased propensity of micro saccades in the direction of the memorised location of that item – even when there is nothing to look at and even when location memory is never asked about. Building on this key observation, we further show that this retrospective 'gaze bias' is specific to cases where the probed memory item is not already in the focus of attention, and predicts the performance benefit associated with such focusing (experiment 2); that externally-induced gaze shifts of similar magnitude are insufficient to place memory items into the focus of attention (experiment 3); and that this gaze bias generalises across the selection of different visual features (orientation and colour; experiment 4). We conclude that the oculomotor system also plays a key role in attentional focusing within the internal space of visual working memory, and that such 'internal focusing' can be studied through the eyes.

Acknowledgement: This research was funded by a Marie Skłodowska-Curie Fellowship from the European Commission (ACCESS2WM) to F.v.E., and a Wellcome Trust Senior Investigator Award (104571/Z/14/Z) to A.C.N.

35.22, 5:30 pm **Real-time triggering reveals sustained attention and working memory lapse together**
Megan T deBettencourt[1,2](debetten@uchicago.edu), Paul A Keene[1], Edward Awh[1,2,3], Edward K Vogel[1,2,3]; [1]Institute for Mind and Biology, University of Chicago, [2]Department of Psychology, University of Chicago, [3]Grossman Institute for Neuroscience, Quantitative Biology and Human Behavior

Attention and working memory are clearly intertwined, as shown by covariations in individual ability and their recruitment of similar neural substrates. Both processes fluctuate over time, and these fluctuations may be a key determinant of individual variations in ability. Theories suggest attention and memory rely upon a common cognitive resource but do not address whether attention and working memory fluctuate together moment-to-moment. The goal of this study was to determine when attention and memory fluctuate in synchrony, and then to leverage fluctuations of attention to optimize memory encoding. To examine this, we developed a novel hybrid task that interleaved a sustained attention to response task and a whole report working memory task. In Experiment 1, we established that performance fluctuations on these tasks correlated across and within participants, as attention lapses led to worse working memory performance. Experiment 2 extended this finding using a real-time triggering procedure that monitored attention fluctuations to probe working memory during optimal (high attention) or suboptimal (low attention) moments. We demonstrated that participants in a low attention state stored fewer items in working memory. Experiment 3 ruled out task-general fluctuations as an explanation for these covariations by showing that the precision of color working memory was unaffected by variations in attentional state. In sum, these findings highlight the utility of adaptive experimental designs to probe the relationship between attention and memory. We demonstrate that attention and working memory lapse together, providing new evidence for the tight integration of these cognitive processes.

Acknowledgement: NIH R01MH087214, ONR N00014-12-1-0972, NIH F32MH115597

35.23, 5:45 pm **Representation of active and latent items in working-memory-guided behavior** Paul S Muhle-Karbe[1,2](paul.muhle-karbe@psy.ox.ac.uk), Nicholas E Myers[1,2], Mark G Stokes[1,2]; [1]University of Oxford, Department of Experimental Psychology, [2]Oxford Centre of Human Brain Activity

Recent evidence suggests that working memories (WM) are encoded in qualitatively different states depending on their momentary task-relevance. Items that are used for current behaviour are thought to in an active state that is encoded in content-specific spiking, which is primed to drive behaviour. By contrast, currently irrelevant items can be held in a latent state that is not reflected in activity, but remains accessible for later use. It remains unknown, however, how latent working memories are transformed into active decision circuits when behavioural priorities change. We used time-resolved decoding of WM items using electroencephalography (EEG) in a task that required cued priority switches between decision boundaries, permitting independent decoding of active and latent boundaries on trials when their priority status switched (requiring transfer from a latent to an active state) vs. when the priority status was repeated. WM switches created transient performance costs that recovered after a single trial. EEG revealed that this behavioural cost is driven by lingering over-representation of the latent item. On priority switch trials, both the newly active and the previously active item could be decoded. Intriguingly, active and latent items were represented in distinct neural patterns: training a decoder on the active item did not permit decoding of the latent one, and vice versa. Importantly, the magnitude of latent item decoding tracked participants' performance cost after switches. On priority repeat trials, only the active item could be recovered from EEG activity, with decoding of the latent item returning to chance. These findings suggest that priority shifts incur transient competition between items for active representation.

Acknowledgement: Research Foundation Flanders, Wellcome Trust, McDonnell Foundation

35.24, 6:00 pm **Is set size six really set size six? Relational coding in visual working memory.** Chaipat Chunharas[1,2](cchunharas@gmail.com), Timothy F Brady[1]; [1]Department of Psychology, University of California, San Diego, [2]King Chulalongkorn Memorial Hospital, Chulalongkorn University, Bangkok, TH

When people are asked to remember many items in visual working memory, performance suffers. Many prominent models claim this is because some items are unrepresented, or represented extremely poorly. For example, when asked to report all 6 items from a set size 6 display, participants appear to have little or no information about the last few items they report (Adam et al. 2017). We propose that this strictly item-based approach to performance is incomplete. Rather than thinking about each item independently, we show that when there are many things to remember, people encode items relative to each other and take advantage of the structure of the display. In particular, we reanalyzed data from previous whole-report visual working memory paradigms (N=22), but rather than looking independently at performance for each item, looked at the relationship between the items people reported. In such paradigms, people have to remember 2-6 items and report all of the items in any preferred order. We find that when the set size is high (>= 4 items), people tend to report the colors that are close to the mean color of the display first, and these first responses are systematically attracted toward each other (e.g., reported closer together in color space than the items truly had been). The number of items that are grouped depends on the entropy of the display (high entropy->more grouping). Examining the last items people report on a given display also reveals they are not random responses. Instead, the later responses (including the last) are systematically repelled from the earlier ones. Thus, rather than encoding items independently, memoranda are compressed by combining and separating items in relation to each other. Overall, we show that no memorandum is an island and each response reflects how that item fits into the whole picture.

Acknowledgement: NSF CAREER BCS-1653457 to TFB, Thai Red Cross Society to CC

35.25, 6:15 pm **Serial dependence requires retrieval of relevant information from the previous trial** Giyeul Bae[1](freebird71@gmail.com), Steven J. Luck[1]; [1]University of California, Davis

Studies of serial dependence have shown that the perception and memory of the current-trial stimulus are systematically biased by stimuli seen on previous trials. Is this effect driven by the perception of the previous stimuli or by the use of these stimuli to achieve given task goals? To answer this question, we designed a two-feature discrimination task in which random dot arrays moved in one of several directions and were drawn in one of several colors. At the end of the stimulus period, a feature cue was presented to indicate which of the two features (direction of motion or color of the dots) should be reported. Observers either reported the perceived motion direction by adjusting a response line or reported the color of the moving dots by selecting a color from two alternative color patches. The two colors could be from the same category (e.g., two pinks) so that mere categorical color memory was not sufficient to perform the task. Crucially, the feature cue was completely unpredictable (p = 0.5), so observers had to perceive and remember both the color and the direction of motion. We assessed serial dependence for motion perception as a function of whether the observer had been cued to report motion direction or color on the previous trial. We found a typical serial dependence effect in motion perception only when observers reported motion direction in the previous trial. To ensure that this effect was not driven by the difficulty of the color task, we replicated the main results in Experiment 2, in which dots were always either pink or green. Together, these findings suggest that the serial dependence effect is not merely driven by perceiving a given feature but also requires the report/retrieval of the relevant feature on the previous trial.

Acknowledgement: This work was supported by grant R01MH076226 to SJL.

35.26, 6:30 pm **Consolidation: How information limits visual working memory capacity** Qian Yu[1](qianyu@jhu.edu), Justin Halberda[1]; [1]Johns Hopkins University

Previous research suggests that visual information exerts an impact on working memory and visual search.For example, as visual information per item increases, the number of items that can be remember decreases (Alvarez & Cavanagh, 2004; but see Awh, Barton & Vogel, 2007). Some have suggested that this is because both visual search and VWM are information-limited.But what if this is not true?What if a third factor mediated the role of information in these tasks?Here, we investigated whether consolidation time for single objects of different categories correlated with the effects of information on VWM and visual search.First, we replicated the VWM and visual search effects for a famous set of stimuli (Alvarez and Cavanagh, 2004) that included several different categories (e.g., letters, line drawings, Chinese Character, 3-D cubes, etc).Next, we assessed each person's rate to consolidate single items from each category. We reasoned that, if consolidation time is the mediating mechanism by which information load influences both VWM capacity and visual search, then we should see systematic differences in the rate for consolidation across the various categories and these differences should correlate with measures of VWM capacity and visual search rate. To test the consolidation rate of visual information, participants saw a single target item randomly selected from one of the categories.After a variable delay, a mask appeared to disrupt consolidation, then the participant was asked to identify the item they saw from an array of options. Consistent with our predictions, consolidation rates correlated with both VWM capacity and visual search rate for these same items. This suggests that the consolidation rate could be a mechanism through which visual information influences working memory performance.

35.27, 6:45 pm **Visual ZIP files: Mental rotation overcomes capacity limits by compressing objects** Hauke S Meyerhoff[1](h.meyerhoff@iwm-kmrc.de), Nicole Jardine[2], Mike Stieff[3], Mary Hegarty[4], Steve Franconeri[2]; [1]Leibniz-Institut für Wissensmedien, Tübingen, Germany, [2]Department of Psychology, Northwestern University, Evanston, IL, USA, [3]Departments of Chemistry and Learning Sciences, University of Illinois at Chicago, [4]Psychological and Brain Sciences, University of California, Santa Barbara

Given a set of simple objects, lab-based studies show that our visual working memory capacity drops from 3-4 down to only 1-2 when the display rotates (Xu & Franconeri, 2015). But real-world STEM experts somehow overcome these limits: chemists rotate novel multi-object molecules. What are lab-based studies missing? The chemistry education literature suggests that these experts don't store all information in its raw form, but instead compress sets of objects across repeated features. We tested how leveraging repeated features could improve mental rotation performance in a visual working memory task. METHOD: Participants briefly saw a layout of four colored shapes, either all distinct or with repetitions of color, shape, or paired color+shape (e.g., two green squares among a blue triangle and a yellow diamond), with a concurrent verbal suppression task. A rotating 'windmill' cued that the layout was to be rotated 90° clockwise or counterclockwise, and participants reported potential swaps (layout change/no change). RESULTS: In experiments 1A-1C, repetition improved performance for color, shape, and paired color+shape. But critically, Experiments 2A-2B found that the benefits of multiple repetitions fell apart when color and shape repetitions were split across different objects (e.g., green square, green triangle, red triangle, along with a yellow diamond). The combined repetition needs to fall on the same objects to substantially improve mental rotation performance. CONCLUSION: Visual compression is an effective encoding strategy (Morey et al., 2015) that may spatially tag identical objects that repeat (see also Brady & Tenenbaum, 2013), creating the visual equivalent of a ZIP file format. But this format cannot leverage repetitions of features separated across multiple objects. Improving student performance in STEM education requires that we understand these limits of visual compression, and individual differences in who can and cannot leverage it.

35.28, 7:00 pm **Evolution and Development of Signature Limits in Mental Manipulation** Irene M Pepperberg[1](impepper@media.mit.edu), Melissa Libertus[2], Lisa Feigenson[3], Justin Halberda[3], Hrag Pailian[1]; [1]Department of Psychology, Harvard University, [2]Department of Psychology, Pittsburgh University, [3]Department of Psychology, Johns Hopkins University

The abilities to store and manipulate representations in visual working memory (VWM) allow us to build mental models of the world and reason beyond our perceptual experiences. However, human adults can store only up to 4 items simultaneously (Luck & Vogel, 1997) and manipulate up to 2 items with little-to-no cost (Pailian & Halberda, 2015). Here, we probe the developmental and evolutionary origins of storage and manipulation limits, by testing adults, 6-to-8-year-old-children, and an African Grey Parrot on a live version of the "Shell-Game". In this task, participants were presented with 2-4 colors that were subsequently occluded by opaque cups. All cups either remained stationary (storage) or swapped positions up to 4 times (manipulation). Memory for a cued item was tested. Consistent with previous findings, adults were able to store up 4 items perfectly and manipulate 2 items with relatively no cost - though manipulating larger set sizes led to errors that increased as a function of the number of swaps performed. In contrast, developmental differences were observed such that children experienced greater difficulty in storing more than 2 items, as well as increased errors across swaps for all set sizes. However, no significant correlation existed between the magnitude of manipulation costs and children's age. Taken together, these results may suggest that storage and manipulation develop independently across the lifespan. Lastly, the parrot demonstrated above-chance level performance across all conditions, providing evidence that storage and mental manipulation are not uniquely human capacities. Namely, the parrot not only outperformed children's performance, it demonstrated storage and manipulation abilities that were equal (if not better) than adults' for all conditions. These results suggest that storage and manipulation may be limited by an evolutionary determined upper-bound, and that investigating mechanisms/substrates shared across these species may prove instrumental towards identifying the loci of VWM constraints.

Acknowledgement: The Alex Foundation

SUNDAY AFTERNOON POSTERS

Faces: Experience, expertise

Sunday, May 19, 2:45 - 6:45 pm, Banyan Breezeway

36.301 **Individual Differences in Holistic Processing of Mooney Faces** Teresa Canas Bajo[1](teresa_canasbajo@berkeley.edu), Mauro Manassi[1], David Whitney[1]; [1]UC Berkeley

Humans perceive faces holistically rather than as a set of separate features (Sergent, 1984). Previous work demonstrates that some individuals are better at this holistic type of processing than others (Wang et al., 2012). Here, we show that there are unique individual differences in holistic processing of specific faces. To examine individual differences in holistic processing, we used Mooney faces (stimuli extracted from Schwiedrzik, Melloni, & Schurger, 2018), which are readily perceived as faces despite lacking low-level segmentable face-specific features. We used the magnitude of the face inversion effect as a measure of the degree to which individual Mooney faces were processed holistically. In each experimental trial, participants viewed two images for two seconds: an intact Mooney face and a scrambled version of the same face. The intact face was presented upright or inverted randomly on each trial. After the display disappeared, participants were asked to determine which of the two images was a face (regardless of the orientation). We calculated a holistic processing index for each Mooney face in our stimulus set by comparing the difference in accuracy between upright-face trials and inverted-face trials. The images varied considerably in this inversion effect, but there was little between-subject agreement; specific faces that were processed holistically by one observer were not by other observers. Individual subject data, on the other hand, was highly reliable and consistent. Our findings reveal that there are idiosyncratic individual differences in the perception of Mooney faces.

36.302 **Normative data for two ecologically valid tests of face identity matching** Lisa Stacchi[1](lisa.stacchi@unifr.ch), Eva Huguenin-Elie[1], Roberto Caldara[1], Meike Ramon[1]; [1]Department of Psychology, University of Fribourg

Unfamiliar face identity processing is highly variable across individuals. For many years, studies have aimed to determine which factors are responsible for successfully accomplishing this task. Experiments have been carried out under highly controlled experimental settings. While on one hand these tests can help isolating different variables influencing face processing, on the other hand they confront observers with unrealistic situations and stimuli. Therefore, the degree to which the observed in-lab performance could provide information on real-life efficiency remains unclear. Here, we present normative data of a large group of individuals for two ecologically valid, but underused, tests of unfamiliar face matching. The Facial Identity Card Sorting Test (FICST; n=218) (Jenkins et al., 2011) assesses the ability to process facial identity despite superficial image variations, while the Yearbook Test (YBT; n=252) (Bruck et al., 1991) investigates the impact of aging-related changes in facial appearance. Additionally, a subsample of these observers (n=181) also took part in three more commonly used tests: one assessing face recognition (Cambridge Face Memory Test long form, CFMT+) and two testing face perception (Expertise in Facial Comparison Test, EFCT; Person Identification Challenge Test, PICT). Focusing on the top performers for each test, we found that, compared to the EFCT and PICT, YBT and FICST provide a better prediction of the top performers at the CFMT+ and vice-versa. Our observations indicate that assessment of individuals' unfamiliar face identity processing abilities should be carried out using multiple tests addressing different aspects. Moreover, if we wish to use in-lab performance to predict individuals' real-life face processing proficiency, standard and controlled tests should be paired with more ecological assessments resembling real-life challenges.

36.303 **The Cost of Matching Depth-Rotated Faces: A Simple Function of Image Similarity** Irving Biederman[1,2](bieder@usc.edu), Tianyi Zhu[2], Miles Nelken[1], Emily X Meschke[1], Catrina M Hacker[1]; [1]Neuroscience, University of Southern California, [2]Psychology, University of Southern California

When unfamiliar faces are to be recognized or matched at different orientations in depth, sizeable costs in the speed and accuracy of performance have been documented attributable to the disparity in orientations. There have been no rigorous, quantitative assessments of these costs. Here we evaluated the effects of orientation disparity in a minimal match-to-sample paradigm of a triangular display of three faces, with one of the two test faces physically identical to the sample (Fig.1, left). The other test face was a foil. Both test faces had the same orientation in depth at an angle that differed by 0° to 20° from the sample (Fig. 1, right). The dissimilarities of the faces were scaled by the Gabor jet model (Lades et al., 1993), a model based on V1 simple cell tuning that predicts psychophysical similarity almost perfectly when the faces are at the same orientation (Yue et al., 2012). The greater the dissimilarity of the rotated matching face to the sample and the greater the similarity of the foil and matching test faces the longer the reaction times (RTs). The second of these two factors—the similarity of matching to foil test faces—had three times the effect per unit of Gabor similarity than the dissimilarity of the matching test face to the sample. These two costs were additive and were sufficient to account for all the costs of orientation disparity (Fig. 2). The design also allowed a test of whether individuals who incurred greater costs on RTs of increasing similarity of foil-to-matching faces at 0° would also suffer greater costs when the similarity of the matching to sample face was reduced because of rotation disparity. They did not, suggesting that the capacity for discrimination of highly similar faces is independent of the capacity for achieving invariance over viewpoint.

Acknowledgement: HWD Research Fund

36.304 **High test-retest reliability of a neural index of rapid automatic discrimination of unfamiliar individual faces** Milena Dzhelyova[1,2](dzhelyova@yahoo.com), Giulia Dormal[1], Corentin Jacques[1], Caroline Michel[1], Christine Schiltz[2], Bruno Rossion[1,3,4]; [1]Psychological Sciences Research Institute and Institute of Neuroscience, Université catholique de Louvain (UCLouvain), 1348 Louvain-la-Neuve, Belgium, [2]Cognitive Science and Assessment Institute (COSA), University of Luxembourg, Luxembourg, [3]Université de Lorraine, CNRS, CRAN, F-54000 Nancy, France, [4] Université de Lorraine, CHRU-Nancy, Service de Neurologie, F-54000 Nancy, France

A key aspect of human individual face recognition is the ability to discriminate unfamiliar individual faces. Since many general processes contribute to explicit behavioural performance in individual face discrimination tasks, measuring unfamiliar individual face discrimination ability in humans is challenging. In recent years, a fast periodic visual stimulation approach has provided objective (frequency-locked) implicit electrophysiological indices of individual face discrimination that are highly sensitive at the individual level. Here we evaluate the test-retest reliability of this response across scalp electroencephalographic (EEG) recording sessions separated by more than two months, in the same 30 individuals. We found no test-retest difference overall across sessions in terms of amplitude and spatial distribution of the EEG individual face discrimination response. Moreover, with only 4 minutes of recordings, the variable individual face discrimination response across individuals was highly stable (i.e., reliable) in terms of amplitude, spatial distribution and shape. This stable EEG response was also significantly correlated with speed, but not accuracy rate, of the Benton face recognition task (BFRT-c, Rossion, & Michel, 2018). Overall, these observations strengthen the diagnostic value of FPVS-EEG as an objective and rapid flag for specific difficulties at individual face recognition in the human population. Rossion, B., & Michel, C. (2017). Normative data for accuracy and response times at the computerized Benton Facial Recognition Test (BFRT-c). Behavior Research Methods

Acknowledgement: FNRS, CNRS

36.305 **The two-faces of recognition ability: better face recognizers extract different physical content from left and right sides of face stimuli** Simon Faghel-Soubeyrand[1,2,5](simonsoubeyrand@gmail.com), Arjen Alink[3], Eva Bamps[1,2,4], Rose-Marie Gervais[5], Frédéric Gosselin[5], Ian Charest[1,2]; [1]School of Psychology, University of Birmingham, UK, [2]Centre for Human Brain Health, University of Birmingham, UK, [3]UMC Hamburg-Eppendorf, University of Hamburg, Germany, [4]Faculty of Psychology, KU Leuven, Belgium, [5]Département de Psychologie, Université de Montréal, Canada

Why are some individuals better at recognizing faces than others? Research has only recently begun to unveil possible perceptual mechanisms responsible for such individual differences. These include tuning to horizontal

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facial information, "holistic" processing, and reliance on the eye region (e.g. DeGutis et al., 2013; Duncan et al., 2017; Faghel-Soubeyrand et al., 2018). However, neither these visual determinants have been investigated together, nor have they been related to specific neural processes. Here, we address these issues by using diagnostic feature mapping (DFM; Alink & Charest 2018), a novel classification image technique that efficiently reveals the location, spatial frequency, and orientation information used to resolve perceptual tasks. A large sample of neurotypicals (N=120) were asked to discriminate the gender and expression (happy vs. fear) of randomly sampled face stimuli during two separate sessions (2400 trials per subject per task, for a total of 576,000 trials). We discovered that face recognition ability (assessed using the CFMT+ and CFPT; Duchaine & Nakayama, 2006) correlates with the use of specific spatial frequencies (4-6; 12-18 cpi)—but not with orientation information—in the right-eye area from the observer's viewpoint for the face-gender task (cf. Faghel-Soubeyrand et al. 2018) while it correlates with the use of specific orientations (150-180 deg)—but not with spatial frequency information—in the left-eye area for the face-expression task. This indicates that skilled face recognisers, depending on the task at hand, extract different physical content from either the left or right-eye. High-density EEG revealed that this lateralized and qualitatively different use of information occurs as early as 187 ms after face onset. We will discuss these findings in the context of brain lateralization effects such as the coarse/fine information processing bias (e.g. Quek et al., 2018) and the right-hemisphere dominance for visuo-spatial attention (ThiebautDeSchotten et al., 2011).

Acknowledgement: NSERC, FRQNT, RRSV, MITACS

36.306 **The Good, the Bad, and the Average: Characterizing the Relationship Between Face and Object Processing Across the Face Recognition Spectrum** Christian Gerlach[1](cgerlach@health.sdu.dk), Rebecca Hendel[2], Randi Starrfelt[2]; [1]Department of Psychology, University of Southern Denmark, [2]Department of Psychology, University of Copenhagen, Denmark

Face recognition skills vary considerably both in the normal population and in various clinical groups, and understanding the cognitive mechanisms contributing to this variability is important. We investigated whether: (i) a group of good face recognizers (high performers; HPs) were better than control subjects in face and object recognition, (ii) if any dissociations between face, object, and word processing could be demonstrated in HPs, and (iii) compared the performance of the HPs to a group of poor face recognizers (developmental prosopagnosics; DPs). We found that HPs were significantly better than matched control subjects on tests of both face and object recognition including a reading task, but they did not show a disproportionally larger inversion effects on typical tests of face processing (the CFMT and the CFPT). There was also no evidence of dissociations between face and object processing in the HPs when compared to controls, indicating superior performance across visual domains. In the DP group, however, we found significant dissociations between face and object recognition performance on a group level, indicating that face processing is disproportionally affected. On this basis, we propose that superior face processing in HPs rely on more general cognitive or perceptual processes shared with object processing. Hence, while face processing in DPs seems qualitatively different from the normal population, there is no such difference between average and high performing face recognizers. What underlies superior face processing in HPs might be conceived as a general factor in the visual domain, a VG-factor, akin to the G factor in intelligence.

Acknowledgement: Independent Research Fund Denmark (DFF – 4001-00115)

36.307 **Super-Recognizers in Criminal Investigation – Hype or Hope?** Meike Ramon[1](meike.ramon@gmail.com); [1]Department of Psychology, University of Fribourg

Over the past years, there has been an increasing interest in so-called "Super-Recognizers" (SRs) – individuals with above average face processing capacities. Originating from the field of neuropsychology, our knowledge of this infant field is extremely limited, with an abundance of outstanding questions. Despite these considerable knowledge gaps, there is an increasing demand for application of SRs in law enforcement. Private companies offering SR services are emerging, as are associations providing certificates to paying members seeking new professional opportunities. The main problem is that the actual benefit of real-life SR deployment remains unestablished. Bridging the lab-world gap, this study involved collaborations with international law enforcement agencies (State Polices in Germany and Switzerland). Individuals with superior face cognition were tested to assess their ability to correctly identify perpetrators based on CCTV footage from criminal investigations conducted by the Cantonal Police of Fribourg (Switzerland). Importantly, different observer groups were tested, including SRs reported previously in the literature, or identified through large-scale online testing, as well as individuals identified through on-the-job performance, and forensic facial examiners. The results demonstrate important limitations of procedures commonly used for SR identification, which did not reliably predict superior perpetrator identification. The implications of these findings in terms of real-life SR deployment, and progress in the domain of SR research are clear. On the one hand, careful and diligent interdisciplinary exploration should precede commercial exploitation. On the other hand, they highlight the need for optimized research design enabling systematic assessment of various aspects of ecologically meaningful face processing abilities.

Acknowledgement: Swiss National Science Foundation & Fonds d'action facultaire (University of Fribourg)

36.308 **Not just in FFA: becoming an expert also drives the activity, and changes the pattern, of early visual cortex** Chien-Shu Chu[1](xov830415@gmail.com), Kuo Liu[1], Chun-Chia Kung[1,2]; [1]Departments of Psychology, National Cheng Kung University, Tainan, [2]Mind Research and Imaging (MRI) center, National Cheng Kung University, Tainan

In this fMRI study, we aim to investigate Greeble training effect, especially in early visual areas, in participants who were trained to recognize Greebles with either Gauthier97 (or Gauthier and Tarr, 1997) or Gauthier98 (or Gauthier et al., 1998) paradigm. A retinotopic mapping procedure was used to delineate early visual areas (V1, V2, V3, V4, and/or V3a). Then, these ROI masks were applied to the passive viewing task of faces, objects, and Greebles, both before and after training and in both Gauthier97 and Gauthier98, to evaluate respective BOLD changes in V1 to V4 ROIs associated with Greeble training. We compare brain activity by both univariate and multivariate analysis, which show quite different pictures: while univariate analysis (both ROI time course comparisons and GLM contrasts) showed no significant BOLD changes across early visual area (and no difference across both Gauthier97 and 98); multivariate analyses, including both ROI-MVPA and whole-brain searchlight, present significant classification (Greebles_before vs. _after) accuracies across V1-V4 ROIs (via ROI-MVPA), and wide-spread training effects across many brain regions (including parietal and prefrontal regions, via MVP searchlight), once again across both training paradigms. To further verify that whether early visual area would be recruited by automatic attention, the bird expertise fMRI study in Yang et al. was also analyzed with retinotopic procedure, and was found that in passive viewing task (but not in 1-back identity), subject's behavioral expertise also predict the involvement of early visual cortex.Taken together, these results suggest that while FFAs have been 'sharpened' by Greeble training; multivariate analyses reveal widespread changes in both visual and associative areas. In addition, early visual cortex could also be predicated by expertise-driven attention, consistent with Harel et al. (2010).

36.309 **Beyond activity changes: appropriate expertise training not just drives higher activities, but also faster BOLD onset and better classifications for Greebles**Chun-Chia Kung[1,5](chunkung@mail.ncku.edu.tw), Chien-Shu Chu[1], Yi Lin[1], Hanshin Jo[2], Kuo Liu[1]; [1]Departments of Psychology, National Cheng Kung University, Tainan, Taiwan, [2]Institute of Medical Informatics, National Cheng Kung University, Tainan, Taiwan, [3]Mind Research and Imaging (MRI) center, National Cheng Kung University, Tainan, Taiwan

Previous discussions about the role of FFA in face and/or expertise processing focused on whether Greebles are face-like (e.g., Brants et al., 2011 JOCN). But in our previous work (Liu et al., 2017 OHBM), we have identified that it was more likely due to the appropriate training, than on the stimulus category per se (e.g., face-likeness of Greebles), that caused the FFA activity increases. In this study, we report a companion jittered event-related fMRI experiment where participants did the same verification task that they were kept trained on. Our hypothesis is that, as the correct trial RTs for Greeble verifications became faster, their FFA BOLD responses should also rise earlier, and such earlier rise also predicts earlier and higher classification accuracy for Greebles. With previous reported training protocols and fMRI results (Liu et al., 2017), where 16 participants underwent two different Greeble training regimes (n=8 for each of Gauthier97 and Gauthier98, respectively) and scanned during and after training, we first plotted the average FFA time courses and noted that it did rise earlier in Gauthier97, but not in Gauthier98, after training (and later confirmed with estimates of BOLD rising time via BOLD Latency Mapping, or BLA), suggesting the earlier rise even before the appearance of Greebles. In addition, MVPA classifications, either ROI-based or whole-brain searchlight mapping in comparing during-

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vs. after-training Greebles, also reveal that these early BOLD rises help classify Greebles significantly, in response to the trained task requirements: earlier rise (Gauthier97) recruited temporal and prefrontal areas in the earlier time frame (3-8s after trial onset), whereas Gauthier98 showed classification successes much later (5-15s) and persisted comparatively in ventral temporal areas. Taken together, these results exemplify the effect of expertise training beyond single ROI (e.g., FFA) and single dimension (e.g., magnitude, time, and classification accuracy).

Acknowledgement: MOST 107-2420-H-006-007

36.310 **A direct support for the perceptual expertise hypothesis of FFA: interactive face- and bird-selectivity in bird experts.** Nian Ting Yang[1](a27060818@gmail.com), Chun Chia Kung[1], Chien Shu Chu[1]; [1]Department of Psychology, National Cheng Kung University, Tainan, Taiwan

One of the unsolved debates in the prolonged exchanges between face specificity and perceptual expertise hypothesis of FFA (e.g., Gauthier et al., 2007; 2017; Kanwisher et al., 2017) has been on whether the BOLD activities in FFA for objects of expertise correlate with their behavioral expertise. While early studies found positive evidence (Gauthier et al., 2000; Xu, 2015), later replications by other labs did not (Grill-Spector et al., 2004; Rhodes et al., 2004; Moore et al., 2006). Until today, the reason behind these disparate expertise-FFA correlation results remain unsolved. In this study, we recruit bird experts, and look from the opposite side of the expertise-FFA correlation: whether there is an adaptation-like negative correlation between face selectivity (faces vs. objects) and bird expertise in FFA. 16 Taiwanese birders and 17 American birds were both evaluated with behavioral expertise index, and later scanned with various fMRI tasks, including FFA localizers (Taiwan only), passive viewing and 1-back identity tasks of 4 conditions : Asian faces, familiar birds, unfamiliar birds, and objects. While the localizer-defined rFFA showed insignificant FFA-expertise correlations (r14=.3, p=.3), consistent with much of the majority of previously mentioned literature, the face selectivity (faces vs. objects) shows significant negative correlation (r14 = -606, p=.022). In other words, the default face-responsive fusiform area, when sandwiched between blocks of objects of expertise, could become face un-responsive! Complementary whole-brain correlations with “birds vs. objects” and “faces vs. objects” contrasts (N=33) also showed adjacent but distinctive rFG regions for both positive and negative expertise-correlated regions, not only rapport to the ROI analysis results, but also explains that when focusing on the suboptimal bird stimuli in the default face-selective FFA, the brain-behavior correlation might be sub-optimal. Together, these results once again support the Flexible mid-Fusiform Area (FFA, Tarr and Gauthier, 2000) under various tasks.

36.311 **The dynamics of face learning: Insights from similarity ratings.**Kristen A Baker[1](kb09gi@brocku.ca), Catherine J Mondloch[1]; [1]Psychology, Brock University.

Recognizing that multiple images belong to the same identity is challenging for unfamiliar faces. We examined the dynamic process of face learning by showing participants multiple images of unfamiliar faces and measuring both likeness ratings and the ability to recognize new images. In Experiment 1, participants (N = 110) learned an identity by rating the “likeness” of 3, 6, or 10 images; recognition of new images of the identity was tested and compared to a no-learning control group. Participants in the rating conditions recognized more new images than controls (p< 0.001), providing evidence of learning. Across four identities and despite the order of images being randomized, likeness ratings decreased linearly in the 3-image condition, p< .001. Higher-order trends were significant in the 6- and 10-image conditions, ps< .01, with dips observed during familiarization. This pattern suggests that building a representation of a new identity involves refining expectations about the range of each person’s variability in appearance (Burton et al., 2016). In Experiment 2 (N = 46) we examined whether expectations extend to the context in which faces are presented. Participants rated the likeness of four repeated images of two identities (presented on consistent background scenes) and four novel images presented on the same background scene vs. a novel, unexpected background. We replicated the likeness-rating effects from Experiment 1 for the first four images; a quadratic trend showed that ratings decreased at the 3rdimage, p< 0.001. Critically, likeness ratings for the four novel images were lower than likeness ratings for the four repeated images only when presented on an unexpected background, p = 0.03. We interpret our findings in light of the predictive coding model (Trapp et al., 2018), which predicts that learning occurs when predictions (e.g., how someone looks, the context in which someone is seen) are violated.

Acknowledgement: NSERC.

36.312 **Inducing the use of information for face identification** Jessica Tardif[1](jessica.tardif.1@umontreal.ca), Caroline Blais[2], Frédéric Gosselin[1]; [1]Département de Psychologie, Université de Montréal, [2]Département de Psychoéducation et Psychologie, Université du Québec en Outaouais

Faghel-Soubeyrand et al. (in press) trained observers to use the facial information most correlated with skilled face-sex discrimination — the eye on the right of the face stimulus from the observer’s viewpoint — and showed that these observers’ performance increased more than that of control participants. Here, using a similar implicit induction procedure, we attempted to train observers to use the information associated with skilled — mostly the two eyes— or unskilled face identification (Tardif et al., 2018). First, participants completed 500 Bubbles trials where they were asked to identify a celebrity, to reveal their use of information pre-induction. Second, participants carried out 500 more trials of the Bubbles task, during which, unbeknownst to them, the base face stimuli were tampered with. In the best-information induction subject group, the information related to skilled face identification was made available (N=8; mean age=21.9; 2 women) and, in the worse-information induction subject group, the information related to unskilled face identification was made available (N=7; mean age=21.9; 3 women). Third, and finally, observers completed 500 more Bubbles trials to reveal their use of information post-induction. For each subject group, we computed classification images, showing the visual information used before and after the induction trials. As expected, results show that participants from the worse-information group used the mouth before and after the induction, whereas participants from the best-information group used mainly the mouth before induction and the two eyes after induction (Cluster Test: p< .05; sigma=26; tC=2.70; Sr=21901; Chauvin et al., 2005). We believe this induction procedure shows promise as a mean for individuals specifically impaired in face recognition (e.g. developmental prosopagnosics) and professionals relying on strong face processing (e.g. police officers) to improve their abilities.

Acknowledgement: NSERC

36.313 **The Development of Emotion Perception: Evidence from an Unconstrained Sorting Task** Catherine J Mondloch[1](cmondloch@brocku.ca), Claire M Matthews[1], Shelby Howlett[1]; [1]Psychology, Brock University

In most studies investigating the development of emotion perception, the number of categories is constrained (e.g., by verbal labels, by the predetermined number of categories into which expressions can be sorted). Here we adapted a task developed by Yan et al. (2016) in which participants freely sort photographs based on expression. We tested children’s ability to recognize (i.e., to put multiple images of the same expression into the same pile) and discriminate (i.e., to put images of different expressions into different piles) facial displays of emotion. We measured the number of piles made (correct = 4), number of confusion errors (calculated by subtracting 1 from the number of emotions in each pile and summing across piles, correct = 0), and the pattern of errors (in a confusion matrix). Children aged 5 to 11 years (n=25) sorted one of two sets of 20 photos, each comprised of 5 images of 4 expressions: sad, anger, fear, and disgust. They were free to make as many/few piles as they wanted. Both the mean number of piles (4.56) and mean number of confusion errors (2.48) were comparable to those observed by Yan et al. (2016) when adults sorted own-race faces, with no age-related change in performance, ps>.20. The number of different piles into which each expression was placed (reflecting over-discrimination) varied across emotion, p< .001, with fear faces being placed into more piles (M = 2.28) than the other expressions (Ms < 1.6). A confusion matrix revealed that most errors involved confusion of sad and fear (20% of confusion errors) and disgust with anger (36% of confusion errors); sad was rarely confused with anger or disgust (< 6% of errors) and fear was rarely confused with anger (8% of errors). We discuss the implications for theories of development of emotion perception.

Acknowledgement: Social Sciences and Humanities Research Council of Canada

36.314 **The Importance of Within-Person Variability in Appearance in Adults’ and Children’s Face Learning** Claire M Matthews[1](cm10ph@brocku.ca), Kay L Ritchie[2], Sarah Laurence[3], Catherine J Mondloch[1]; [1]Psychology, Brock University, [2]Psychology, University of Lincoln, [3]Psychology, Keele University

By age 6, children recognize ambient images of familiar faces without error, but accuracy for unfamiliar faces increases between 5 and 12 years of age (Laurence & Mondloch, 2016). When memory demands are high (i.e., a

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face is learned via video) children require exposure to high within-person variability in appearance (HV) to learn a new face; they learn if the video is captured across 3 days, but not a single day (LV). Adults learn in both the HV and LV conditions. In a purely perceptual task, children show adult-like learning from just 6 images captured on different days (Matthews et al., 2018). We examined whether adults and children show evidence of learning after viewing 6 images captured on the same day in a perceptual matching task. Children and adults (n=18/group) read a story about three characters (targets) embarking on adventures. Along the way, they collected either 6 LV images (captured on one day), 6 HV images (captured on different days) or a single image of the target. At test, they were asked to identify novel target images presented amongst distractors, while collected images remained visible. Young children (4-5 years) showed no evidence of learning. Older children (6-12 years) and adults recognized more novel target images in the HV than LV or single image condition (ps < .037); nearly all participants showed evidence of learning. There was no evidence of learning in the LV condition. Misidentification errors were rare. Viewing 6 images of an identity across a single encounter is insufficient for learning. Viewers require exposure either to variability in appearance across several encounters to learn a new face or to more photos (at least 10, Ritchie & Burton, 2016; Baker et al., 2017) if taken from the same day. Our results have implications for models of development and applied settings.

Acknowledgement: NSERC

36.315 **Learning newly encountered faces from variable images in adults and children** Sarah Laurence[1](s.k.laurence@keele.ac.uk), Nicola Ralph[1], Eloise De Carvalho[1], Valentina Proietti[2], Catherine J Mondloch[3]; [1]School of Psychology, Keele University, [2]Department of Psychology, Trinity Western University, [3]Department of Psychology, Brock University

Most people are prone to error when recognising unfamiliar faces across appearance changes, but are good at familiar face recognition. Recent work has examined how a face transitions from unfamiliar to familiar by studying exposure to within-person variability during face learning. Using this approach, several studies have shown that exposure to variability helps adults learn the faces of new people (e.g. Ritchie & Burton, 2017; Murphy et al., 2015) and the same is also true of children (Baker et al., 2017). The present work aimed to replicate and extend previous findings by examining individual differences in adults and factors that affect face learning in children. Adults (n = 60) completed a face recognition task in which they were asked to identify a target from naturally varying images depicting the target (n = 9) and a similar foil (n = 9). Before completing the face recognition task participants watched a 1-minute video or a sequence of static images that depicted the target on a single day (low variability) or across three days (showing high variability in appearance). Participants also completed a standardised test of face memory (CFMT). Participants performed better on the face recognition task after familiarisation (e.g. watching the video/viewing static images) compared to the control condition in which participants were not previously familiarised with the target. There was a positive correlation between the standardised memory test and performance on the face recognition task after participants were familiarised with the target, but not when there was no familiarisation phase. These findings suggest a dissociation between perceptual matching and memory. An ongoing study with children (aged 7 – 9 years; n = 30 to date) further explores perception vs. memory processes in children and suggests variability and duration of exposure help children learn the faces of new people.

Acknowledgement: British Academy/Leverhulme

36.316 **The Capacity for Face Perception is Independent of the Capacity for Face Memory** Catrina M Hacker[1](chacker@usc.edu), Irving Biederman[1,2]; [1]Program in Neuroscience, University of Southern California, [2]Department of Psychology, University of Southern California

Although it would not seem implausible for face recognition proficiency to reflect capacities for both perceptual differentiation of faces as well as memory for faces, rigorous, quantitative assessments of whether these capacities are correlated or independent across individuals have not been assessed. We addressed this issue in a delayed match-to-sample task. Participants viewed a computer-generated face (the sample) and after 0, 4 or 12 seconds viewed that identical image and a distractor of varying degrees of similarity, indicating which of the two matched the sample (Fig. 1a). To suppress rehearsal during the delay period, subjects judged which of a series of headshots were famous. There was a marked cost of delay on both accuracy and RTs (Fig. 2). To assess the capacity for perceptual differentiation independent of memory, subjects performed a separate match-to-sample task in which all three images (sample and test faces) were displayed simultaneously (Fig. 1b). The diagonal arrangement of the faces defeated a strategy of local feature/pixel search. Dissimilarity between the sample and the distractor image was quantified using the Gabor Jet model, a model that predicts psychophysical similarity of faces almost perfectly. For each subject a "cost of similarity" and a "cost of delay" were calculated as the slope of error rates over variation in Gabor dissimilarity for the former and the slope of error rates over the delay interval for the latter. These measures were highly reliable as evidenced by 1st vs 2nd half and odd-even correlations ranging from .73 to .92. Nonetheless, the correlation, over subjects, for the costs of perceptual differentiation of faces and face memory was essentially zero, indicating that capacity for the perceptual differentiation of faces and capacity for face memory are independent (Fig. 3).

Acknowledgement: Harold W. Dornsife Research Fund

Attention: Capture

Sunday, May 19, 2:45 - 6:45 pm, Banyan Breezeway

36.317 **Testing a Priming Account of the Contingent-Capture Effect** Ulrich Ansorge[1](ulrich.ansorge@univie.ac.at), Tobias Schoeberl[1], Florian Goller[1]; [1]Faculty of Psychology, University of Vienna, Austria

In the contingent-capture protocol, singleton cues having a target's searched-for feature capture attention, but cues not having the target's searched-for feature do not, a result labelled the contingent-capture effect. The contingent-capture effect is usually regarded as evidence for the observers' ability to establish search settings for certain non-spatial features in a top-down manner. However, in recent years, it has become increasingly clear that selection history is also a powerful mediator of attentional capture. In this vein, it was suggested that contingent-capture effects could emerge as a result of (inter-trial) priming: The idea is that features that have been encountered previously in the target are primed so that cues having these features automatically capture attention in a subsequent encounter. Here, we tested a strong version of the priming account of the contingent-capture effect. We wanted to know whether cues having target features would capture attention when the corresponding features were not part of the instructions (i.e., when the corresponding features were task-irrelevant). Results suggested that a strong version of the priming account of contingent capture is not supported. In five experiments, we found little evidence that the contingent-capture effect could be explained by (inter-trial) priming of task-irrelevant features alone. These results show that processes beyond priming through task-irrelevant features are critical for contingent-capture effects.

36.318 **Statistical learning can modulate contingent attentional capture** Matthew D Hilchey[1](matthew.hilchey@utoronto.ca), Blaire J Weidler[2], Jay Pratt[1]; [1]University of Toronto, [2]Towson University

Contingent capture cueing paradigms have long shown that salient visual stimuli – both abrupt onsets and color singleton cues – fail to reliably capture attention if they do not resemble the search target. Recent evidence indicates that abrupt-onset cues may capture attention in this paradigm in easy, but not difficult, search displays. Regardless of why this is, we hypothesized that if a cue reliably captures attention, people should be able to pick up on any regularities between it and the target location. That is, it should be possible to expose any latent capture generated by the cue through statistical learning. To test this, we ran two versions of the contingent capture paradigm with easy search displays. In both versions, the target was defined by its unique color in an array of distractors and was preceded by a cue, which matched the target feature in one condition (match cue). The mismatch cue in Experiment 1 was a color singleton and in Experiment 2 it was an abrupt onset. Unbeknownst to participants, in both experiments, the target predictably appeared at the same location as the mismatch cue (81.5%) whereas the match cue did not predict the target location (25%). Replicating typical findings, capture was robust and stable over time for match cues. Mismatch color cues consistently failed to produce capture throughout the experiment. Importantly, mismatch abrupt-onset cues did produce capture after the first block of trials (i.e., after statistical learning). The dissociation exposes latent capture by abrupt-onset cues in easy search. Together, the findings suggest that attentional control sets are not so powerful that all information is filtered out while also showing that statistical learning is not so powerful that it undermines all top-down control.

Acknowledgement: Natural Sciences and Engineering Research Council

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36.319 Context-specific long-term habituation of attentional capture

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Attentional capture triggered by an onset distractor is subject to habituation, an ancestral form of plasticity consisting in a response reduction to a repeated irrelevant stimulation. Even if habituation is usually considered a form of non-associative learning, evidence from animal studies has shown that habituation can be specific for the context in which it takes place. In the present work, we used a two-session paradigm to investigate the hypothesis of a context-specific long-term habituation of attentional capture in humans. The task of participants was to report as fast as possible the orientation (left vs. right) of a target line presented in a cued location. On half of trials, the occurrence of the target was preceded by a visual onset distractor appearing in a different location. The key feature of our paradigm was the context manipulation, with the context defined by the background images (naturalistic images in Experiment 1, and abstract-geometrical images in Experiment 2). In both experiments, one group of participants maintained the same background image across the training and the test sessions, whereas the other group was exposed to a background change in the test session. In both experiments, in the training phase we documented an initial attentional capture that decreased gradually with practice, as exposure to the irrelevant distractor continued across blocks. Crucially, in the test phase, a robust recovery of the attentional capture emerged for the group of participants that was exposed to a context change. Our results strongly support the idea that habituation of attentional capture is context-specific, and that a context change leads to a disruption of the model of the habituating distractor, a result suggesting that the distractor filtering mechanisms take into account also the context in which the irrelevant information is presented.

36.320 Surprise capture of the eyes can be (almost) as reliable and fast as top-down contingent capture

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An unexpected novel (surprise) feature is said to capture attention and gaze later than contingent capture by a target-defining feature, or singleton capture by a single salient item. Different tasks, however, may bias estimates of latency. For instance, contingent capture has been examined in a spatial cueing task, where the cueing display precedes the target display such that the cue is presented with little competition for attention from other stimuli. In contrast, surprise capture has mainly been examined in a visual search task, where the surprise feature competes with task-defined target candidates. In addition, latency estimates may concern the earliest or the average latency of an effect. One conclusion is that latencies have to be compared within the same experimental paradigm, using the same definition of latency. Here, we use a spatial cuing task to compare the effect of an unexpected novel feature to the effect of an unexpected target-defining feature on eye movements. In a series of experiments, we find that gaze is strongly and quickly captured by both cue variants, with little differences between them. This result is interpreted in a priority map framework, where attentional allocation depends on the competition between surprise-related and task-related signals. This account also implies that estimates of latency are specific to the task in which the measurements are made, because the task influences the amount of competition within a display. Further discussion concerns the role of different variables and criteria for latency estimates.

Acknowledgement: The work was supported by the Cluster of Excellence – Cognitive Interaction Technology 'CITEC' (EXC 277) at Bielefeld University, which is funded by the German Research Foundation (DFG), and by DFG grant HO 3248/2-1 to Gernot Horstmann.

36.321 The role of attention in the action effect

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Previous research had shown how simple action towards an object (prime) can help prioritize the allocation of attention onto the same object in the later unrelated visual search task (Weidler & Abrams, 2014). This so-called "action effect" yielded reaction time (RT) benefit only when the target was embedded in the acted-on object. To explore the role of attention in action effect, we examined the allocation of attention at the precise moment of action. In experiment 1, participants were instructed to respond (go) when the prime (colored circle) appeared, and not to respond (no-go) when "X" was on the prime. Next, participants searched for a tilted bar (target), which could appear on the same colored object (valid) or different colored object (invalid). Analysis results showed that the validity effect in experiment 1 was larger for trials with action, replicating the action effect. In experiment 2, participants were instructed not to respond when the prime appeared alone, and to respond when "O" was on the prime. Participants then engaged in the same visual search task as the first experiment. In contrast to experiment 1, analysis results did not show action effect in experiment 2, contributing to the overall significant three-way interaction between action, validity, and experiment. We interpreted that action alone did not benefit subsequent visual search. In experiment 2, action effect was not observed perhaps because attention was located on "O" and action was made toward "O" not the prime. Therefore, it seems that the attended object and the acted-on object match to produce action effect. Furthermore, we suggest that action effect is not just due to the presence of action, but a product of selective attention accompanied by action toward an object.

36.322 Influences of Prediction Errors in Establishment of Attentional Control Settings during Incidental Associative Learning

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Prediction errors, differences between predicted and actual stimuli, play a critical role in associative learning: when events momentarily cease to accurately predict their consequence, associability may increase or decrease. However, previous studies on whether incidental associative learning affects establishment of attentional control settings (e.g., contextual cueing) have a biased implicit assumption: when contexts no longer reliably predict characteristics of search targets, the contexts are no longer used for search. In an attentional capture paradigm, we explored how prediction errors influence attentional control settings during incidental associative learning. In Experiment 1, while searching for target letters, the shape of task-irrelevant placeholders (contexts) accurately predicted task-irrelevant color of targets in the learning and test sessions. Critically, two mismatch trials, where the context-color associations were violated (prediction errors), were inserted between the sessions. Results showed that the associations were used for search only after the mismatch trials, suggesting that prediction errors triggered the effect. However, it was unclear whether the effect was driven by the learning or test session because the same associations were used in the two sessions. Experiment 2, where the associations were reversed between the sessions, showed no effect after the mismatch trials, possibly because prediction errors allowed the associations both after and before the prediction errors to be active and cancel each other out. This possibility was confirmed in Experiment 3, where the color-context associations were present in the learning session but absent in the test session. An effect was observed only in the test session, suggesting that the effect came from learning during the learning session. This study suggests that prediction errors not only facilitate learning of associations after the prediction errors, but also restore associations learned before the prediction errors for establishment of attentional control settings.

36.323 Electrophysiological Evidence for Competition in Spatial Attention by Entirely Irrelevant Unisensory and Multisensory Distractors

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Salient stimuli are widely held to compete for spatial attention, either resulting in direct attentional selection or generating an 'attend-to-me' signal that must be actively suppressed (e.g. Sawaki & Luck, 2010). The N2pc and PD (Hickey, Lollo & McDonald, 2008) event-related components are thought to reflect these processes, respectively. However, previous research examining spatial capture of attention by salient stimuli has typically utilized stimuli that share a degree of relevance to the task participants are currently engaged in, such as distractors matching target features or appearing in a potential target location. Here, we test whether spatial attention can also be captured by distractor objects that are entirely irrelevant to the participants' task, by recording EEG while participants carried out a task designed to be sensitive to measuring the PD component. Participants completed a letter search task, while ignoring lateralized visual (e.g., a dog), auditory (e.g., a dog's bark), or simultaneous multisensory (e.g., dog image + sound) distractors. Results showed that visual and multisensory distractors elicited a PD component indicative of active lateralized distractor suppression. This ERP evidence of spatial attentional processing was observed in the absence of any behavioural distractor interference, suggesting effective early visual suppression. Interestingly, there was no evidence to suggest enhanced ability of multisensory distractors to compete for attentional selection, despite previous proposals of a 'special' saliency status for such items. Our results

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demonstrate that entirely irrelevant distractor stimuli are able to compete for spatial attention, while highlighting that such competition may not always be visible on behavioral measures alone.

36.324 Acute stress, either social or physical, alters the priority of salient feared distracters but not neutral salient distracters

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Stress increases involuntary attention capture by emotional stimuli. It is unclear, however, how the predictability of feared stimuli modulates this effect relative to a neutral stimulus. Participants completed a visual search task that could include feared (spider) or neutral (butterfly) salient distracters following a stress induction and appropriate control intervention. Stress was induced either using the cold pressor test (CPT, n=31) or the Trier Social Stress test (TSST, n=27) prior to the visual search task. Salient distracters captured attention under all conditions, such that reaction times (RT) were slower when a salient distracter was present than when absent. In blocks where the valence of the salient distracter was predictable, but not blocks where either valence was equally likely, there was a three-way interaction between stress state (stress vs. control), valence (feared vs. neutral), and the presence of a salient distracter on RT ($F(1,57)=6.74$, $p=.011$, $\eta 2=.11$), which did not change as a function of stress type (CPT vs. TSST, $p=.777$). Neutral distracters captured attention similarly under both the stress and control conditions (present vs. absent, $F(1,57) = 57.7$, $p < .001$, $\eta 2 = .50$; interaction with stress vs. control, $p =.577$). Capture by feared distracters was influenced by stress (present vs. absent X stress vs. control, $F(1,57) = 12.16$, $p < .001$, $\eta 2 = .18$), such that it was greater under stress than control. However, compared to neutral distracters, capture by a feared distracter was both greater under stress (spider vs. butterfly, $M\Delta = 25 > 18$ ms) and less ($M\Delta = 11 < 21$ ms) under control. These results indicate that stress, either social or physical, not only increases the priority of feared salient stimuli, but also abolishes some protective suppression from the effect of feared salient stimuli present under control conditions when its appearance is predictable.

Acknowledgement: U.S. Army Research Office Grant W911NK-09-0001

36.325 Prior reward learning biases selective attention among 9-12-month-old infants

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Traditional models of attention include exogenous attention mechanisms driven by perceptual saliency and endogenous selective attention mechanisms based on goal-relevant information. However, recent adult studies have identified a third mechanism known as value-driven attentional capture (VDAC). Consistently associating a stimulus with a reward generates an attention bias so that the rewarded stimulus is more likely to be attended, even when no longer task-relevant (Anderson, et al. 2011). Despite growing evidence for this VDAC mechanism in adulthood, its developmental trajectory is currently unknown. Twenty-six 9-12-month-old infants (anticipated N=75) completed a modified VDAC task (Figure 1). During learning, infants searched for a target color within a six-item array. Infants saw a high-value reward (a happy face; N=13) or a low-value reward (a neutral face; N=13) immediately after looking at the target color. At test, infants viewed novel shape arrays, with one dynamic target shape and five static distractor shapes. Critically, during half of the test trials (reward-present trials), one distractor appeared in the previously rewarded color. We examined VDAC by comparing eye movement response times during reward-absent trials vs. reward-present trials. Infants were faster to orient to the rewarded target by the end of the learning phase ($M_{Begin}=874.04$ ms, $SD=385.76$ ms, $M_{End}=615.68$ ms, $SD=256.84$ ms; $p= .011$), indicating learning of the target-reward association. At test, infants in the high reward condition showed slower orienting to the target during reward-present trials ($M_{Present}= 871.69$ ms, $SD= 237.44$ ms; $M_{Absent}= 768.57$ ms, $SD= 161.20$ ms). Infants in the low reward condition were instead faster to orient to the target during reward-present trials ($M_{Present}= 823.16$ ms, $SD= 314.24$ ms; $M_{Absent}= 850.78$ ms, $SD= 234.35$ ms). These preliminary data suggest that reward learning among 9-12-month-old infants may elicit an attention bias such that the rewarded stimulus subsequently captures attention and slows responses to a perceptually salient target.

Acknowledgement: Tulane University School of Science and Engineering

36.326 Frequency of exposure and target salience affect the extinction of value-driven attention capture

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Our work has demonstrated that previously rewarded features that remain task relevant continue to capture attention during an extinction phase. Here, we investigated the conditions under which such value-driven capture is extinguished. In three experiments (E), participants learned to associate a target color with reward, and another with no reward in a visual search paradigm. One week later, during the extinction phase, this association was no longer reinforced. In E1, the colors that previously defined targets were presented as distractors, as is typical of paradigms in this literature, however we failed to observe an effect of former reward-associations on RT, suggesting that reward did not reliably capture attention when task-irrelevant. E2 was identical to E1, but included an absent condition where neither formerly rewarded or non-rewarded colors were present. In E2 a value-driven capture effect was not observed. However, trials containing either a previously rewarded or non-rewarded distractor that had previously been selected were significantly slower compared to trials where no previously selected stimulus was present, which persisted throughout extinction. These findings demonstrate that the role of selection history (previous experience selecting a feature) appears to play a critical role in shaping attention, unique from that of reward history. E3 was also identical to E1 but targets were defined as salient shape singletons during extinction, another common feature in this literature. In contrast to E1 and E2, value-driven attention capture by formerly reward associated colors was extinguished. The rate of extinction in E3 was rapid, which could be the result of competition for attentional priority between the salient singleton and the distractor. These findings demonstrate that the extinction of value-driven capture depends on various factors that affect priority for attention, especially those features that bias attention away from reward-associated features.

Acknowledgement: Institute for Collaborative Biotechnologies through grant W911NF-09-0001 from the U.S. Army Research Office

36.327 Modulating attentional capture via Transcranial Magnetic Stimulation (TMS) of right TPJ

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In visual search, the presence of a salient, yet task-irrelevant, distractor in the stimulus array interferes with target selection and slows-down performance. This is partly due to the unwanted shift of attention to the salient stimulus - the so-called attentional capture effect, which delays deployment of attention onto the target. Although automatic and unintentional, previous evidence indicated that attentional capture by a salient distractor is nonetheless modulated by cross-trial contingent history: The distractor cost is more robust when there is no distractor on the previous trial, compared to when there is one, perhaps implying dynamic engagement of proactive filtering mechanisms in the latter condition. Here we used transcranial magnetic stimulation (TMS) to shed light on the causal role of two crucial nodes of the ventral attention network, namely the Temporo-parietal Junction (TPJ) and Middle Frontal Gyrus (MFG), in the exogenous control of attention and its history-dependent modulation. Participants were required to locate a target arrow amongst non-target items and to discriminate the direction of the arrow while ignoring a task-irrelevant salient distractor, when present. Immediately after display onset, 10 Hz triple-pulse TMS was delivered either to TPJ or MFG on the right hemisphere. Compared to a suitable sham condition, results demonstrated that stimulation of right TPJ enhanced the cost associated with the distractor. Crucially, this effect was selectively observed when the preceding trial was a no-distractor trial. No significant effect was observed after MFG stimulation. These findings indicate that TMS of right TPJ exacerbates the interfering effect of a salient distractor, likely reflecting enhanced stimulus-driven control of attention. Since the effect was selectively obtained when the system was more susceptible to attentional capture (i.e., following a no-distractor trial), the evidence further demonstrates a causal role of TPJ in mediating the history-dependent modulation of attentional capture.

36.328 **Under Load: Attentional Capture for a Dynamic Looming Singleton in a Dual-Task Paradigm** Joanna E Lewis[1](joanna.lewis@unco.edu), Mark B Neider[2]; [1]Psychology, College of Education and Behavioral Sciences, University of Northern Colorado, [2]Psychology, Colleges of Sciences, University of Central Florida

A salient, but irrelevant singleton can capture attention independent of task goals. However, attention capture effects appear to be less consistent when an observer is concurrently engaged in a competing working memory task (e.g., Boot et al., 2005). Under a high working memory load (WML), different types of unique singletons have been shown to both exacerbate (color singleton) and eliminate (onset singleton) attention capture effects as measured by response time (RT). These conflicting findings relied on a comparison of static and dynamic singletons, and may be attributable to the unique temporal dynamics of these two singletons classes. In the current studies, we evaluated whether another type of dynamic singleton, looming motion, would capture attention under a high WML. Unlike an onset stimulus, the looming singleton status continues beyond a single frame, similar to a persisting color singleton. In Experiment 1, participants searched for a target object with a looming singleton, where the target was the looming singleton at chance. Concurrent WML was manipulated by having participants maintain a digit string (1 or 6 digits) in memory. After the search trial, participants responded to the absence/presence of a single digit in the previously presented digit string. We found that RTs were faster when the target loomed under high WML, but there was no additive cost for looming distractors. It is possible participants may have prioritized looming objects by restricting their attentional set to dynamic events. We tested this possibility in our Experiment 2 by adjusting our target to be a color singleton. As such, participants only needed to monitor for a static, color singleton. RT differences between looming targets and distractors were mitigated under the high WML. We interpret these results as evidence that a concurrent WML can delay the deployment of selective attention processes for dynamic, irrelevant singletons.

Acknowledgement: NSF

36.329 **Dimensional constraints on distractor handling during pop-out search** Heinrich R. Liesefeld[1,2](Heinrich.Liesefeld@psy.lmu.de), Hermann J. Müller[1,3]; [1]Department Psychologie, Ludwig-Maximilians-Universität München, Munich, Germany, [2]Graduate School of Systemic Neuroscience, Munich, Germany, [3]Birkbeck College, London, UK

Salient-but-irrelevant objects have the potential to distract attention and interfere with the task of searching for relevant objects. A very potent mechanism for reducing this interference, the (top-down) down-weighting of the distractor's (bottom-up) saliency signal, is suggested by the dimension-weighting account. Various strands of behavioral and neuroimaging evidence indicate that people can very effectively down-weight a whole distractor dimension, but not a specific distractor feature when searching for a target that stands out from a background of homogenous non-targets (pop-out): Most notably, (a) physically identical distractors cause strong or weak interference depending on the currently searched-for target (same vs. different dimension), and (b) a distractor standing out in the same dimension as the target induces extremely reliable electrophysiological markers of attentional capture (distractor N2pc) and delays attention allocations towards the target (target N2pc), whereas a distractor standing out in a different dimension is typically directly suppressed (Pd) without attracting attention. These patterns emerge even when the task design is otherwise held constant and both types of distractor trials are randomly intermixed, and even when targets and same-dimension distractors are highly dissimilar. Electrophysiological as well as behavioral data can be well accounted for quantitatively by a dimension-weighting-based computational model of visual search that assumes a partial (though not perfect) down-weighting of the distractor whenever target and distractor stand out in different dimensions.

Perception and Action: Decision making, neural mechanisms

Sunday, May 19, 2:45 - 6:45 pm, Banyan Breezeway

36.330 **Confidence and perceptual judgments are based on different internal representations** Kyuin Kim[1](polarbearjj1a@gmail.com), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

It has been assumed that confidence and perceptual judgments access the same information based on the positive correlation between confidence and judgment accuracy (CA correlation). Here, we investigated whether confidence and perceptual judgments were based on the same internal representations of stimuli. We manipulated an orientation similarity using a set of 10 oriented bars. Among them, one bar had a salient orientation (orientation difference from the closest orientation: 55°) and the other bars had similar orientations (orientation difference from the closest orientation: 5°). After a brief presentation of the stimuli, observers adjusted a probe bar to report the target orientation designated by a cue and then drew their confidence ranges in clockwise and counterclockwise directions separately from the reported orientation. We expected that orientation judgments would reflect the categorical representations of orientations: an outlier orientation and an ensemble of similar orientations. Observers' bias in target responses confirmed this prediction. Similar orientations were biased toward their mean, whereas bias of the outlier orientation did not follow this trend, suggesting the formation of two categories. However, all orientations were biased toward the mean of all orientations in confidence bias (relative difference in the confidence ranges between clockwise and counterclockwise directions), suggesting the formation of one category. Furthermore, the salient orientation was precisely represented without much perceptual bias, but its confidence bias was quite significant. These results suggest that perceptual judgments and confidence are based on different representations of presented orientations. Nevertheless, trial level correlations between absolute objective errors and subjective uncertainty were consistently observed for all reported orientations. These results suggest that the CA correlation cannot be simply regarded as a direct evaluation of actual objective errors using the same information of perceptual judgments. The CA correlation can be significant even with different internal representations between confidence and perceptual judgments.

Acknowledgement: This work was supported by National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (NRF-2016R1A2B4016171).

36.331 **Comparing visual discrimination and detection: the special status of 'no' responses** Matan Mazor[1](matanmazor@outlook.com), Lucie Charles[2], Karl J. Friston[1], Stephen M. Fleming[1,3]; [1]Wellcome Centre for Human Neuroimaging, Institute of Neurology, University College London, [2]Institute of Cognitive Neuroscience, University College London, [3]Max Planck UCL Centre for Computational Psychiatry and Aging Research

Making a decision about whether something is there or not (detection) is qualitatively different from making a decision about what is there (discrimination). A key aspect of detection is the asymmetry in the availability of evidence for 'yes' and for 'no' responses. While discrimination requires a comparison between the relative evidence for different options, in a detection setting, evidence is only available for the presence of a stimulus and not for its absence. This means that confidence in the absence of a stimulus cannot rely on the magnitude of "evidence for absence" and must instead be based on other information. In line with this conceptual difference, previous studies identified behavioural dissimilarities between 'yes' and 'no' responses: confidence in 'no' responses is generally lower, and is less predictive of objective accuracy (Kanai, Walsh, & Tseng, 2010; Meuwese, van Loon, Lamme, & Fahrenfort, 2014) not only in visual detection but also in detection-like tasks (such as recognition memory; Higham, Perfect, & Bruno, 2009). Here, we set out to further characterise the distinct cognitive processes involved in reporting stimulus absence compared to reporting stimulus presence or identity. We present the results from two psychophysical experiments in which participants were asked to perform detection and discrimination tasks on the same class of stimuli, in different blocks. Although there was no difference in overall accuracy between the two tasks, we find markedly different behavioural signatures for discrimination and detection responses. Specifically, we replicate findings of a weaker relationship between accuracy and confidence for 'No' responses (lower area under the type 2 ROC) and show that 'No' responses exhibit a weaker negative association between reaction-time and confidence compared to both 'Yes' and discrimination responses. We discuss our observations in the context of possible cognitive models, such as unequal-variance SDT and temporal evidence accumulation models.

36.332 **'Priors' need not occur at perception: Pre vs. Post-stimulus cueing in a delayed matching task.** Syaheed B Jabar[1](sbj2@nyu.edu), Daryl Fougnie[1]; [1]New York University Abu Dhabi, Department of Psychology

Imagine being asked to select from a color wheel the hue of the last stop sign you saw. Your choice would likely be biased to a prototypical red, even if the actual last seen sign happened to be off-color. Such 'priors', or pre-existing beliefs about reality, are known to affect perceptual decision-making.

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While these effects are often assumed to occur in a Bayesian manner, little is known about its underlying mechanisms. Since stimulus expectations has been hypothesized to bias pre-stimulus visual activity, one could posit that priors would interact with incoming perceptual information in a similar way. If true, the effect should depend on the prior being available during or near to stimulus encoding. Alternatively, priors could be affecting post-perceptual decision-making. If this is the locus of priors, then Bayesian effects should not significantly depend on whether the prior was made available before or after stimulus encoding. With a delayed color-matching task, we demonstrate that while both pre and post-stimulus priors result in Bayesian-predicted effects – such as perceptual estimation reports being biased to the prior (N=41, both ps< .01 compared to control) – the effect of these two priors were not significantly different from each other. Incorporation of priors can occur post-stimulus, suggesting more of a decisional locus than a perceptual one, at least in situations where the 'prior' is explicitly provided and constantly changing. However, even when priors were fixed, presumably allowing perceptual changes to accrue over time, the effects were not significantly different from having a prior that changes trial-by-trial (ps>.5 for both bias and precision, N=16). This reinforces the notion that changes in early perception contributes little to the effect of priors, at least in comparison to later downstream changes. Future research should carefully consider the method and the loci of effects when expectations are altered.

Acknowledgement: NYUAD Research Enhancement Fund REF-175

36.333 **Assessing the visual capabilities of the ferret using psychophysics and electrophysiology.** Erika L Dunn-Weiss[1,2](e-dunnwe1@jhmi.edu), Kristina J Nielsen[1,2]; [1]The Solomon H Snyder Department of Neuroscience, Johns Hopkins University, [2]The Zanvyl Krieger Mind/Brain Institute, Johns Hopkins University

The ferret is one of the primary animal models for studying the development of visual cortex. Indeed, ferrets do not open their eyes until around postnatal day 32; thus the development of ferret visual cortex before and after eye-opening is accessible to experimental investigation and manipulation. Yet, despite the significance of the ferret model for visual development research, relatively little is known about the adult ferret's behavioral visual capabilities. Here, we used two-alternative forced-choice psychophysical tasks to evaluate the ferret's visual acuity, motion perception, and form perception. Visual acuity was assessed by determining contrast sensitivities for detection and orientation discrimination tasks at different spatial frequencies. Additionally, just-noticeable-differences were measured for fine orientation discriminations about vertical and oblique reference orientations. Form integration was evaluated based on discriminations between horizontal and vertical Glass patterns at different coherence levels, and similarly, motion integration was evaluated with random-dot kinematograms at different coherence levels. Ferrets performed above 90% on the easiest condition on all tasks, and psychometric curves were fit to their performance with high fidelity. To complement our psychophysical assessment of motion integration, we performed anesthetized extracellular recordings from neurons in PSS, a higher-order visual area that has been shown to be involved in motion processing in the ferret, and used this data to estimate neurometric motion coherence thresholds. We found that our psychometric motion integration threshold estimates agreed well with the constraints suggested by our neurometric threshold estimates. Taken together, this work provides a comprehensive characterization of visual psychophysics in the adult ferret. Hence, this work broadens the possibilities for future visual development research, as investigators could study both how these visual capabilities develop normally, as well as the impact of manipulations during development on any of these visual capabilities.

36.334 **Confidence as a priority signal in perceptual decision-making** David Aguilar Lleyda[1](aguilarlleyda@gmail.com), Maxime Lemarchand[1], Vincent de Gardelle[2]; [1]Centre d'Économie de la Sorbonne (CNRS & Université Paris 1 Panthéon-Sorbonne), [2]Paris School of Economics & CNRS

When dealing with multiple tasks, we often find ourselves in the problem of establishing the order in which to tackle them. We hypothesized that confidence, the subjective feeling in the accuracy of our decisions or actions, plays an active role in task ordering. We tested this by presenting an array of O or X, colored blue or orange. Participants had to report both which letter and color were more frequent in each trial, and to rate their confidence on each choice. Crucially, they could report the choice on each dimension in the order they chose. The difficulty of one dimension relative to the other was varied across trials. We found an effect of confidence in priority: participants tended to address first the dimension they were more confident in. In subsequent studies, we replicated this finding using task difficulty and response accuracy as proxies for confidence: participants first responded to the easiest of the two tasks, and their first choice was also more likely to be correct. We showed that this effect was not due to a difference in response availability between dimensions. We also extended our finding to situations of prospective confidence, and to situations involving non-perceptual (mental calculation) decisions. Our results support the role of confidence as a priority signal, thus strengthening the evidence for confidence having an active role shaping our future behavior.

36.335 **Making a sound decision from temporally accumulated conflicting visual information** Viola Mocz[1](viola.mocz@yale.edu), Yaoda Xu[1]; [1]Department of Psychology, Yale University

How do humans evaluate temporally accumulated evidence and arrive at a decision despite the presence of conflicting evidence? In the present study, we showed human participants a sequential presentation of shape exemplars drawn from two novel shape categories (A and B). All shapes were shown at fixation and the presentation order of the exemplars from the two shape categories was randomly intermixed. Participants had to decide whether a given presentation contained more exemplars from A or B. The ratio of exemplars from the two shape categories was either 1:2 or 2:3. Within a given ratio, the total number of shapes shown also varied. For example, for ratio 1:2, a sequence could contain 2 As and 4 Bs, 4 As and 8 Bs, or 6 As and 12 Bs. This allowed us to examine how decision making would be influenced by the ratio and the total number of shapes present. We found that both factors significantly impacted performance. At the same ratio, decision performance was better (i.e., shorter reaction time and higher accuracy) when the difference in the number of exemplars shown was greater between the two shape categories. When the difference in number was equated, greater difference in ratio produced better performance. Together, these results suggest that humans use both the absolute amount of difference and the ratio between two conflicting sets when evaluating temporally accumulated evidence.

36.336 **Overlapping and unique neural circuits support perceptual decision making and confidence** Jiwon Yeon[1](j.yeon@gatech.edu), Dobromir Rahnev[1]; [1]School of Psychology, College of Sciences, Georgia Institute of Technology

Perceptual decision making is the process of making a judgment based on sensory information. Perceptual decisions are naturally accompanied by a sense of confidence in the accuracy of the decision. Although the neural correlates of perceptual decision making and confidence have been the subject of substantial research, it is controversial whether the two processes share the same neural circuits. We designed a functional MRI study to address this question. Twenty-five participants performed direction detection tasks of moving dots. We separated the decisional and confidence processes temporally by obtaining the confidence responses after the decision response was made. In addition, we decorrelated the fMRI regressors for the decision and confidence periods by collecting confidence on only 55% of all trials. We found that decision and confidence were associated with large overlapping areas of brain activity in MT+, IPS, FEF, iPCS, IFC, MFG, doral ACC, and anterior insula. However, even though there was a relatively small correlation between fMRI regressors for decision and confidence, it is possible that these results were affected by this correlation. Therefore, in a separate analysis, we first regressed out the influence of one regressor on the fMRI signal, and then re-computed the activations for the other regressor. The same overlapping regions remained robustly activated. Finally, we analyzed whether any brain regions were relatively more selective for decision vs. confidence. We found that confidence recruited a number of unique regions over and above the decision process such as aPFC, dlPFC, dACC, and TPJ. On the other hand, we found no regions that are directly associated with the decision process but not confidence. These results demonstrate that overall decision and confidence are processed in highly overlapping neural circuits, but that several regions are preferentially involved in confidence computation.

36.337 **Mixing different contrasts inflates estimated metacognitive ability in perceptual decision making** Dobromir Rahnev[1], Stephen M Fleming[2,3]; [1]School of Psychology, Georgia Institute of Technology, [2]Wellcome Centre for Human Neuroimaging, University College London, [3]Max Planck UCL Centre for Computational Psychiatry and Ageing Research, University College London

It is becoming widely appreciated that higher stimulus sensitivity trivially increases estimates of metacognitive sensitivity (the correspondence between confidence and performance). Therefore, meaningful comparisons of metacognitive ability across conditions and observers necessitates

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equating stimulus sensitivity. To achieve this, one common approach is to use a continuous staircase that runs throughout the duration of the experiment under the assumption that this procedure has no influence on the estimated metacognitive ability. Here we critically examine this assumption. Using previously published data, we find that, compared to using a single level of stimulus contrast, staircase techniques lead to inflated estimates of metacognitive ability across a wide variety of measures including area under the type 2 ROC curve ($F(2,30) = 8.66$, $p = .0005$), the confidence-accuracy correlation phi ($F(2,30) = 8.38$, $p = .0006$), meta-d' ($F(2,30) = 9.68$, $p = .0002$), Mratio ($F(2,30) = 8.45$, $p = .0006$), and Mdiff ($F(2,30) = 9.61$, $p = .0002$). Further, this metacognitive inflation correlates with the degree of stimulus variability experienced by each subject (this correlation was significant for each of the five measures above). Finally, we show that the degree of stimulus variability in a staircase procedure may itself be driven by individual differences in metacognitive ability. These results suggest that studies using a staircase approach are likely to report inflated estimates of metacognitive ability. Further, we argue that similar inflation likely occurs in the presence of variability in task difficulty caused by other factors such as fluctuations in alertness or gradual improvement on the task. We offer practical solutions to these issues, both in the design and analysis of metacognition experiments.

36.338 **The nature of metacognitive imperfection in perceptual decision making** Medha Shekhar[1](bsmedha@gmail.com)**,** Dobromir Rahnev[1]; [1]School of Psychology, Georgia Institute of Technology, Atlanta, GA

Humans have the metacognitive ability to judge the accuracy of their own decisions via confidence ratings. A substantial body of research has demonstrated that human metacognition is fallible but it remains unclear how metacognitive imperfection should be incorporated into a mechanistic model of confidence generation. In this study, we show that the psychometric properties of metacognitive measures along with empirical zROC functions can be used to reveal the mechanisms underlying metacognitive imperfection. We found that contrary to what is typically assumed, metacognitive imperfection depends on the level of confidence: across five different published datasets and four different measures of metacognition (meta-d', Mratio, phi, and Type-2 AUC), metacognitive ability decreased with higher confidence ratings. To understand the nature of this effect, we collected a large dataset of 20 subjects completing 2,800 trials each and providing confidence ratings on a continuous scale. Our findings demonstrated robustly concave zROC curves, despite a decades-old assumption of linearity. These results suggest that noise during confidence generation increases for higher confidence criteria, thereby making higher confidence ratings less reliable. We incorporated this mechanism into a new process model of confidence generation, which assumes the existence of lognormally-distributed metacognitive noise – that is, noise affecting the confidence ratings but not the perceptual decision – whose variance scales with the mean. The model outperformed competing models either lacking metacognitive noise altogether (average AIC difference = 29.70) or featuring Gaussian metacognitive noise (average AIC difference = 17.39). Finally, our model also yielded a measure of metacognitive ability that is independent of confidence levels unlike all currently popular measures such as meta-d', Mratio, phi, Type-2 AUC, or Type-2 d'. These findings establish an empirically-validated model of confidence generation, have significant implications about measures of metacognitive ability, and begin to reveal the underlying nature of metacognitive imperfection.

36.339 **All-optical stimulation and imaging in macaque V1 reveals neural and behavioral masking effects of optogenetic stimulation in a threshold detection task** Spencer C Chen[1](spencer.chen@utexas.edu)**,** Giacomo Benvenuti[1]**,** Matthew P Whitmire[1]**,** Yuzhi Chen[1]**,** Eyal Seidemann[1]**,** Wilson S Geisler[1]; [1]Center for Perceptual Systems, College of Liberal Arts, University of Texas at Austin

Electrophysiological recording and electrical micro-stimulation in the visual cortex of behaving primates has provided a wealth of knowledge about how neural activity is related to behavioral decisions.Recent advances in optogenetics are opening new possibilities for recording and modifying neural activity in behaving primates.Using viral vectors, we co-expressed a red-shited microbial opsin (C1V1) and a calcium indicator (GCaM6f) in excitatory neurons in macaque V1. Using widefield imaging, we measured robust GCaMP6f neural responses to both normal visual and direct optical stimulation (optostim) at low (0.6 mW/mm2) light levels. We further found that optostim and visually-evoked activity interact in a sublinear way.Specifically, optostim reduced the magnitude of the visually-evoked neural response and reduced the monkey's behavioral sensitivity in a Go/No-Go visual detection task.A monkey was trained to detect a small Gaussian target presented at the retinotopic location corresponding to the C1V1/GCaMP co-expression site (~ 1.5o eccentricity).The monkey reported target present with a saccade to the target.Under purely visual stimulation, the monkey's contrast detection threshold was 5%. In separate blocks, with 0.6 mW/mm2 optostim, the detection threshold between optostim-blank and optostim-plus-target trials was 8%. With optostim, V1 neural response representing the target reduced by 33% (±10% sem) after accounting for the optostim component. Doubling the optostim intensity further increased the threshold and reduced the neural signal.By contrast, when the target was placed ~1° away at retinotopic location corresponding to a V1 site expressing only GCaMP6f (no opsin), we found no optostim driven behavioral or neural effects on target detectability. In conclusion, our results represent a first step toward an all-optical platform for manipulating population activity in behaving macaques and studying the effect of these manipulations on visual processing and behavior.

Acknowledgement: NIH/NEI R01EY024662 and R01EY016454, NIH/BRAIN U01NS099720, DARPA-NeuroFAST, DARPA-NESD

36.340 **Title: Trading off probability and reward in structured lottery tasks** Laurence Maloney[1,2](ltm1@nyu.edu)**,** Mordechai Z Juni[3]**,** Denise Bercovitch[1]**,** Todd M Gureckis[1]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University, [3]Department of Psychological & Brain Sciences, University of California, Santa Barbara

In planning speeded reaching movements where each possible outcome is associated with a reward or penalty, the participant is in effect searching through a large collection of possible movement plans for the one plan that maximizes expected reward. It is plausible that, in searching among movements, observers take advantage of the highly ordered structure of the lotteries: small changes in movement plans in terms of space and time produce small changes in expected value. We developed a structured lottery task involving choice among eleven ordered lotteries, each lottery representing an explicit tradeoff of probability of reward and amount of possible reward, each successive lottery promising a higher probability of winning a smaller amount. In a first experiment we measured the performance of 120 participants each of whom participated in one of four conditions, each condition a different set of ordered lotteries.Each participant made exactly one choice, precluding any contribution of learning or "hill climbing". We compared human decision performance to ideal performance maximizing expected gain. Overall, participants in different conditions altered their strategy appropriately and their expected winnings were 83% to 90% of the maximum possible. However, across all conditions, participants on average chose lotteries with higher probability of reward but lower potential reward than optimal. The failure was small in monetary terms but highly patterned. In a second experiment, we examined whether an additional 120 participants treated winning itself as an additive intrinsic reward that tipped the tradeoff toward increasing probability of winning at the expense of reward. We rejected this possibility. We conjecture that participants' failure to maximize expected value is primarily due to a distortion in their use of probability information.

Acknowledgement: LTM: Guggenheim Fellowship, TMG: Intelligence Advanced Research Projects Activity (IARPA) via Department of the Interior (DOI) contract D10PC20023.

36.341 **Monitoring and proactive control of visual search speed-accuracy tradeoff by supplementary eye field** Thomas Reppert[1,2,3](thomas.reppert@vanderbilt.edu)**,** Richard P Heitz[1,2,3]**,** Jeffrey D Schall[1,2,3]; [1]Department of Psychology, Vanderbilt University, [2]Center for Integrative and Cognitive Neuroscience, Vanderbilt University, [3]Vanderbilt Vision Research Center. Vanderbilt University

Neurophysiological mechanisms of speed-accuracy tradeoff (SAT) have only recently been investigated. Previous studies with macaque monkeys showed that SAT of inefficient visual search was accomplished by modulation of salience map evidence representations in frontal eye field (FEF) and superior colliculus (SC). Saccade initiation occurred when movement activity was either reduced or equivalent in Accurate-cued relative to Fast-cued trials. Targeting errors occurred when salience neurons in the FEF and the SC treated distractors as targets. Here, we report new observations about SAT performance and neurophysiological results from the supplementary eye field (SEF), located in medial frontal cortex, which contributes to executive control of gaze behavior but not to saccade target selection. In two monkeys, we found natural preference for quick responding, with more choice inaccuracies. On trials with choice errors, the monkeys often executed a post-primary saccade to the foregone target, which was generated later in the Accurate than the Fast condition. SEF neurons signaled choice errors, and the magnitude of this signal predicted whether the post-primary saccade

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was corrective in nature. In the Accurate condition, when slower responding was required, the rate of choice errors decreased, but the rate of premature timing errors increased. After timing errors, SEF neurons signaled negative reward prediction error at the time of expected reward. We assessed the distribution of signaling of choice errors and reward prediction errors across the sample of SEF neurons. Some neurons signaled both types of error, whereas others signaled either choice error or reward prediction error. We also found evidence for proactive control of response time. Baseline activity was a strong predictor of response time in both Fast and Accurate conditions. Taken together, these results indicate that SEF may be a source of the modulation observed in FEF and SC and inform new models of distributed decision making.

Acknowledgement: This work was supported by NEI (F32-EY019851, T32-EY07135, R01-EY019882, and R01-EY08890), and by Robin and Richard Patton through the E. Bronson Ingram Chair in Neuroscience.

36.342 **Decision threshold in a perceptual task is influenced by information content of a pre-training stimulus** Tyler Barnes-Diana[1], Yuka Sasaki[1], Takeo Watanabe[1]; [1]Brown University

It has been found that minor differences in pre-training procedure have lasting effects on performance on a perceptual task (Barnes-Diana, Sasaki & Watanabe, 2016). Using hierarchical Bayesian parameter estimation of the parameters of a drift diffusion model (DDM), we decompose that behavioral effect into the information threshold necessary before making a decision as well as the speed of information accumulation. In the first experiment, we used a peripheral coarse discrimination task in which subjects responded in each trial to a concurrently presented central letter (T or L) and peripheral task (tilted lines left or right from vertical). An example image, presented only once for 100ms prior to training, was varied across two groups of subjects. One group (n=11) was exposed to a peripheral noise patch and the other (n=11) a peripheral vertically oriented stimulus. DDM analysis indicated that the group that received the noise patch had a lower information threshold than the group exposed to the vertical reference. We thus found that a high information threshold was set when the first exposure to experiment-related stimulus had high information content (the vertical reference), whereas a low information threshold was set when the information content was low (the noise patch). However, the DDM analysis of the original experiment estimated non-decision times that were shorter than the interval between stimulus and prompt onset, giving rise to a question as to whether the reaction times reflected a true reaction time or a prediction error of the prompt onset. Accordingly, a second experiment was done with the same task (n=7), shortening the interval between stimulus and prompt onset. The results were consistent with a difference in threshold across groups. From these results we conclude that the decision threshold is influenced by the information content of a pre-training stimulus.

Acknowledgement: NIH R01EY019466, NIH R21EY028329, NIH R01EY027841, BSF2016058

Eye Movements: Perception

Sunday, May 19, 2:45 - 6:45 pm, Banyan Breezeway

36.343 **Control and coordination of fixational eye movements in the Snellen acuity test** Janis Intoy[1, 2](jintoy@bu.edu), Michele A Cox[2], Michele Rucci[2, 3]; [1]Graduate Program for Neuroscience, Boston University, [2]Center for Visual Science, University of Rochester, [3]Department of Brain & Cognitive Sciences, University of Rochester

The ability to resolve spatial details as small as 1-arcmin is a remarkable accomplishment of the human visual system, especially considering that the eyes are always in motion. Humans continually perform fixational eye movements (FEM), consisting of an incessant jitter of the eye (drift) occasionally interrupted by small, rapid gaze shifts (microsaccades). Previous studies have shown that, under monocular viewing conditions, FEM are beneficial for the perception of fine details. FEM both enhance relevant spatial information in the form of temporal modulations and precisely center the stimulus within the fovea, resulting in an overall increment in acuity by 40% in the Snellen test. This is the equivalent of the difference between the 20/30 and the 20/20 lines of an eye chart. Here we investigated oculomotor behavior and coordination during normal binocular execution of a Snellen test. Emmetropic human observers (n=5) identified the orientations of 6 tumbling-E optotypes on the 20/16 line of an eye chart. High-resolution eye movements were recorded by a Dual Purkinje image eye-tracker, while custom gaze-contingent calibration procedures ensured high accuracy in the localization of the two lines of sight. Extending previous monocular results, we report that microsaccades and drift are finely tuned in both eyes. Microsaccades were highly conjugate and jointly moved the two eyes' lines of sight across optotypes. In the intervals between microsaccades, both eyes drifted significantly slower during the Snellen test relative to when observers were asked to maintain steady fixation on a marker. Drift statistics were highly similar in the two eyes, however, the eyes drifted independently. These findings demonstrate that during normal binocular execution of a high-acuity task, the movements of both eyes are finely tuned. They raise the question of how binocular signals are combined given that the two eyes move independently most of the time.

Acknowledgement: NIH F31 EY02956 and R01 EY18363, NSF BCS-1457238

36.344 **Perceptual sensitivity to fine detail across the foveola** Martina Poletti[1](martina_poletti@urmc.rochester.edu), Natalya Shelchkova [1]; [1]Department of Neuroscience, University of Rochester

The foveola covers less than 1% of the visual field. Yet, it is the only retinal region that allows for fine spatial vision. Previous work has shown that fine pattern vision starts to deteriorate already within the foveola. Here we mapped perceptual sensitivity to fine spatial stimuli presented at different foveal locations 20′ away from the center of gaze. To this end, we relied on a combination of techniques allowing for high-resolution recordings of eye position and accurate gaze localization. Observers (n=4) fixated on a marker surrounded by eight boxes (5′x5′) arranged in a circle (20′ radius). Stimuli were presented foveally. Observers were instructed to maintain their gaze at the center of the array throughout the trial. Then, nine probes (7′x2′ bars) were briefly flashed one in each box, and one at the center of gaze. To eliminate confounding factors associated with eye movements, we selected for analysis only trials without microsaccades, in which subjects maintained tight fixation on the central marker. After a blank period, a response cue appeared. Subjects reported the orientation of the probe previously presented at the location indicated by this cue. Performance was assessed at each probe location. Our findings show that fine pattern discrimination was highest at the central location, corresponding to the preferred fixational locus, and, consistently with previous findings, it dropped approximately 20% at the other peripheral locations. Not only subjects were better at discriminating stimuli presented at the preferred fixational locus, but they were also ~250 ms faster in reporting their orientation. Even if the peripheral locations tested were all equidistant from the center of gaze, sensitivity across the foveola was not homogenous. Each subject showed an idiosyncratic distribution of sensitivity, with some foveal locations characterized by higher sensitivity compared to others.

Acknowledgement: NSF- BCS-1534932

36.345 **Oculomotor strategy classification in simulated central vision loss** Marcello Maniglia[1](marcello.maniglia@gmail.com), Kristina M Visscher[2], Aaron R Seitz[1]; [1]Department of Psychology, University of California, Riverside, Riverside, CA, USA, [2]Department of Neurobiology, University of Alabama at Birmingham, Birmingham, AL, USA

Age-related visual diseases, such as Macular degeneration (MD), are a central public health concern, further aggravated by the increasingly aging population. MD patients must overcome loss of central vision by adopting compensatory oculomotor strategies, with a large majority developing an eccentric fixation spot (preferred retinal location, or PRL). Understanding the process of development of the PRL would be extremely useful in understanding individual differences in compensatory strategies that can in turn help develop appropriate interventions. However, numerous factors seem to play a role, making it difficult to investigate this phenomenon over a largely inhomogeneous sample. This is further complicated by the challenges that clinical research has to face, from recruitment and compliance to the diverse etiologies and extent of the visual loss. Several labs have therefore begun to simulate visual diseases in a healthy population, which opens up the possibility of testing the development of compensatory strategies and possible intervention approaches. However, this field is still in its initial stage and few elements are taken into account when looking at eye movement patterns in the context of simulated vision loss. Here we propose a systematic approach to classify eye movements after central vision loss that distinguishes different oculomotor components, namely Saccadic Re-referencing, Saccadic Precision, Fixation Stability, and Latency of Target Acquisition. We tested this model in a group of healthy individuals in which peripheral looking strategies were induced through the use of a gaze contingent display obstructing the central 10 degrees of visual field. Results show that it is possible to observe and characterize different oculomotor behaviors on the basis of the proposed components. This more complete characterization of eye movements will help the field understand individual differences in eye movement strategies and how these interact with gaze contingent training and explain differences in task performance.

Acknowledgement: 1R01EY023582

36.346 **The robust vertical visual field asymmetry for pre-saccadic fixation durations: A meta-analysis** Harold H Greene[1](greenehh@udmercy.edu), James M Brown[2], Gregory P Strauss[2]; [1]University of Detroit Mercy, [2]University of Georgia, [3]University of Georgia

INTRODUCTION: The literature reports better contrast sensitivity and faster manual reaction times, for stimuli located below eye fixation.In contrast, saccade reaction times to a target tend to be quicker when the target appears above eye fixation. Recently, asymmetry has been reported in only three studies for presaccadic fixation durations (PSFDs) during free-viewing, such that fixation durations are shorter if the eyes are directed above eye fixation. A need exists to determine the robustness of this asymmetry, if it is to be considered in the modelling of free-viewing eye movement behavior. In the present study, we report a meta-analysis of published and unpublished results of the vertical asymmetry in PSFDs. The goal was to determine the robustness, and quantify the extent of PSFD asymmetry during free viewing. METHOD: Twenty sets of eye movement data were obtained from research conducted at three laboratories. Only tasks without gaze-contingent manipulations were included. Twelve of the datasets utilized visual search tasks, seven utilized scene viewing, and one involved the viewing of Rorschach inkblots. Eye movements were tracked using Eyelink systems at 250Hz, 500Hz, or 1000Hz. RESULTS: PSFDs for saccades directed within a 90deg radius above, and below current eye fixations during free viewing were calculated.On average, PSFDs for up-directed saccades were shorter by 26 ms. Standardized extent of asymmetry was quantified by Hedge's g for each data set. The combined effect size (with a random effects model) was 0.96, z= 8.73, p< .01. CONCLUSION: The meta-analysis shows a statistically significant asymmetry in PSFDs, such that during free viewing, fixation durations are shorter if the eyes are directed above eye fixation. In effect, the asymmetry in PSFDs is important for modelling when the eyes move during visual exploration.

36.347 **Age effects on saccadic suppression** Doris Braun[1](doris.braun@psychol.uni-giessen.de), Alexander C Schütz[2], Jutta Billino[1], Karl R Gegenfurtner[1]; [1]Allgemeine Psychologie, Justus-Liebig-Universität Gießen, Gießen, Germany, [2]Allgemeine und Biologische Psychologie, Philipps-Universität Marburg, Marburg, Germany

Saccadic suppression is an important neuronal mechanism for visual stability. Healthy aging is characterized by a loss of visual contrast sensitivity and prolonged saccadic latencies, but little is known about age effects on saccadic suppression with exception of a single study showing greater suppression in children and adolescents (Bruno et al., J. Neurophysiology, 2006).We used an adaptive staircase procedure to measure contrast sensitivity for the detection of a luminance line stimulus flashed 8 ms above or below the horizontal midline. Thresholds were measured during central fixation and 15 ms after the onset of a 10° horizontal saccade to the left or right. Eye position signals were recorded with an EyeLink 2000 system. 49 observers from 8 to 78 years participated, with 25 younger observers (average 26.4y) and 24 older observers (average 64.6y). All subjects had normal or corrected to normal vision. As expected, luminance contrast thresholds increased with age (5.3% for the younger group vs 8.0% for the older group). The comparison of younger and older subjects revealed a significant age effect on saccadic suppression. Suppression was 59% for the younger and 71% for the older group (t47= 3.03; p< 0.01). A linear regression showed an increase in saccadic suppression of 3% every 10 years. We found a significant increase with age for saccadic suppression of luminance, but with 3% per decade it is relatively small in magnitude. It is different in sign from the decrease in surround suppression reported earlier (Betts et al., JoV 2009). Therefore mechanisms for saccadic suppression seem to be quite stable during healthy aging.

Acknowledgement: Deutsche Forschungsgemeinschaft SFB/TRR 135

36.348 **Novel offline technique to process and understand interaction with printed imagery** Anjali K Jogeshwar[1](akj5177@rit.edu), Gabriel J. Diaz[1], Jeff B. Pelz[1]; [1]Chester F. Carlson Center for Imaging Science, Rochester Institute of Technology

Gaze fixations are used to monitor tasks and guide hand movements. Simple tasks have been studied extensively, and some complex tasks have been studied in 2D environments (e.g., Ballard, et al. 1992). Much remains to be learned about complex interactions in the natural world. How is gaze distributed to support motor movement and information gathering in complex interactions? We designed a sorting task with 2-dimensional printed imagery and monitored gaze and grasp of participants to explore these questions and understand how gaze and grasp interact when a sorting task requires information gathering, manual interaction, and placement. Using a head-mounted Pupil Labs eye tracker, which recorded their eyes at 120 Hz and the scene at 60 Hz and a custom-designed system to monitor their grasp, we designed a novel system which used a template of the objects, and mapped the fixations and grasp data onto the templates. The eye data-processing procedure starts with finding the fixations in the scene, then detecting if the fixation is on an object, and identifying that object from among the templates. Once the object is identified, the fixation is projected onto the object's template. A similar procedure is followed for processing the hand data. The hand is located, followed by detecting and identifying the object, and finally the hand is mapped onto the object's template. Monitoring gaze and grasp concurrently, we observed that during the interaction, eye movements are made for both seeking information and guiding motor movements. This now allows us to perform finer spatio-temporal analyses to understand eye and hand coordination in complex interactions. We report results in the sorting task.

36.349 **Controlling readability of head-fixed large field-of-view displays** Alexander Toet[1](lex.toet@tno.nl), Frank L. Kooi[1]; [1]AEOLUS Human Performance Innovation Center, TNO

Background. The information displayed on a Head Mounted Display (HMD) can only be read by making eye movements, since head movements have no effect on the ocular image position. Aniseikonia (a common visual deficit) is expected to cause eye strain and limit the readability of large FoV binocular HMDs. As the FoV increases, the screen layout needs to optimize overall display readability by preventing clutter while taking common optometric conditions into account. Methods. We measured the ability to quickly determine the orientation of a target T (T vs ⊥) surrounded by 4 randomly oriented (up, down, left, right) flanker T's as a function of target-flanker spacing and eccentricity, in conditions where the target had either the same or opposite opposite luminance polarity as the flankers. All 12 subjects scored normal on relevant optometric tests (stereopsis, visual acuity, Awaya aniseikonia test, phoria). An aniseikonic lens placed in front of one eye optically enlarged the image by 2½%, simulating a common optometric condition. The additional delay caused by the presence of the four flankers is adopted as the 'Crowding component' of the reaction time. Results. Compared to the Same polarity condition, Opposite polarity reduced the Crowding time by a factor of 2.3 (p< 0.001). The Crowding times can be described as an extension of Fitts' law. Unexpectedly, the mild aniseikonia condition doubled the Crowding time (p< 0.001) and caused the highest level of eye strain (p< 0.001). Conclusion. For all eccentricities and target-flanker spacings, the Crowding time more than halved in the opposite polarity condition, while it doubled due to the addition of just 2½% aniseikonia. Practical implications. Even users with mild aniseikonia are likely to experience problems while reading a large FOV HMD. 'Polarity decluttering' can significantly enhance symbology legibility.

Acknowledgement: Air Force Office of Scientific Research, Air Force Material Command, USAF, grant number FA9550-18-1-7022

Eye Movements: Natural and less natural scenes

Sunday, May 19, 2:45 - 6:45 pm, Banyan Breezeway

36.350 **Evidence for closed-loop visual acquisition** Liron Zipora Gruber[1](lironzgruber@gmail.com), Ehud Ahissar[1]; [1]Department of Neurobiology, Weizmann Institute of Science, Rehovot 76100, Israel

The visual system acquires visual information via eye movements, which are typically classified as saccades (quick transitions of the gaze from one region of interest, ROI, to another) and drifts (slow scanning motions in each ROI). Two contrasting perceptual schemes can be consistent with this movement pattern: a computational and a dynamical scheme. In both schemes ROI selection obeys, at least in part, closed-loop dynamics in which target selection depends on the accumulated visual information. The computational scheme, however, assumes that at each ROI the visual system computes an internal representation of the image through an open-ended sequence of computations, much like in computer vision. The dynamical scheme, on the other hand, suggests that the entire process is inherently closed-loop and that there are no open-loop computations at any level. Instead, the system dynamically converges towards (though never reaches) perceptual steady-states in all its levels, including those controlling the ocular drift at each ROI. To test the predictions of the two schemes, we measured ocular behavior

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while modulating the available spatial information (by reducing image size and by mimicking tunnel vision). We show that the ocular drift (i) dynamically converges to a condition-specific speed, (ii) converges anew after each saccade within < 100 ms, (iii) exhibits increased periodic activity around 10 Hz when vision challenged and (iv) its trajectory depends on concurrent sensory data. This behavior strongly challenges the open-loop scheme and suggests that "early" visual processes are accomplished dynamically within low-level retinal-neuronal-ocular loops. Consistent with this suggestion, the visual system maintained selected acquisition strategies across conditions, via a coordinated control of saccade-rate and drift kinematics. Importantly, part of the saccade-drift coordination occurred at the resolution of individual saccades. These results suggest that vision is inherently a closed-loop process, which dynamically and continuously links all brain levels to their environment.

36.351 **Towards End to End head-free gaze classification** Rakshit S Kothari[1](rsk3900@rit.edu), Zhizhuo Yang[2], Chris Kanan[1], Jeff Pelz[1], Reynold Bailey[2], Gabriel J Diaz[1]; [1]Chester F. Carlson Institute of Imaging Science, Rochester Institute of Technology, [2]B. Thomas Golisano College of Computing & Information Sciences, Rochester Institute of Technology

The study of gaze behavior benefits from the classification of the time series into distinct movement types, or events, such as saccade, pursuit, and fixation. Because the manual identification of events is time consuming and subjective, there is a need for automated classifiers. Although there are several solutions for the classification of the eye-in-head signal, there are no established solutions for classification of the coordinated movements of the eyes and head that will occur in less constrained contexts, for example, when wearing a virtual or augmented reality display. Our approach involves training various temporal classifiers on our new Gaze-in-Wild dataset, recorded from over 20 unrestrained participants and hand-coded by 5 practiced labellers. Subjects were instrumented with a 6-axis 100 Hz inertial measurement unit (mean drift: 0.03 deg/sec), a 30 Hz ZED stereo camera, and a 120Hz Pupil labs eye tracker (mean calibration AngError < 1 deg within 10 degrees from calibration pattern center) to record eye and head orientation. The effort culminated in over 2 hours and 20 minutes of hand labelled head-free gaze behavior data, with approximately 20000 detected fixational movements, 18000 saccades, 1400 pursuit events, and 4000 blinks. We use this hand labelled data to benchmark our dataset using standard machine learning classifiers and train our recurrent network model which leverages multiple Neural Arithmetic Logic Units to classify gaze behavior directly from raw, unfiltered eye-in-head and head vectors. Activation map of various hidden units provides insight on learned representations of eye and head coordination and velocity based feature representations which are directly comparable with hand-crafted features. The performance of our classifier is evaluated using various event based metrics and shows that it can attain near-human level classification (>kappa 0.70, event F1> 0.85).

Acknowledgement: Google Daydream grant

36.352 **Hardware Modification for Improved Eye Tracking with the Pupil Labs Virtual-Reality Integration** Clara Richter[1](richt22c@mtholyoke.edu), Catherine A Fromm[2], Gabriel J Diaz[2]; [1]Physics, Mount Holyoke College, [2]Chester F. Carlson Center for Imaging Science, Rochester Institute of Technology

Integrated eye tracking in virtual reality is a crucial tool for the field of vision science, and one that frees the stimulus from the stationary 2D plane defined by conventional desktop displays, allowing for the monitoring of task-coordinated movements of the eyes, head, and body, interaction via gaze, and the use of gaze-contingent displays. The Pupil Labs integration into the HTC Vive and Vive Pro is a notable solution, because it is extremely cost effective, and completely open source. One notable limitation, however is that the lack of space between the user's face and the helmet optics has required that clip-on eye cameras are positioned below the helmet optics, looking up at the eyes at an extreme angle, and this affects the quality of the Pupil Labs eye tracking algorithm. Here, we present the results of a DIY hardware modification that replaces the large 120 Hz eye cameras positioned outside the optics with smaller 200 Hz eye cameras positioned behind the optics, inside the body of the Vive or Vive Pro, and aimed at a specially coated "hot" mirror positioned between the lens and the display. This mirror allows the visible light from the display to pass through to the viewer while reflecting an infrared image of the eye to the eye cameras above. This design provides a clear an on-axis eye image that is well-suited for computer-vision detection of the pupil, a key feature used by Pupil Labs' eye tracking software. Here, we report on the accuracy and precision of the integrated eye tracking system, and provide instruction and resources to interested researchers looking to modify their own integrations.

36.353 **Can you look at your finger in the dark?** Eli Brenner[1](e.brenner@fbw.vu.nl), Lotte Laan[1], Erik van Lopik[1], Jeroen BJ Smeets[1], Irene A Kuling[1]; [1]Department of Human Movement Sciences, Vrije Universiteit Amsterdam

There is a tight coupling between the eyes and the hand in many aspects of human behaviour. One might therefore expect people to be able to direct their gaze to their finger without seeing the finger. However, there are two reasons to doubt whether they can. Firstly, the eyes are known to drift in the dark, so people may not be able to maintain their gaze on anything in complete darkness. Secondly, people make reproducible idiosyncratic errors of up to a few centimetres when they try to align a visible target to their own finger hidden below a surface. Thus, they fail to notice the offset between the position of their finger and where they are looking when guiding the visible target. We measured ten participants' finger and eye movements to examine how accurately they could look at their finger in the dark. Their task was to place their finger on a frontal surface and then to look at the finger, first in the dark and then under dim illumination. Not surprisingly, they were less precise when they could not see their finger. They could fixate in the dark, but made idiosyncratic errors. The magnitude of these errors was similar to that when matching a visual target to their hidden finger. We propose that the systematic errors in both tasks arise when relating arm proprioception to direction of gaze.

36.354 **Cognitive and Perceptual Influences on Eye Movements and Object Memory in Real Environments** Sara Spotorno[1, 2](sara.spotorno@gmail.com), Ioana Dragusin[1], Clare Kirtley[1], Benjamin W Tatler[1]; [1]School of Psychology, University of Aberdeen, UK, [2]School of Psychology, Keele University, UK

Our everyday experience is shaped by the interplay between our cognitive processes and the perceptual characteristics of our surroundings. However, cognitive and perceptual influences have been examined mostly in laboratory settings, while little is known about how they act in real environments. We studied these influences on eye-movement behaviour and on memory representation of color and position of objects placed in different types of real rooms. In Experiment 1 we used a memorisation task. We manipulated object-context semantic association (consistent, inconsistent) and objects' perceptual salience (low, high). Recognition memory was tested with a four-AFC paradigm. Perceptual salience had no effect. Inconsistent objects were not selected earlier than consistent ones, but they were fixated for longer. Memory for color and position was better for inconsistent than consistent objects, but this arose from the longer inspection. In Experiment 2 we aimed to disentangle the role of semantic association and task relevance of memory encoding. We used a visual-search task and an object counting task (this latter to encourage fixation of all objects), followed by a surprise four-AFC memory test. All tested objects were of low perceptual salience, and could be consistent or inconsistent and searched or non-searched. Semantics had no effect. Memory for color was enhanced by longer object inspection and was better for searched than non-searched objects. This memory benefit of object search was enhanced for the latest selected objects. Our results suggest that, in the real world, cognitive guidance overrides perceptual guidance and that, within sources of cognitive guidance, task relevance overrides semantics. Moreover, they suggest that any benefit for recognition memory related to cognitive guidance either is a by-product of (case of semantic association) or is modulated by (case of task relevance) how this guidance acts on viewing behaviour during encoding.

36.355 **Characterization of natural head and eye movements driving retinal flow** Paul R MacNeilage[1](pmacneilage@unr.edu), Luan Nguyen[2], Christian Sinnott[1]; [1]Department of Psychology, Cognitive and Brain Sciences, University of Nevada, Reno, [2]Department of Computer Science, University of Nevada, Reno

In the absence of moving objects, retinal flow is determined by eye velocity relative to the environment as well as by the structure of the environment. Eye velocity in space is the sum of head-in-space and eye-in-head velocity. To gain a better understanding of head and eye velocity driving retinal flow, we developed a system to measure both head and eye velocity during everyday behaviors outside the lab. The system consists of a Pupil Labs eye tracker with an inertial measurement unit (IMU) rigidly attached to the world camera. Head velocity is reconstructed using a computer vision algorithm known as simultaneous localization and mapping (SLAM) which works by tracking features in the scene to determine frame-to-frame image deformation, then solving for the camera motion that generated that deformation. The SLAM estimate is supplemented by angular velocity, linear acceleration, and magnetometer data from the IMU. The result is measurement of six-degree-of-freedom (6DOF) head velocity at 20 Hz with eye velocity sampled at 120

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Hz. Head and eye velocity were recorded for participants performing a range of activities around campus. Not surprisingly, participants tend to fixate features of the stationary environment, and robust oculomotor stabilization leads to retinal flow that is minimal near the fovea. Linear components of retinal flow are driven by linear velocity of the head. Angular components, however, do not depend strongly on angular head velocity because angular optic flow is largely cancelled by compensatory eye movements. Instead, angular components of retinal flow are driven by compensation for linear optic flow at fixation, which depends on fixation eccentricity relative to the heading direction as well as distance to the scene. Consequently, we observe that retinal flow is driven most strongly by three factors: 1) linear head velocity, 2) fixation direction and distance, and 3) the structure of the environment.

Acknowledgement: Research was supported by NIGMS of NIH under grant number P20 GM103650.

36.356 **Decoupling eye movements from retinal image motion reveals active fixation control** Michele A Cox[1](michele.a.cox@gmail.com), Norick R Bowers[2], Janis Intoy[1,3], Martina Poletti[1,4], Michele Rucci[1,5]; [1]Center for Visual Science, University of Rochester, [2]Vision Science Graduate Group, UC Berkeley, [3]Graduate Program for Neuroscience, Boston University, [4]Department of Neurosciences, University of Rochester Medical Center, [5]Brain and Cognitive Sciences, University of Rochester

Even when fixating steadily on an object, the eyes continually jitter in an ostensibly erratic manner. This movement, known as ocular drift, has an instantaneous speed of almost 1 deg/s and can cover an area as large as the entire foveola (1 deg2). Previous studies have demonstrated that the visual system is sensitive to the temporal modulations resulting from ocular drift on the retina and suggested that this motion is under active oculomotor control. To examine mechanisms of drift control, here we manipulated retinal image motion using a custom, high-resolution system for gaze-contingent display.If retinal image motion is actively controlled, we expect eye drift to be attenuated as retinal image motion increases and vice versa. Subjects (n=10) viewed natural scenes. During periods of ocular drift, the image either remained stationary on the display or moved proportionally to the subject's measured drift. In the first condition, retinal motion naturally arose from subjects' eye movements only. In the latter, retinal motion was a function of both eye drift and how the image moved on the display. In this way, retinal motion could be attenuated (i.e. stabilized or halved) or amplified (i.e. doubled or tripled) relative to drift. We found that when retinal motion was attenuated, both drift speed and area increased ~20% relative to normal vision. When retinal motion was amplified, drift became more curved by ~10%. Taken together, these results demonstrate that the dynamics of ocular drift actively change to compensate for varying amounts of retinal motion. The eye moves faster and curves less when retinal motion is lower than normal and moves slower when retinal motion is higher.These findings are consistent with mechanisms of drift control to maintain a specific amount of retinal image motion.

Acknowledgement: NIH EY18363, NSF 1457238, NSF-BCS-1534932

36.357 **Initial fixations differ for brightness and stiffness judgements** Lorilei M Alley[1](lorilei.alley@psychol.uni-giessen.de), Matteo Toscani[1], Robert J Ennis[1], Katja Doerschner[1,2]; [1]Department of Psychology, Justus-Liebig-University, Giessen, Germany, [2]Department of Psychology and National Magnetic Resonance Research Center, Bilkent University, Ankara, Turkey

A surprising amount of information can be gathered in just a single glance at a scene. In a few hundred milliseconds, we can gather the gist of a scene and obtain critical information about the environment. How do expectations about objects, and prior knowledge about their typical locations, sizes, or materials affect this rapid information acquisition? Here we investigate eye movements in an experiment in which we manipulate observers' expectation about the object's material properties. Five naïve participants' gaze was tracked while they performed Two-Interval-Forced-Choice (2IFC) tasks comparing the stiffness and (in a separate block) the lightness of gelatinous blobs. The stimuli were 3D, computer-rendered animations showing wobbling, diffusely-reflecting objects hanging from the ceiling. Both the stiffness and lightness of the objects varied in 5 perceptually distinct steps. We trained a linear classifier on landing positions to differentiate between the two perceptual tasks. Results indicate that the first fixation for both tasks is at the center of the object. However, by the 4th fixation, the landing position can be used to reliably classify the task (1st: 50.57%, 2nd: 60.11%, 3rd: 67.73%, 4th: 74.94%, 5th: 69.77% classification accuracy with chance performance at 50%). For lightness judgments, fixations tended to be near the brightest region on the object, while for stiffness judgments, fixations tended to gravitate towards regions of higher motion energy. Our results show that observers' expectations enable them to adopt an optimal sampling strategy. Ultimately, identifying where people fixate on an object will allow us to understand which cues are relevant in the perception of material qualities in dynamic scenes.

Acknowledgement: This research was supported by a Sofja Kovalevskaja Award from the Alexander von Humboldt Foundation, sponsored by the German Federal Ministry for Education and Research.

36.358 **Gaze Behavior During 360°, Naturalistic Scene-Viewing** Thomas L Botch[1](Thomas.L.Botch@dartmouth.edu), Jeff Mentch[1], Caroline E Robertson[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH

Little is known about gaze behavior in 360° naturalistic scenes. Much of what we know about gaze behavior comes from eye-tracking studies on fixed displays (computer monitors), where the fields of view are typically limited to ~20° visual angle, stimuli do not match real-world size, and images are not explored from a egocentric perspective via head-turns. Mobile eye-tracking studies overcome many of these limitations, affording a natural FOV, but the range of eye-tracking is typically limited to ~60°, and stimuli cannot be varied and controlled across participants. Here, we studied gaze-behavior in a headmounted display (FOV ~100°/120°), while subjects explored a set of naturalistic, 360° panoramic scenes from a first person perspective via head-turns. 20 individuals took part in this study. On each trial (40 trials; 20s each), participants viewed complex, real-world 360° panoramic scenes using a head-mounted display (resolution: 960x1080; field-of-view: ~100°; 75Hz). Viewing behavior was measured using an in-headset eye-tracker (120Hz; 5.7ms latency; 0.5° accuracy). During each trial (20s), participants actively explored a novel 360° panoramic scene, using head turns to change their viewpoint as they would in a real-world environment. We found that average saccade length during 360° scene exploration was much larger than expected: 24.3° visual angle +/= 2.49 STD, ~5° greater than the maximum possible measurements afforded by eye-tracking studies using a typical computer screen. Surprisingly, fixations were rarely at head center: only 4.6% (+/- 2.05 STD) fell within a 5° radius of head center on average. Lastly, we observed an "equator bias" in gaze behavior: fixations, raw gaze, and head direction were often directed participant within 20° of the equator of the panoramic scene 49% +/- 10.96 STD of the trial.

36.359 **The effect of the Pre-Flight Introduction training (PFI) on gaze behavior and flight performance of student pilots** Stephanie Brams[1](stephanie.brams@kuleuven.be), Rafaël F Rejtman[2], Ignace TC Hooge[3], Gal Ziv[4], Oron Levin[1], Ken Evens[5], Tony De Wolf[5], Werner F Helsen[1]; [1]Movement Control & Neuroplasticity Research Group, KU Leuven, Leuven, Belgium, [2]Engineering School, University of São Paolo, São Paulo, Brazil, [3]The Academic College at Wingate, Wingate institute, Netanya, Israël, [4]Experimental Psychology, Department of Psychology, Utrecht University, Helmholtz Instituut, Utrecht, The Netherlands, [5]CAE Oxford Aviation Academy, Brussels, Belgium

In aviation, systematic visual scan patterns of cockpit instruments appear to enhance flight performance (i.e., Allsop & Gray, 2014 and Schriver et al., 2008). This has been the reason for the CAE aviation academy Brussels to set-up a 3-day Pre-flight introduction (PFI) training during which specific scan patterns were taught that allow students to efficiently read cockpit instruments. To assess the impact of the PFI on gaze behavior, students (n=18) completed a flying task in a simulator before and after training. A control group (n = 15) included students that only completed the flying task during a pre- and post-session without any training intervention. To assess gaze behavior, participants wore Tobii Pro Glasses 2 eye-trackers (Tobii Technology AB, Sweden). As expected, pilot students in the trained group performed better (p = .04) on the flying task compared to the control group during the post-session. With respect to eye-movements, only the number of dwells changed as effect of training, resulting in a decreased number of dwells (p = .02) in the trained group (pre: 10541.94 ±4578.96; post: 8965.12 ±3612.75) and an increased number of dwells in the control group (pre: 8299.43 ±3831.52; post: 10596.43 ±3160.99). Interestingly, the control group also showed more scanning patterns (p = .02) in total during the post-session (33.93 ±18.08), suggesting a more chaotic scanning compared to the trained group (19.39±15.81). To conclude, the PFI impacts students' gaze behavior probably by pointing their gaze towards critical instruments. As a result, the students in the PFI group developed better insights into the

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interactions between instruments and the importance of certain instruments for maneuvers. This probably signifies a more organized scanning of cockpit instruments.

36.360 **ZoomMaps: Using Zoom to Capture Areas of Interest on Images** Zoya Bylinskii[1,2](zoya.gavr@gmail.com), Anelise Newman[1], Matthew Tancik[3], Spandan Madan[1], Fredo Durand[1], Aude Oliva[1]; [1]CSAIL, MIT, [2]Adobe Research, [3]UC Berkeley

Eye movements can help localize the most attention-capturing, interesting, or confusing regions of images or user interfaces (Jacob & Karn, 2003). Consequently, there have been significant efforts to find more scalable alternatives for collecting user attention, including moving-window methodologies (e.g., BubbleView, see Kim, Bylinskii, et al., 2017). In this work, we propose an extension of the moving-window methodology, by taking advantage of user viewing behavior on mobile screens. A mobile screen provides a naturally restricted window to explore multiscale content with the help of the zoom functionality. In this work, we present an approach to capture zoom behavior using a mobile interface, we use the collected spatial zoom patterns as a proxy for attention that we call ZoomMaps (which can be visualized as heatmaps), and we propose applications that can be built on top of zoom data. In one set of experiments, we collected the ZoomMaps of 14 participants using our zoom interface on mobile devices with a set of natural images from the CAT2000 dataset (Borji & Itti, 2015). We found that ZoomMaps are highly correlated with image saliency and ground truth eye fixation maps. In a separate set of experiments on academic posters, 10 participants spent 30 minutes exploring 6 posters. We found that zoom data could be used to generate personalized GIFs of subjects' viewing patterns that were more effective at eliciting subsequent memory than static thumbnails. These experiments suggest that ZoomMaps provide an effective and natural interface for collecting coarse attention data that can be harnessed for a variety of applications. For instance, zoom can be used to measure the natural scale of visual content, to summarize visual content, or to act as a debugging tool for designs.

36.361 **The Effect of Visual Long-Term Memory on Eye Movements over Time** Lisa F Schwetlick[1](lisa.schwetlick@uni-potsdam.de), Hans A Trukenbrod[1], Ralf Engbert[1]; [1]Experimental and Biological Psychology, University of Potsdam

Visual long-term memory (VLTM) of complex visual stimuli such as photographs of scenes has previously been shown to significantly affect eye movements. This effect manifests as a decrease in saccade amplitude and increase in fixation duration as images are shown repeatedly within one experimental session. VLTM is known to have a much longer temporal persistence, however. In a series of two experiments we investigate the transfer of the effects of VLTM on eye movements to longer time scales. The first experiment was comprised three sessions spread over several days. In each session participants viewed and memorized a sequence of images. In Session 1 all presented images were unfamiliar to participants. Sessions 2 and 3 included (a) images familiar from Session 1, (b) semantically and structurally similar images, and (c) unfamiliar images. Participants showed the expected proficiency in recognizing images even days after exposure. However, using a mixed linear model approach, we found no evidence of image familiarity on eye movement measures like fixation duration and saccade amplitude.The effect on target selection, as quantified by the likelihood of fixation locations given the empirical distribution of fixation locations, was weakly significant. In a second experiment we reduced the time between sessions by conducting Session 1 and 2 on the same day, and Session 3 on the following day. As in the previous study, the results showed that the influence of VLTM on eye movements is weaker than when presentations occur within the same session. These results are compatible with the view that, while memory of an image remains intact over days, the immediate effect of VLTM on eye movement metrics decays much faster. Only hours after memorizing an image, scene exploration is primarily driven by the current visual input and independent of VLTM.

Acknowledgement: CRC 1294, DFG

36.362 **How body movements in a task predict visual attention dynamically** John A Harston[1](j.harston17@imperial.ac.uk), William W Abbott[1], Aldo Faisal[1,2]; [1]Department of Bioengineering, Imperial College London, [2]Department of Computing, Imperial College London

The visuomotor system is critical to every interaction we make with our environments, and yet much remains unknown, even superficially, about the natural dynamics and mechanisms of freely-moving visuomotor behaviour. Visual and motor behaviours are tightly spatiotemporally coupled (Hayhoe & Ballard, 2005; Land, 2006), yet few studies of freely-moving gaze dynamics account for dynamics of the body, thereby ignoring a fundamental component of the perception-action loop. To address this we use whole body motion capture suits (XSENS, 60Hz, 65 DOF) in tandem with time-synced eye-tracking glasses (120Hz, SMI) on freely-moving subjects during urban mobility in public spaces, and whilst performing high-dimensionality natural tasks such as cooking, thereby capturing a wide range of motion and frequent object interaction. We obtained 30+ hours of egocentric video and eye-tracking data with synced whole body motion across a range of natural tasks to investigate the body-gaze relationship. By building deep learned vector autoregressive models with exogenous input (DeepVARX), using body kinematics as an exogenous control signal, we show that gaze autoregression with exogenous body kinematics input is a better predictor of future gaze than simple gaze autoregression alone (past gaze dynamics predicting future gaze dynamics). Regression from body dynamics to gaze also gives higher prediction rates (0.867AUC on the ROC Curve) than gaze autoregression alone (a more advanced form of central fixation bias). We find up to 60% of the variance in eye movements can be explained using non-linear body dynamics alone in a context-naive manner, demonstrating the high predictive power body kinematics hold, even before taking the critical element of task or environmental context into account - this is because ultimately body kinematics carry task information in an implicit form.

Acknowledgement: EPSRC

36.363 **The fixation-related N400 during natural scene viewing: Investigating the foveal vs. extrafoveal processing of object semantics** Moreno I Coco[1,4](moreno.cocoi@gmail.com), Antje Nuthmann[2], Olaf Dimigen[3]; [1]School of Psychology, The University of East London, London, UK, [2]Department of Psychology, Christian-Albrechts-Universität Kiel, Kiel, Germany, [3]Department of Psychology, Humboldt-Universität zu Berlin, Berlin, Germany, [4]Faculdade de Psicologia, Universidade de Lisboa, Lisbon, Portugal

In vision science, a topic of great interest and controversy is the processing of objects that are (in)consistent with the overall meaning of the scene in which they occur. Two interrelated questions are at the core of this debate. First, how much time is needed to determine the meanings and identities of objects in a scene, and second, whether foveal vision is required to access object-scene semantics. Results from eye-movement studies have been mixed, ranging from rapid processing of semantic information in peripheral vision to a lack of evidence for extrafoveal semantic processing. Here, we aimed at contributing to this debate by co-registering eye-movements and EEG during unconstrained viewing of naturalistic scenes. Participants inspected photographs of real-world scenes (e.g. a bathroom) in which the consistency of a target object (e.g. toothpaste vs. flashlight) was systematically manipulated in preparation of a later change detection task. The EEG was analyzed using linear deconvolution modelling to examine the fixation-related brain potentials (FRPs) evoked by the first fixation on the target object (t), the preceding fixation (t-1), as well as all other non-target fixations on the scene. The eye-movement data showed that inconsistent objects were prioritized over consistent objects (looked at earlier) and were more effortful to process (looked at longer). The FRPs demonstrated that the frontocentral N400 effect for scenes generalizes from steady-fixation paradigms to natural viewing. Crucially, this fixation-related N400 initiated during the pre-target fixation t-1 and continued throughout fixation t, which suggests that the extraction of object semantics already began in extrafoveal vision. However, there was no significant effect of consistency on the probability of immediate target fixation and on the ERP aligned to scene onset, which suggests that object-scene semantics was not immediately accessed. Taken together, these results emphasize the usefulness of combined EEG/eye-movement recordings for understanding high-level scene processing.

Acknowledgement: This research was supported by the Leverhulme Trust (award number: ECF-014-205) and Fundação para a Ciência e Tecnologia (award number: PTDC/PSI-ESP/30958/2017) to MIC

Perceptual Organization: Grouping

Sunday, May 19, 2:45 - 6:45 pm, Banyan Breezeway

36.364 **A striking discontinuity in visual number estimation at 20 is unaffected by extended exposure time** Frank Durgin[1](fdurgin1@swarthmore.edu), Makayla Portley[1]; [1]Department of Psychology, Swarthmore College

It has recently been demonstrated that there are two discontinuities in the estimation of visual number: For very low, numbers up to about 4 or 5, estimation is exact, thereafter, it is inexact.There is evidence for a second discontinuity at about 20 items (Durgin, 2016), which is stable against changes in the range of numbers estimated (Portley & Durgin, submitted). Below 20 items, number estimates have a slope of about 1; above 20, estimates are best fit with a power function with an exponent less than 1.Here we tested the stability of the second visual number estimation discontinuity across a six-fold change in exposure duration. Forty undergraduates participated. Half were tested with brief (500 ms) presentations; half were tested with long (3000 ms) exposures. The dots were white-center, black surround luminance-balanced dots presented in one of two display sizes at 24 numerosities ranging (logarithmically) from 3 to 224, with 8 trials per numerosity. Subjects typed estimates on screen with neither time pressure nor the requirement of a delay. Analyses were conducted of the mean estimates, the variance of the estimates and the response times. Three major observations emerged: (1) mean estimates were essentially identical across exposure durations (2) within-subject variance was higher for brief durations between about 6 dots and 20 dots (i.e., in this range added time was particularly useful), (3) response times increased with number similarly in both conditions until they plateaued, for brief exposures, at about 3200 ms for 8 dots or more.For long exposures the plateau occurred at about 4200 ms for 20 dots or more.Overall, extended time increased the precision of estimates between 6 and 20 dots, but did not substantively effect estimates beyond 20 dots either in precision or accuracy. The cause of the discontinuity at 20 is unclear.

36.365 **Displaying Variability Better: Can We Leverage Gestalt Principles to Aid Display Comprehension?** Mike Tymoski[1](tymoski@rams.colostate.edu), Jessica K Witt[1]; [1]Colorado State University

Making an evacuation decision for a hurricane requires one to weigh the probability of the hurricane hitting their city and the laborious nature of actually evacuating. Probablistic information about hurricane trajectory is often displayed via diagrams known as "cones of uncertainty": a cone which represents the area that could be affected by any of the probable paths the hurricane could take, where variability in the computer models' predicted locations of the storm is represented by the width of the cone. However, this design relies heavily on a forecaster explaining relevant aspects of the display as well as the potential evacuee's understanding of variability (Broad et al., 2007). This design then requires evacuees to keep in mind their understanding of variability and the explanation given about the cone's meaning in order to interpret; given of course, that either of these two things are/were present. In order to bolster understanding of, and overcome poor prior knowledge about, variability we created diagrams that consisted of a series of dots that represented places which the hurricane could touch down over time. These plots intend to leverage the Gestalt principle of proximity whereby, as variability increases, so does distance between dots. To test the efficacy of these plots a within-subjects experiment was conducted in which participants completed two blocks of questions regarding probability and variability while viewing either cone of uncertainty plots or our plots. The order of the blocks was counterbalanced between participants. Participants answered more questions correctly while viewing our plots (M= 0.42) than when viewing cones of uncertainty (M=0.34), t =2.0, p= 0.042, d=0.2. Generally, these results suggest that comprehension of visual displays is bolstered when the displays are designed in a way that parallels information we are attempting to display with basic principles of how visual perception operates.

Acknowledgement: NSF

36.366 **Color tuning mechanisms for perceptual grouping competition in the chromatic Glass patterns** Lee Lin[1](b03207028@ntu.edu.tw), Chien-Chung Chen[1,2]; [1]Department of Psychology, National Taiwan University, Taipei, Taiwan, [2]Center for Neurobiology and Cognitive Science, National Taiwan University, Taipei, Taiwan

We investigated color tuning mechanisms in perceptual grouping by pitching two global patterns with different chromatic properties competing each other for a final stable percept. We use a tripole Glass patterns (tGPs) paradigm. A tGP is composed of randomly distributed sets of three dots, or tripole. Each tripole contained one anchor dot and two context dots. An observer would perceive a clockwise (CW) or a counter-clockwise (CCW) spiral by grouping the anchor dot with either one of the context dots respectively. The hue of the anchor dot was fixed at an intermediate color direction half way between +L-M and S color directions (45° azimuth on equiluminance plane). One of the context dot has the same hue as the anchor dot, whereas the other dot varied in color directions within the range of ±135° relative to +L-M. The contrast of the anchor dot was fixed at twice the detection threshold, while the contrast of both context dots varied from near threshold to four times of the threshold. Participants were asked to answer whether they perceived a CW or CCW spiral. When the CW dot had the same hue as the anchor dot, the probability of perceiving a CW spiral, or P(CW), first increased and then decreased when the CW contrast increased, resulting in an inverted-U curve. The peak of P(CW) curve decreased and shifted rightward with CCW contrast when CCW dot had a color direction at around the +L-M axis. However, when the color direction of the CCW dot was near the S axis, P(CW) curves saturated and was not affected by a change in CCW contrast. The result suggests that, instead of narrowly tuned mechanisms centered at intermediate color directions (Mandelli et al., 2005), broadly tuned mechanisms, centered at around S and +L-M axes respectively, dominate perceptual grouping.

36.367 **A Neural Circuit for Perceptual Grouping, Segmentation, and Selection** Maria Kon[1](mkon@purdue.edu), Gregory Francis[1]; [1]Department of Psychological Sciences, Purdue University, USA

Francis et al. (2017) showed that a neural circuit for grouping and segmentation explains a variety of visual uncrowding effects. When a central target did not group with flankers, the circuit could segment out the flankers, thereby freeing the target from crowding effects. A limitation of that model is that fixed parameter values strictly determine the range of perceptual grouping. We describe a revised grouping circuit that allows for top-down control of grouping range via modification of a single timing parameter. Different values can result in different groupings of elements in a scene. Depending on how the grouping circuit connects visual elements, the segmentation process may select individual items, all items, or a subset of items. Based on the behavior of this revised model, we propose that various empirical tasks designed to measure grouping track how easily observers can segment and select relevant parts of a visual scene. Model simulations that quantify ease of grouping closely match reported subjective ratings of target distinguishability (Manassi et al., 2012). Such judgments are well explained by the segmentation process. Flankers larger than the target, for example, are not grouped with the target for a wide span of top-down range control values. In contrast, flankers equal in size to the target cannot form separate groups: either all or none of the elements group together. The same model also accounts for objective measures of grouping. Palmer and Beck (2007) varied spacing between items and had subjects locate a matching pair of adjacent items. We show that challenging conditions for this task occur when a narrow set of range control parameters are required. This set varies as a function of spacing between items. Overall, we show that the model provides a novel characterization of grouping effects that is applicable to a wide variety of situations.

36.368 **Competing unconscious reference-frames shape conscious motion perception** Oh-hyeon Choung[1], Marc M Lauffs[1], Haluk Öğmen[3], Dirk Kerzel[2], Michael H Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, [2]Faculté de Psychologie et des Sciences de l'Éducation, Université de Genève, Geneva, Switzerland, [3]Department of Electrical and Computer Engineering, University of Denver, CO, USA

Visual processing starts with retinotopic encoding: neighboring points in the real world are projected onto neighboring points in the retina. However, perception is usually non-retinotopic. For example, the motion trajectory of a reflector on a bike appears to be circular (non-retinotopic motion), whereas it is cycloidal in Euclidian and retinotopic coordinates. We perceive the circular motion because we subtract the horizontal motion of the bike (reference-frame) from the cycloidal one. It is impossible to perceive the retinotopic cycloidal motion. It seems that reference-frames for non-retinotopic perception can be generated by low-level stimulus-driven motion-based and higher-level internally-driven attention-based reference frames. Here, we studied how the visual system selects a reference-frame by manipulating the salience of stimulus parts that reinforced specific attention-based coordinates in a Ternus-Pikler Display (TPD). When only retinotopic motion is perceived (reflector presented without the bike), it is impossible to perceive the non-retinotopic motion. Likewise, only 2 disks of the TPD are presented at the same location separated by an ISI of 200ms. In the left disk, a dot rotates clockwise and counterclockwise in the right disk (retinotopic motions). It is impossible to see the non-retinotopic rotation, which would occur when focusing on the left and right disk in alternation. This result surprises because our stimulus is within the capacity of attentional tracking. We propose that the retinotopic motion hinders attentional tracking, but it can be recovered by increasing the salience of stimuli thereby providing a stronger signal to attention-based reference-frames. Hence, our results suggest that the competition among multiple reference-frames is resolved by a variety of mutually suppressive, unconscious mechanisms to create the conscious percepts we eventually perceive.

Acknowledgement: Swiss National Science Foundation (SNF) n 320030_176153. Basics of visual processing: from elements to figures

Sunday PM

36.369 **Perception With and Without Attention: Neural Correlates of Grouping by Similarity in Preattention and Divided-Attention Conditions** Tiffany A Carther-Krone[1](lazart@myumanitoba.ca), Jane Lawrence-Dewar[2], Andrew J Collegio[3], Joseph C Nah[3], Sarah Shomstein[3], Jonathan J Marotta[1]; [1]Perception and Action Lab, Department of Psychology, University of Manitoba, Winnipeg, MB, [2]Thunder Bay Regional Health Sciences Center, Thunder Bay, ON, [3]Department of Psychology, George Washington University, Washington, DC

Grouping local elements of the visual environment is crucial for meaningful perception. While our attentional system facilitates perception, it is limited in that we are unaware of some aspects of our environment that can still influence how we experience our world.It is unclear which brain networks underlie this attentional capability, and whether the same brain networks are responsible for accessing visual stimuli regardless of one's ability to accurately report seeing it.In this study, the neural mechanisms underlying the Ponzo Illusion were investigated under conditions of pre-attention (before awareness of the illusion) and divided-attention (after awareness of the illusion) using fMRI. Participants performed a line discrimination task where two horizontal lines were superimposed on a background of black and white dots. In half of the trials, the dots were organized to induce the Ponzo Illusion if perceptually grouped together.Increased activation was found bilaterally in the early visual cortex (EVC), left lateral occipital complex (LOC), left inferotemporal cortex, right supramarginal gyrus (SMG), and right medial temporal lobe (MTL) to illusory stimuli in the pre-attention condition. Illusory stimuli in the divided-attention condition elicited bilateral activation in the EVC, inferotemporal cortex, superior parietal lobe (SPL), and inferior parietal sulcus (IPS). A direct contrast between pre- and divided-attention conditions revealed increased bilateral activity in IPS, SPL, and EVC for divided-attention, but increased bilateral activation in MTL and frontal cortex for the pre-attention condition. Results show that while there are overlapping regions involved in perceptual grouping regardless of attentional condition, distinct regions of activation arise when grouping is performed under pre-attention versus divided-attention conditions.A different activation of network for pre-attentive grouping suggests that visual information we are unaware of still influences perception of the visual world, and that the neural mechanisms driving perception are modulated by attentional resources.

Acknowledgement: NSERC held by TCK and JJM

36.370 **A Model with Top-down Control of the Range of Perceptual Grouping** Gregory Francis[1](gfrancis@purdue.edu), Alban Bornet[2]; [1]Department of Psychological Sciences, Purdue University, USA, [2]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

Disconnected elements in a visual scene are often interpreted as forming groups or objects. While there are hypothesized grouping rules, such as co-linearity, smoothness, or similarity, that predict some types of grouping, there are many situations where these rules do not seem to apply. In particular, it is possible for an observer to treat a single element as a distinct stimulus but, with a different set of instructions, to treat the element as part of a group. In contrast, neural models of perceptual grouping establish the range of grouping by the spatial size of connections: quite disparate elements can (and must) form a group only if there exist long-range connections. An example is the LAMINART model, which uses properties of grouping to explain a variety of perceptual and neurophysiological phenomena. Here, we introduce a grouping circuit that uses only local connections. Like the bipole cells of the LAMINART model, the new circuit forms illusory contours that connect elements of a group by requiring sufficient input from at least two visual elements. Critically, the new circuit trades off space and time: excitatory signals spread outward until a damping signal arrives to inhibit neural activity that is not supported by at least two sources of excitation. Increasing the delay between excitatory spreading and inhibitory damping allows illusory contours to form over longer distances. We hypothesize that perceptual grouping is subject to top-down control by modifying this relative delay, and that observers can use such top-down control to help perform different types of tasks, such as selecting a group of elements or focusing on a single isolated element in a visual scene. We describe the circuit and show simulations of how it can be applied to various situations

Acknowledgement: Horizon 2020 Framework Programme (Grant Agreement No. 785907 (Human Brain Project SGA2))

36.371 **Spatial mechanisms underlying the detection and localisation of mirror-symmetry** Elena Gheorghiu[1](elena.gheorghiu@stir.ac.uk), Rebecca J Sharman[2]; [1]University of Stirling, Department of Psychology, Stirling, FK9 4LA, Scotland, United Kingdom, [2]Abertay University, Division of Psychology, Dundee, DD1 1HG, Scotland, United Kingdom

Mirror-symmetry is a salient visual feature that plays an important role in object recognition by providing the skeleton or canonical axis for the representation of shape. Here, we examine the extent to which segmentation, and changes to the local orientation, position and shape of the axis of symmetry affect symmetry detection and axis localisation. Stimuli were dot patterns containing different amounts of mirror-symmetry about the vertical axis. The symmetry axis was either continuous or broken into segments of a particular length. We used five segment lengths and varied their local orientation and position. There were three symmetry-axis distortion conditions: (a)'position only'–the vertical axis segments were randomly jittered in a horizontal direction, (b)'orientation only'–positional aligned symmetry-axis segments were of random orientations, (c)'sinusoidal-shaped axis'–both the positions and orientations of the symmetry-axis segments were modulated following a sinusoidal function. We varied the amount of symmetry by changing the proportion of symmetrical dots and measured both symmetry detection thresholds using a 2IFC procedure, and perceived location of symmetry-axis using a point-and-click task. We found that symmetry detection thresholds: (i)were higher for all segmented-axis compared to continuous-axis patterns, with the highest thresholds in the sinusoidal-shaped axis followed by position-only and orientation-only conditions; (ii)increased gradually with decreasing segment-length in the sinusoidal-shape axis and position-only conditions, but not in the orientation-only condition; (iii)increased with the amount of position and orientation jitter. Errors in the axis localisation task were affected by the amount of position and orientation jitter, but not by the segment length. While both the number of axis segments and their degree of positional alignment affect symmetry detection, the localisation of symmetry axis is primarily affected by the positional alignment. The results have implications for symmetry detection models based on early spatial filters relying on the alignment of oriented filters and AND-gate combinations of symmetric filters.

Acknowledgement: This research was supported by a Wellcome Trust Investigator grant (WT106969/Z/15/Z) given to EG

36.372 **Orientation of pattern elements does not influence mirror-symmetry perception** Rebecca J Sharman[1,2](r.sharman@abertay.ac.uk), Elena Gheorghiu[1]; [1]University of Stirling, Department of Psychology, Stirling, FK9 4LA, Scotland, UK, [2]Abertay University, Division of Psychology, Bell Street, Dundee, DD1 1HG, Scotland, UK

Stimuli used to study symmetry perception often lack orientation information. However, orientation noise decreases the salience of symmetrical shapes suggesting that the two signals may interact (Machilsen et al., 2009, JoV). Here we investigate whether (i) orientation and position-symmetry signals interact in the perception of symmetry (Experiment 1), and (ii) symmetry detection mechanisms are sensitive to the orientation of pattern elements (Experiment 2). Stimuli were patterns made of oriented Gabors arranged either symmetrically about the vertical axis or randomly. We varied the amount of position-symmetry by changing the proportion of symmetrical Gabors and measured symmetry detection thresholds using a 2IFC procedure. Experiment 1 had two conditions: (a) 'segregated'- position-symmetric Gabors had one orientation and the noise Gabors had a different orientation, and (b) 'non-segregated'- position-symmetric Gabors were of two orientations in equal proportions, as were the random-positioned Gabors. We varied the separation between the two orientations (0°, 30°, 60°, 90°) in different trials. In Experiment 2, the orientation and position symmetry were manipulated independently. We used (a) position-symmetric patterns in which all Gabors had either the same (asymmetric), mirror-symmetric or random orientations. (b) position-symmetric Gabors had symmetric orientations and noise Gabors had random orientations and positions, (c) patterns with no position-symmetry, and varying amounts of orientation-symmetry. We found that symmetry detection thresholds were not significantly different for the segregated and non-segregated conditions, for all stimulus orientation differences (Experiment 1). The thresholds were also comparable across all conditions containing position-symmetry, but were significantly higher for the orientation-symmetry only (no position-symmetry) condition (Experiment 2). We conclude that symmetry detection mechanisms are not sensitive to orientation information. Although orientation is a dominant visual feature in many visual tasks, it does not affect symmetry detection even when the orientation signals are asymmetric, suggesting that symmetry detection mechanisms are solely reliant on position information.

Acknowledgement: This research was supported by a Wellcome Trust Investigator grant (WT106969/Z/15/Z) given to EG.

36.373 **Remembered Together: Recognition accuracy for visual features of interacting partners is enhanced in the presence of outgroup distractors, but decreased in the presence of ingroup distractors.** Tim Vestner[1](tv551@york.ac.uk), Jonathan C Flavell[2], Richard Cook[1], Steven P Tipper[2]; [1]Birkbeck University, [2]University of York

In previous research we have shown that Social Binding, a process similar to Gestalt Binding, leads to faster processing, spatial distortion and enhanced memory of interacting partners. In this set of experiments we further investigate the underlying mechanisms of Social Binding, particularly in relation to recognition accuracy of previously presented visual features. Recognition for visual features of individuals that were previously seen in the context of a social interaction is enhanced if they are to be discriminated from features of individuals that were part of different interactions. Such recognition is impaired, however, if an individuals' features are to be discriminated from features of individuals that were part of the same interaction. This provides insight into how socially interacting individuals are processed and encoded. We further investigate the influence of different encoding strategies on recognition accuracy, which establishes important boundaries on how visual features of interacting partners are encoded into memory.

36.374 **Biases in the perception of the ambiguous motion quartet across spatial scale** Charlotte Boeykens[1](charlotte.boeykens@kuleuven.be), Johan Wagemans[1], Pieter Moors[1]; [1]Brain and Cognition, KU Leuven

Perception of the ambiguous motion quartet is predominantly characterized by apparent motion in one of two directions. A vertical percept emerges when two dots presented in one frame are perceptually grouped over frames in a vertical direction (i.e. up-down) and vice versa for a horizontal percept (i.e. left-right). Previous studies have documented a vertical bias, indicating vertical apparent motion even when distances between dots across frames are equally large in both directions (Gengerelli, 1948). Wexler (2018) studied percepts of the motion quartet across different orientations and observed large inter-individual variability in biases varying within individuals over time. In this study, we asked whether vertical and horizontal percepts differed between and within individuals for presentations of stimuli across different spatial distances. More specifically, observers reported their percepts of motion quartets with an ISI of 320 ms displaying two dots with radii of 0.36 deg positioned in combinations of 25 horizontal and vertical distances ranging from 0.6 to 5.4 deg. A different group of observers did this task for combinations of 17 horizontal and vertical distances within the same range and repeated this task again after 30 minutes. In between, we measured individual points of subjective equality (PSE) in vertical distances for fixed horizontal distances (0.9, 1.5, 3.0 and 4.5 deg) by means of an adaptive procedure. Our results replicate the vertical bias in most observers, with considerable inter-individual variability where a minority showed veridical perception or even a horizontal bias. Biases did not vary substantially after 30 minutes. Interestingly, transitions between vertical and horizontal percepts seemed to scale with larger spatial distances, indicating that biases in perception are not invariant across spatial scale (i.e., the adaptive procedure showed that aspect ratios for PSEs became bigger and slopes of the psychometric functions became less steep for increasing spatial distances).

Faces: Social and cultural factors

Sunday, May 19, 2:45 - 6:45 pm, Pavilion

36.401 **Manipulating social perceptions with an autoencoding model of faces - ModifAE, a useful tool for face perception studies.**Amanda Song[1](feijuejuanling@gmail.com), Chad Atalla[2], Bartholomew Tam[3], Garrison Cottrell[2]; [1]Cognitive Science, University of California, San Diego, [2]Computer Science and Engineering, University of California, San Diego, [3]Electrical and Computer Engineering, University of California, San Diego

In face perception studies, the ability to have precise control over face stimuli is extremely crucial. A realistic parametric model of faces over social perception space will allow researchers to investigate various questions of interests, such as to discover the facial features that underlying various first impression traits (trustworthiness, intelligence, etc). Traditional simulated faces (from faceGen software) lack ecological validity. Morphing and template-based techniques have limitations in unconstrained situations, such as when the face is partially occluded or is embedded in a noisy background. Thanks to the progresses in deep learning research, a large number of image modification and manipulation models based on Generative Adversarial Networks and autoencoders have emerged. However, most of the existing models have been focused on more objective facial traits such as the apparent gender, age or ethnicity of a face, or the expression, the hair color of a face, addition of glasses or beard into a face, etc. In comparison, fewer efforts have been made to manipulate the subjective properties of faces, such as the trustworthy or attractive level of a face. To bridge the gap, we propose an autoencoder based model, ModifAE, that can simultaneously manipulate multiple traits of a face, including both objective and subjective aspects. As a standalone image manipulation model, ModifAE requires fewer parameters and less time to train than existing models. We construct a large dataset of face impression trait predictions, containing over 200 thousand face photos, then train our ModifAE model based on it. We empirically verify the quality of this dataset and demonstrate that our ModifAE model produces convincing and realistic changes in the specified subjective impression dimensions through human validation. This tool could be used to shed new lights on social impression and face perception studies.

36.402 **An Own-Age Bias in Mixed- and Pure-List Presentations: No Evidence for the Social-Cognitive Account** Sophie L Cronin[1](sophie.l.cronin@postgrad.curtin.edu.au), Belinda M Craig[2], Ottmar V Lipp[1]; [1]School of Psychology, Curtin University, Australia, [2]School of Psychology and Behavioural Science, University of New England, Australia

Identity recognition of unfamiliar faces tends to be biased by face age, such that own-age faces are better recognised than other-age faces. This own-age bias (OAB) has been suggested to be caused by perceptual-expertise and/or social-cognitive mechanisms. An experiment by Bryce and Dodson (2013, Exp 2) provided support for the social-cognitive account, demonstrating an OAB in a mixed- but not pure-list presentation of faces. When participants encountered a mixed-list of both own- and other-age faces at encoding, the OAB was observed. However, when recognition performance was compared between-participants who viewed a pure-list of only own- or other-age faces the OAB was absent. Own-age faces were recognised better in the mixed-list compared to pure-list condition. Bryce and Dodson (2013) argue their data support a social-cognitive account of the OAB wherein unless age categories are made salient by viewing more than one age group, own-age/other-age categorisation does not occur, own-age face recognition is not facilitated, and an OAB is not produced. The present study aimed to replicate this finding and examine its robustness in paradigms including different components of the original. Across three experiments that removed theoretically irrelevant components of the original old/new recognition paradigm, varied face sex, and included stereotypical background scenes, Bryce and Dodson's (2013) results were not replicated. Under both mixed-list and pure-list conditions, the OAB emerged. These results are more consistent with a perceptual-expertise account than a social-cognitive account of the OAB, but may suggest that manipulating age category salience using mixed- and pure-list presentations is not strong enough to alter own-age/other-age categorisation processes.

Acknowledgement: This research was supported by an Australian Government Research Training Program (RTP) Scholarship awarded to SLC and an Australian Research Council Discovery Project (DP150101540) awarded to OVL.

36.403 **the impact of race and affect on infant visual attention to faces** Kelly C Roth[1](kelcroth@vols.utk.edu), Emily K Grimes[1], William J Chollman[1], Jennifer Shearon[1], Cathryn Pryor[1], Cole Green[1], Greg D Reynolds[1]; [1]Department of Psychology, University of Tennessee, Knoxville, TN 37996

Perceptual narrowing is a domain general developmental process involving a loss of perceptual sensitivity to stimuli not regularly encountered in one's native environment. One outcome is the other-race effect, which is characterized by increasing difficulty discriminating other-race faces in infancy (Kelly et al., 2007). This affects selective attention to facial features. White 9-month-olds look most at eyes of own-race and mouths of other-race faces (Wheeler et al., 2011). Affect also affects infant attention to faces. Four- and seven-month-olds spend less time fixated on facial features of angry compared to happy or neutral faces (Hunnius et al., 2011). Eight- to fourteen-month-olds look quicker at static angry than happy faces (LoBue & DeLoache, 2010).This eye-tracking study investigated the effects of race

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and affect on infant selective attention to facial features. Ten-month-old infants (N=10) accumulated 20 seconds of looking to a static image of a woman's face displaying either a neutral or angry affect. Infants repeated the procedure with the same actor displaying the other affect. Infants were tested with either own- or other-race faces, and order of affect was counter-balanced across participants. The impact of race and affect on the distribution of fixations to the eyes, nose, and mouth was analyzed.Results showed a main effect of race ($F(1,8)=7.012$, $p=.029$) and an interaction of race and affect ($F(1,8)=7.560$, $p=.025$) on selective attention to eyes. Infants looked more to own- than other-race eyes. Infants looked similarly across affect to other-race eyes ($p=.424$) but looked more to angry own-race compared to neutral own-race eyes ($p=.031$). These findings indicate 10-month-olds show differential visual scanning based on affect when viewing own-race faces but not when viewing other-race faces. Thus, the other-race effect may be associated with enhanced emotional processing of own- compared to other-race faces by 10 months of age.

36.404 **Race categories and implicit biases in children and adults** Arushi Sachdeva[1](arushisachdeva31@gmail.com), Melissa Mildort[1], Gizelle Anzures[1,2,3]; [1]Department of Psychology, Florida Atlantic University, [2]Brain Institute, Florida Atlantic University, [3]Center for Complex Systems and Brain Sciences, Florida Atlantic University

The implicit association test (IAT) of racial bias in adults measures the association between visual categories of race and positive/negative attributes/concepts/objects (Greenwald, Nosek, & Banaji, 2003). Mostexisting child-friendly versions of the IAT use auditory recordings of positive/negative words for use with preliterate children, or a happy and an angry emoji in lieu of positive and negative categories. We created a child-friendly IAT that more closely mimics the adult version by using pictures of "nice"/ "not-so-nice" categories of attributes/concepts/objects. We also examined whether racial contact is associated with implicit racial biases in children and adults. Caucasian young adults and 5- to 10-year-olds completed our computerized child-friendly IAT. Participants were trained to categorize a) "nice" (e.g., flower, laughing emoji, rainbow, etc.) and "not-so-nice" (e.g., wilted flower, angry emoji, rain cloud with rain, etc.) pictures, and b) Caucasian and East Asian faces by race. Participants were then asked to use the same button to respond to a) Caucasian faces paired with "nice" pictures and b) East Asian faces paired with "nice" pictures (order counterbalanced across participants). Adult participants and parents of child participants reported contact with Caucasians and East Asians. Preliminary results revealed that adults showed implicit own-race biases ($p < .01$), whereas children showed no racial biases ($p > .20$). Both the adult and child age groups showed greater contact with own-race Caucasians than with other-race Asians(p values $< .001$), but these were not related to implicit racial biases (p values $> .20$). Our findings stand in contrast to previous reports of implicit racial biases during early childhood (Baron & Banaji, 2006; Qian et al., 2016), but is likely driven by our participants' multiracial experiences with Caribbean/Black/Hispanic individuals despite their limited experiences with East Asians. Our results allude to a delayed emergence of implicit racial biases in children in multicultural areas.

Acknowledgement: NICHD

36.405 **Event-related potentials, race categorization, and implicit racial biases in children and adults** Haylee F Trulson[1](h-trulson2012@fau.edu), Melissa Mildort[2], Gizelle Anzures[2, 3, 4]; [1]Wilkes Honors College, Florida Atlantic University, [2]Department of Psychology, Florida Atlantic University, [3]Brain Institiute, Florida Atlantic University, [4]Center for Complex Systems and Brain Sciences, Florida Atlantic University

Face perception, a fundamental part of social interaction, is honed from infancy to adulthood and influenced by visual experience. Previous research with adults report mixed results regarding event-related potential (ERP) responses to race, and such responses have yet to be examined in children who already show a behavioral own-race recognition bias (Lee, Anzures, Quinn, Pascalis, & Slater, 2011). Only one study has examined ERP sensitivities to implicit racial biases in adults (Ofan, Rubin, & Amodio, 2011). Thus, here, we examined children's and adults' ERPs to own- and other-race faces, and whether such ERPs are related to implicit biases. Caucasian young adults and 5- to 10-year-olds completed two blocks of a race categorization task while their electroencephalograpic waveforms were recorded. In each block, participants were asked to press a button whenever they viewed a Caucasian or an East Asian face (order counterbalanced across participants). Responses to stimuli that did not require a button press were analyzed. Prior to the EEG task, participants completed a child-friendly implicit association task measuring racial biases. Preliminary results replicate past reports of developmental changes in ERPs with larger P100 and N170 responses and longer latencies in children compared to adults (p values $<$ .001). There was also a trend towards larger P100 responses for other-race compared to own-race faces ($p = .07$). Greater implicit own-race biases were associated with larger bilateral P100 responses to other- than own-race faces in children and adults, and larger bilateral N250 responses to own- than other-race faces in adults (p values $< .05$). Our results suggest that past mixed findings regarding ERPs and race in adult samples may be driven by individual differences in participants' implicit racial biases. Our results also show that implicit racial biases are associated with the P100 in children and adults and the N250 in adults.

Acknowledgement: NICHD

36.406 **Evaluating Trustworthiness: Differences in Visual Representations as a Function of Face Ethnicity** Francis Gingras[1](francis.gingras16@gmail.com), Karolann Robinson[1], Daniel Fiset[1], Caroline Blais[1]; [1]Université du Québec en Outaouais

Trustworthiness is rapidly and automatically assessed based on facial appearance, and it is one of the main dimensions of face evaluation (Oosterhof & Todorov, 2008). Few studies have investigated how we evaluate trustworthiness in faces of other ethnicities. The present study aimed at comparing how individuals imagine a trustworthy White or Black face. More specifically, the mental representations of a trustworthy White and Black face were revealed in 30 participants using Reverse Correlation (Mangini & Biederman, 2004). On each trial (500 per participant), two stimuli, created by adding sinusoidal white noise to an identical base face (White or Black, depending on the experimental condition), were presented side-by-side. The participant's task was to decide which of the two looked most trustworthy. The noise patches corresponding to the chosen stimuli were summed to produce a classification image, representing the luminance variations associated with a percept of trustworthiness. A statistical threshold was found using the Stat4CI's cluster test (Chauvin et al., 2005), a method that corrects for the multiple comparisons across all pixels while taking into account the spatial dependence inherent to coherent images ($t_{crit}=3.0$, $k=246$, $p< 0.025$). Results show that for a White face, perception of trustworthiness is associated with a lighter eye region; for a Black face, perception of trustworthiness is associated with a darker right eye and a lighter mouth. Statistically comparing both classification images ($t_{crit}=3.0$, $k=246$, $p< 0.025$) revealed that the eye region was more important in judging trustworthiness of White faces, while the mouth region was more important for Black faces. The present study shows that facial traits used to form the mental representation of trustworthiness differ with face ethnicity. More research will be needed to verify if this finding generalizes across populations of different ethnicities.

36.407 **Perceptual Experience and Within-Person Variability Affect the Magnitude of the Other-Race Effect** Xiaomei Zhou[1](x.zhou@ryerson.ca), Chun-Man Chen[2], Catherine J. Mondloch[3], Sarina Hui-Lin Chien[2], Margaret Moulson[1]; [1]Department of Psychology, Ryerson University, [2]The Institution of Neural and Cognitive Science, China Medical University, [3]Department of Psychology, Brock University

Adults show an other-race effect (ORE): impaired recognition of other- versus own-race faces1. The ORE manifests as a difficulty recognizing other-race faces across variability in appearance, likely due to asymmetric experience with own- and other-race faces2,3. No study has systematically investigated how the ability to form stable facial representations changes as a function of differential exposure to own- and other-race faces. In Experiment 1, using the Cambridge Face Memory Task (CFMT)4,5, we tested 3 groups of adults (n=132): White and East Asian (EA) adults born and raised in Toronto (highly diverse), and EAs who were born in China and immigrated to Toronto. Whereas White adults and EA immigrants demonstrated a reliable ORE, ps $< .005$, EAs born in Toronto showed no ORE, $p > .080$. Notably, age of arrival predicted the magnitude of the ORE ($B = .006$, $p=.001$, $R2 = 0.23$), suggesting that early experience is more effective in reducing the ORE. In Experiment 2, we developed a new version of the CFMT, with face images that capture extensive natural variability in appearance. We tested five adult groups (projected n=120; currently n=71): the three aforementioned groups plus White adults raised in a majority White city in Canada and EAs raised in a majority EA city in Taiwan. We predict that the ORE might be greater in Exp.2 than in Exp.1, highlighting the challenge of forming stable representations of other-race faces. Additionally, the magnitude of the ORE might present a 'U' shape: Largest in groups who sit on the end of experience distribution (high own-race and low other-race contact), and smaller in groups in diverse environments or with early exposure to other-race faces.

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These experiments provide evidence about how perceptual experience shapes adults' ability to build stable face representations, and highlight the importance of early experience in shaping the ORE.

Acknowledgement: NSERC

36.408 **Learning own- and other-race facial identities through exposure to natural variability: Evidence from behavioural and ERP measures** Simone C Tüttenberg[1](simone.c.tuettenberg@durham.ac.uk), Holger Wiese[1]; [1]Department of Psychology, Durham University, United Kingdom

Face recognition research has recently begun to examine identity learning by exposing participants to multiple, naturally varying images of a pre-experimentally unfamiliar person. Both behavioural and event-related potential (ERP) studies have shown that such exposure to within-person variability leads to the acquisition of stable representations which enable recognition of the learnt identities even from previously unseen images. While there is emerging evidence that identity information is initially harder to perceive in other-race faces, e.g., when different pictures of unfamiliar faces have to be matched for identity, it remains largely unknown whether similar difficulties also arise during identity learning, i.e., when participants become increasingly familiar with a face. Here, we present evidence from both behavioural and ERP experiments investigating learning of own- and other-race facial identities in Caucasian and Asian participants. While Caucasian participants showed better learning of own- than other-race identities in behavioural tasks, a similar own-race learning advantage was absent in Asian participants with substantial other-race contact. ERP results from Caucasian participants further revealed a more negative N250 component for the learnt own-race face images relative to images of novel identities, while the corresponding effect was reduced for other-race faces. The present results thus highlight the challenges to learn other-race identities. At the same time, our findings from Asian participants suggest that such difficulties can be overcome by extensive other-race contact. Implications for our understanding of the neural and cognitive processes involved in own- and other-race face recognition will be discussed.

36.409 **Recognition of faces despite changes in appearance: How similarity and race affect our tolerance for within-person variability** Alexandra R Marquis[1](alexandra.marquis@ryerson.ca), Xiaomei Zhou[1], Margaret C Moulson[1]; [1]Ryerson University

Successful face recognition involves the ability to generalize recognition across within-person variability in appearance (e.g., lighting, expressions). Research shows we are less tolerant of within-person variability in unfamiliar faces1 and particularly for other-race faces2,3. Less is known about how face similarity influences adults' ability to build stable face representations that are tolerant to variability in appearance, and whether this process differs for own- versus other-race faces. We applied a sorting task1 to assess people's ability to recognize faces across variability. White and East Asian adults (currently n = 35) were handed a stack of 40 photographs of two identities and were asked to sort them into different piles based on identity, such that each pile contained all photos of the same identity. Adults were not told the correct number of identities and were randomly assigned to sort either own- or other-race faces and pairs that either looked similar or dissimilar. We analyzed the number of perceived identities (i.e., number of piles created) and intrusion errors (i.e., different person/same pile). Preliminary analysis based on data from the White participants (n = 27) indicated no significant main effects or interaction between face race and similarity on the number of perceived identities (ps > .46; Figure 1). However, we found a significant interaction between face race and similarity on intrusion errors ($F(1) = 4.78$, $p = 0.039$, $\eta 2 = .17$; Figure 2). Consistent with past research4, this finding suggests that the ability to discriminate between identities is impaired for other-race compared to own-race faces particularly when the faces look extremely similar (i.e., densely clustered in face space5). People's ability to form stable facial representations might be influenced by the way in which own- and other-race faces are mentally represented in face space, making this research theoretically important.

Acknowledgement: none

36.410 **Evidence of an other race effect for video game character faces** Jennifer A Day[1](jeaday@ucsc.edu), Nicolas Davidenko[1], Hannah Hart-Pomerantz[1]; [1]University of California, Santa Cruz

Most humans become experts at recognizing faces by adulthood, but a debate arises around how to study the development of this expertise. We propose video game character faces as ecologically valid stimuli to study the development of face expertise. Exposure to these faces can be quantified and video game players typically have hundreds of hours logged for each game. We ran a 3-AFC short-delay recognition task with upright and inverted character faces sourced from The Elder Scrolls V: Skyrim to test if participants show an other race effect (ORE). The two races we tested were Nord (a race based on Nordic Caucasians) and Redguard (a race based on Arabic North Africans). We recruited 49 novice participants who had never played Skyrim from UC Santa Cruz, where African Americans make up 2% of the population (UCSC ODEI, 2016). Results showed a robust face inversion effect: upright faces were correctly recognized significantly more often (M: 0.607, SE: 0.021) than inverted faces (M: 0.426, SE: 0.016; $t(48) = 8.68$, $p < 0.00001$). We also found a smaller but reliable ORE: performance for upright Nord faces (M: 0.648, SE: 0.021) was significantly higher than for upright Redguard faces (M: 0.566, SE: 0.029; $t(48) = 2.80$, $p=0.007$), whereas there was no difference in performance for inverted faces ($p>0.5$). However, the size of the inversion effect was only marginally larger for Nord faces than Redguard faces ($p=0.10$). Our results demonstrate evidence of expertise and other race effects in video game faces in a novice population. In a follow-up study we investigate whether Skyrim experts (participants who have played more than 50 hours of the game) will show an even stronger ORE based on their level of expertise.

36.411 **The impact of gender on visual strategies underlying the discrimination of facial expressions of pain.** Camille Saumure[1](sauc14@uqo.ca), Marie-Pier Plouffe-Demers[1,3], Daniel Fiset[1], Stéphanie Cormier[1], Miriam Kunz[2], Caroline Blais[1]; [1]Département de psychoéducation et psychologie, Université du Québec en Outaouais, [2]Department of General Practice and Elderly Care Medicine, University of Groningen, [3]Département de psychologie, Université du Québec à Montréal

Previous studies have found a female advantage in the recognition/detection (Hill and Craig, 2004; Prkachin et al., 2004) of pain expressions, although this effect is not systematic (Simon et al., 2008; Riva et al., 2011). However, the impact of gender on pain expression recognition visual strategies remains unexplored. In this experiment, 30 participants (15 males) were tested using the Bubbles method (Gosselin & Schyns, 2001), which randomly sampled facial features across five spatial frequency (SF) bands to infer what visual information was successfully used. On each of the 1,512 trial, two bubblized faces, sampled from 8 avatars (2 genders; 4 levels of pain intensity), were presented to participants who identified the one expressing the highest pain level. Three difficulty levels, determined by the percentage of pain difference between the two stimuli (i.e 100%, 66% or 33%) were included. Number of bubbles needed to maintain an average accuracy of 75% was used as a performance measure (Royer et al., 2015). Results indicated a trend towards a higher number of bubbles needed by male (M=57.7, SD=30.4) in comparison to female (M=40.2, SD=23.2), [$t(28)=2.02$, $p=0.05$]. Moreover, this difference was significant with the highest level of difficulty [$t(28)=2.22$, $p=0.04$], suggesting that pain discrimination was more difficult for male (M=77.6, SD=36.8) than female (M=52.3, SD=24.5). Classification images, generated by calculating a weighted sum of the bubbles position (where accuracies transformed in z-scores were used as weights), revealed that female made a significantly higher use of the lowest band of SF ($Z_{crit} = 2.7$, $p < 0.05$; 5.4-2.7 cycles per face). These results suggest that gender impacts the performance and the visual strategies underlying pain expression recognition.

Acknowledgement: Social Sciences and Humanities Research Council

36.412 **Neural Correlates of Emotional Expression Processing of East-Asian Faces: An fMRI and Dynamic Causal Modeling Investigation** Ya-Yun Chen[1](chenyayun9683@gmail.com), Chi-Chuan Chen[2], Yu Song Haw[1], Chin-Hui Chen[3], Joshua O. S. Goh[2], Shih-Tseng Tina Huang[1,4], Gary C.-W. Shyi[1,4]; [1]Center for Research in Cognitive Science, National Chung-Cheng University, Taiwan, [2]Graduate Institute of Brain and Mind Sciences, National Taiwan University, Taiwan, [3]Department of Computer Science and Information Engineering, National Taiwan University, Taiwan, [4]Department of Psychology, National Chung-Cheng University, Taiwan

Growing evidence shows that the posterior region of superior temporal sulcus (pSTS) is engaged in emotional processing, especially during cross-modal integration. However, most of these studies used Caucasian participants and Western-based stimuli. Critically, studies have demonstrated that a person's cultural background modulates the manner of how facial expressions are processed. Here, we examined the neural mechanisms underlying the processing of East Asian facial expressions and elucidated the role of pSTS in the visual modality using contrast analyses and dynamic causal modeling (DCM) of fMRI responses. Facial expressions of different identities portraying the six basic emotions, including anger, disgust, fear,

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happiness, sadness, and surprise, were contrasted with those portraying neutral expression. At the beginning of each block, an affective label in Chinese was displayed followed by 8 sequentially presented faces from the same emotional category. Participants judged the emotional intensity of each facial expression. The results showed significant neural activation in the pSTS across all emotional contrasts, especially in the right hemisphere, except for the facial expression of happiness. This finding suggests the pSTS plays a general, rather than cultural specific, role in emotional processing. Only disgusted expressions showed activation in the middle and anterior cingulate cortex, and only surprised expressions activated the amygdala, a widely regarded hub for emotional processing in the brain. DCM indicated that (a) the fusiform gyrus (FFG) and pSTS in the two hemispheres were interconnected, and (b) the projection between bilateral FFG and amygdala were modulated by bilateral pSTS. These results partially confirm Müller et al.'s (2012, Neuroimage) findings, and suggest a critical role for pSTS in emotional processing even in the processing of emotion conveyed in a single visual modality via faces.

Acknowledgement: The study reported here was supported by the Ministry of Science and Technology, Taiwan (No.: 107-2420-H-194-006)

36.413 **Cross-species differences in the perception of dynamic facial expressions** Nick Taubert[1](nick.taubert@uni-tuebingen.de), Michael Stettler[1], Louisa Sting[1], Ramona Siebert[2], Silvia Spadacenta[2], Peter Dicke[2], Hans P. Thier[2], Martin A. Giese[1]; [1]Section Computational Sensomotorics, Department of Cognitive Neurology, CIN&HIH, University Clinic Tuebingen, Germany, [2]Department of Cognitive Neurology, CIN&HIH, University Clinic Tuebingen, Germany

In primates facial expressions represent an important channel to communicate emotions. Human and monkey expressions of the same emotion can be quite different. How efficiently can we learn to recognize facial expressions of another primate species, and can we understand human facial movements even if it is linked to faces of another species? METHODS: To clarify these questions, exploiting state-of-the-art technology in computer animation, we have developed a highly realistic model of a dynamically moving monkey head, which is animated by monkey and human motion capture data. The model is based on a monkey MRI scan, adding relevant surface structures, like skin and fur. Animation is based on a ribbon structure that mimics the monkey and human facial muscle system. In addition, we developed a corresponding realistic human head avatar model. Using a hierarchical generative Bayesian models (combining GP-LVMs and GPDMs), we are able to interpolate continuously between the facial movements representing emotional expressions in humans and monkeys. We validated the accuracy of the generated movements exploiting a 'Turing test' that contrasts generated and original captured motion. We investigate the categorization of two different emotions (anger and fear) with respect to human- and monkey-specific movements, presenting these movements on human and as well as monkey avatars. RESULTS: Preliminary results suggest that the generated motion is highly accurate and indistinguishable from the original motion-captured motion. Participants are able to recognize human expressions presented on a monkey avatar. The exact dependence of emotion categorization on motion and the avatar type (human or monkey) is presently being studied. This implies that human-specific facial motion can be recognized even when it is presented on the face of another primate species.

Acknowledgement: HFSP RGP0036/2016, DFG GZ: KA 1258/15-1 EC H2020 CogIMon ICT-23-2014 /644727, BMBF FKZ 01GQ1704, BW Stiftung NEU007/1.

36.414 **Facial features for age judgments across cultures** Nicolas Dupuis-Roy[1](nicolasdupuisroy@gmail.com), Frederic Gosselin[1], Qin Lin Zhang[2], Zach Schendel[3], Amir Ashkenazi[3], Ed Covell[3], Kevin Blot[3], Jean-Marc Dessirier[3], Helen Meldrum[3]; [1]Département de psychologie, Université de Montréal, Montréal, QC, Canada., [2]School of Psychology, Southwest University, Chongqing 400715, China, [3]Unilever R & D, Trumbull, CT.

Until recently, face processing was thought to be culturally invariant. Cross-cultural studies have shown, however, that culture shapes how the brain processes face information to recognize expression (Jack et al., 2009; Jack et al., 2012), ethnicity (Blais et al, 2008), or identity (Tardif et al., 2017; Estéphan et al., 2018). Although it is known that the physical signs of facial aging vary across ethnicities—e.g. Chinese skin starts to wrinkle about 10 years after European skin (Nouveau-Richard et. al., 2005)—and that differences in sociocultural practices can impact on the efficiency of facial-age judgments (Anzures et al., 2010), no study has yet investigated how culture affects the use of facial features for making age judgments. We asked 128 Western-Caucasian women and 132 Chinese women from five age groups (20-30, 31-40, 41-50, 51-60, and 61-70 year-olds) to complete a three-hour age estimation task on 300 high-resolution color photos of Western-Caucasian and Chinese women faces from the same five age groups. We applied the Bubbles technique (Gosselin & Schyns, 2001) to reveal directly the facial areas that subtend facial age judgments. Each observer was submitted to 1,600 "bubblized" faces from one ethnicity in a full factorial design. Facial information was sampled through randomly located Gaussian apertures, or "bubbles", at five spatial frequency scales. The GLM was used to assess effects of culture and ethnicity in use of facial information for making age judgments (Murray, 2012). Our most intriguing result is that within-culture age judgments relied mostly on the eye areas in mid-to-high spatial frequencies whereas between-culture age judgments relied on many facial areas spread across all spatial frequencies.

Acknowledgement: Unilever

36.415 **Religious-Contingent Aftereffects for Christian and Muslim Faces** Victoria Foglia[1](fogliav@mcmaster.ca), M.D. Rutherford[1]; [1]McMaster University, Department of Psychology, Neuroscience & Behaviour

Introduction. Face recognition has been attributed to norm-based coding: individual faces are perceived based on their resemblance to a face prototype (Valentine, 1991). These face prototypes are malleable, updating based on changes in faces viewed. Adults have multiple face prototypes based on social categories such as race and gender (Jaquet, Rhodes, & Hayward 2008; Little, DeBruine, & Jones, 2005). Here we test whether faces depicting members of different religions (Christian and Muslim) are perceived using distinct face-templates using an opposing aftereffect paradigm. Methods.120 undergraduates participated, 60 of which were the control condition. During pre-adaptation, participants viewed 48 face pairs of the same model, one compressed by 10% and one expanded by 10% and selected which face they found more attractive. An audio clip introduced the face model with a name associated with one of the two religions. During adaptation, participants viewed Muslim and Christian faces expanded or contracted by 60%, with faces from each religious category altered in the opposite direction. An audio clip labelled the religious identity. During post-adaptation, participants again viewed 48 face pairs, selecting the most attractive. The control participants completed the same procedure with religiously neutral audio clips. Results. There was a significant difference in change scores when viewing Christian versus Muslim faces ($t=2.30$, $p=.041$). In addition, significantly more contracted Christian faces were selected as more attractive than expanded Christians faces in post adaptation ($t=2.982$, $p=.018$), consistent with adaptation. Though the scores for contracted Muslim faces selected did not significantly differ ($t=-1.059$, $p=.320$), the change was in the expected direction, consistent with adaptation. Preliminary results for the experimental condition reveal evidence of opposing aftereffects approaching. There were no significant differences in change scores in the control condition. Evidence of opposing aftereffects implies separate face templates for different categories of religion.

Acknowledgement: Social Sciences and Humanities Research Council (Canada)

36.416 **The Relationships Between Waist-to-Hip Ratio (WHR), Waist-to-Stature Ratio (WSR), and Body Mass Index (BMI) on Ratings of Women's Body Attractiveness and Health** Amanda D Golden Eddy[1](agoldeneddy@csu.fullerton.edu), Jessie J Peissig[1]; [1]Department of Psychology, College of Humanities and Social Sciences, California State University, Fullerton

Evolutionary psychologists hypothesize that men's mate preferences for attractive and healthy women are based on waist-to-hip ratio [WHR], waist-to-stature ratio [WSR], and body mass index [BMI] because these characteristics are informative of fertility (i.e. estrogen levels) (Jasienska, et al., 2004); however these hypotheses are largely unsubstantiated (Jones, et al., 2018). In the current study, participants provided saliva samples, at the same time and day, over four weeks, which were sent to SALIMETRICS to be analyzed. Participants' body characteristics (e.g. waist, hip, height, and weight) were measured to calculate their WHRs, WSRs, and BMIs. Photos of their bodies, excluding their heads, were presented to a separate set of participants, who were randomly assigned to rate the photos using either an attractiveness or health Likert-like scale from 1-7, with 1 being very unattractive or very unhealthy and 7 being very attractive or very healthy. This study revealed a significant positive correlation between attractiveness ratings and health ratings ($r = .895$, $p < .000$). This relationship has been established for faces but not for bodies (Thornhill & Moller, 1997). Preliminary correlations between health ratings and estradiol concentrations showed nonsignifi-

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cant positive correlations (r = .098, p > .739). Although non-significant, the correlation between attractiveness ratings and estradiol concentrations is higher (r = .303, p > .292), suggesting that with more participants this may reach significance. Moreover, WSR (r = -.589, p < .027), and BMI (r = -.617, p < .019) showed a significant negative correlation to attractiveness ratings, however WHR was not significantly correlated to attractiveness ratings (r = -.428, p > .127). Thus, these results suggest that WSR and BMI are better correlates of attractiveness than WHR.

Acknowledgement: Maximizing Access to Research Careers grant to CSUF from the National Institutes of Health [2T34GM008612-23]

36.417 **"You're my doctor?": Stereotype-incongruent identities impair recognition of incidental visual features** Austin A. Baker[1,2](austinacbaker@gmail.com), Jorge Morales[2], Chaz Firestone[2]; [1]Department of Philosophy, Rutgers University, [2]Department of Psychological and Brain Sciences, Johns Hopkins University

Social stereotypes shape our judgments about people around us. What types of judgments are susceptible to such biased interference? A striking example of stereotype bias involves the treatment of people whose identities run counter to our stereotypes—as when women are assumed to be students, research assistants, or nurses rather than professors, principal investigators, or doctors. Can such stereotypes also intrude on representations that have nothing to do with the content of the stereotype in question? Here, we explore how the assumptions we make about other people can impair our ability to process completely incidental, and surprisingly low-level, aspects of their appearance—including even their location in space. We collected professional headshots of male and female physicians from a major medical institution, and asked subjects simply to indicate the direction of the depicted subject's shoulders (left or right)—an extremely straightforward task that subjects performed with near-ceiling accuracy. The key manipulation was a cue on each trial that the upcoming image would be of a "doctor" or a "nurse", and a regularity in the experiment such that "doctor"-labeled images tended to face one way and "nurse"-labeled images tended to face the other way. Even though the gender of the subjects was completely irrelevant to any aspect of the task, subjects were slower to judge the orientation of stereotype-incongruent people (female "doctors" and male "nurses") than stereotype-congruent people (male "doctors" and female "nurses"), even though the images were identical in both conditions (with only the labels changing)—including in a large direct replication. Follow-up experiments without these regularities showed that this effect couldn't be explained by the raw surprisingness of, e.g., seeing a man when expecting a nurse; instead, these results suggest that even straightforward forms of statistical learning (here, between labels and orientations) can be intruded upon by long-held social biases, and in ways that alter processing of incidental and basic visual features.

Acknowledgement: JHU Science of Learning Institute

36.418 **A Quick Read: Affective Empathy Reduces the Time to Recognize Identity in Video Morphs** Pascaline Mugiraneza Munezero[1](pascaline.munezero@richmond.edu), Olivia Stibolt[1], Kendall Stewart[1], Jane Song[1], Thalia Viranda[1], Christopher Cotter[1], Cindy M. Bukach[1]; [1]Psychology, University of Richmond

Empathy is associated with better emotion detection, and studies suggest that this relationship is due to affective rather than cognitive aspects of empathy (Gery, et al., 2009; Balconi, M. & Canavesio, Y., 2014). The ability to recognize emotional expressions is also associated with face recognition (Biotti & Cook, 2016). Further, facial expressions influence identity recognition (Chen at al., 2015). However, there is little current evidence that empathy modulates identity recognition: using the Interpersonal Reactivity Index, our prior study showed that empathy modulated recognition of anger and fear, but not identity. Here, we use the Questionnaire of Cognitive and Affective Empathy (QCAE) to further investigate the relationship between empathy and recognition of facial expression and identity. QCAE measures affective (sharing emotional experience) and cognitive (understanding emotional experience) components of empathy (Reniers et al., 2011). In addition to the QCAE, participants (N = 56) completed identity and emotion recognition tasks by stopping morphed videos as soon as they could recognize the identity or emotion (happy, sad, angry, or fearful) of the model. They then selected the appropriate response in a forced-choice task. Contrary to expectations, neither affective nor cognitive empathy was associated with expression recognition. Others also have failed to find an association with QCAE and expression recognition (Girolamo et al., 2017). Surprisingly, in our current study, high scores on affective empathy were associated with quicker video stop times for identity judgment (r = -0.264, p = 0.05). The faster video-stop time for participants who score high on affective empathy can be explained either by more skillful processing of facial information, or increased self-efficacy.

Acknowledgement: James S. MacDonnell Foundation

36.419 **Variation of empathy in viewers impacts facial features encoded in their mental representation of pain expression.**
Marie-Pier Plouffe Demers [1,3](plom09@uqo.ca), Camille Saumure[1], Daniel Fiset[1], Stéphanie Cormier[1], Miriam Kunz[2], Caroline Blais[1]; [1]Département de psychoéducation et psychologie, Université du Québec en Outaouais, [2]Department of General Practice and Elderly Care Medicine, University of Groningen, [3]Département de psychologie, Université du Québec à Montréal

The experience of pain includes sensory, affective, cognitive and behavioral components (Boccard, 2006) and leads to the contraction of specific facial muscles (Kunz et al., 2012) that are, to some extent, encoded in the mental representation of onlookers (Blais et al., in revision). Exposition to facial expressions of pain has been demonstrated to entail a neural emphatic experience in the viewer (Botvinick et al. 2005, Lamm et al. 2007), which varies as a function of subjects' empathy level (Saarela et al. 2007). This experiment aims to verify the impact of empathy variations on the facial features stored by individuals in their mental representation of pain facial expressions. 54 participants (18 males) were tested with the Reverse correlation method (Mangini & Biederman, 2004). In 500 trials, participants chose from two stimuli the face that looked the most in pain. For each trial, both stimuli consisted of the same base face with random noise superimposed, one with noise pattern added, and the other subtracted. Empathy level was measured using the Emotional Quotient test (Baron-Cohen & Wheelwright, 2004) and used as weight to generate two Classification images (CI) for high-empathy and low-empathy levels. Those CIs were then presented to an independent sample (N=24) who identified High-empathy CI as significantly more intense in regions usually associated with pain expression (i.e. brow lowering [x2=24, p< 0.005], nose wrinkling/upper lip raising [x2=10.67, p< 0.05]) and eyes narrowing [x2=6, p< 0.05]). A CI of difference was then generated (i.e. High-empathy CI - Low-empathy CI), and submitted to a Stat4CI cluster test (Chauvin et al., 2005) resulting in a significant difference in the mouth area (ZCrit=2.7, K=80, p< 0.025). Taken together these results suggest that mental representation of pain expression varies with individual differences in empathy.

Acknowledgement: Social Sciences and Humanities Research Council

36.420 **Role of implicit social attitude on holistic face perception** Olivia S. Cheung[1](olivia.cheung@nyu.edu), Wei Chen[1], Mahlet T. Kassa[2]; [1]Psychology, Science Division, New York University Abu Dhabi, [2]Center for Mind/Brain Sciences, University of Trento

Most people are experts at recognizing faces and process faces holistically. While individual differences have been observed for the magnitude of holistic face processing, observers generally recognize faces of their own race or age groups better than faces of a different race or age group. It has been suggested that holistic processing is enhanced by increased visual experience and is driven by bottom-up sensory information. However, recent findings revealed mixed evidence that high-level socio-cognitive influences, such as arbitrary assignment of faces to in- vs. out-groups, may also modulate holistic processing. To further investigate socio-cognitive influences on face perception, we examined the effect of implicit social attitude on holistic face processing. While observers may not be consciously aware of their implicit social attitudes towards an out-group, the biases are often consistent across time within individual observers and might potentially influence behavior. Here we used images of infants, a group that the participants (n=59) had little experience with. Holistic processing for infant and adult faces was measured in a composite task; implicit social attitude towards infants and adults was measured in an implicit association test. We found that holistic processing, indicated by the congruency effect, was observed for both infant and adult faces at the group level. Among individual participants, implicit biases towards infants ranged from positive to negative. Critically, a significant correlation was observed between the magnitude of implicit social attitude for infants and the magnitude of holistic processing for infant faces (r=.26, p=.047), revealing stronger holistic processing with increased positive implicit social attitude. This finding suggests that individual differences on holistic processing, at least for faces of an 'other' group, are modulated by implicit social attitude. Taken together, holistic processing is unlikely a mere bottom-up perceptual effect, and high-level socio-cognitive processes can influence face perception.

 See page 3 for Abstract Numbering System

36.421 **Individual differences in attractiveness perception predict social inferences, but not all altruistic desires**
Glenn Rose[1](glenn.rose@richmond.edu), Edwin J Burns[1], Cindy Bukach[1]; [1]Department of Psychology, University of Richmond

Attractive faces are perceived to be more extraverted, healthy, trustworthy, intelligent and are more likely to obtain altruistic behaviours from others. We therefore wondered if individual differences in attractiveness perception could also interlink these cues; if I find everyone attractive, am I a more helpful person? We tested this hypothesis across a series of tasks where 29 student participants had to report their perceptions of attractiveness, intelligence, trustworthiness, health, extraversion, employability, parenting skills, and altruistic motivations for a series of faces. We replicated prior work in finding attractive faces were rated more positively on social traits and were more likely to elicit altruistic desires. However, while individual differences in attractiveness perception predicted all social trait appraisals (intelligence, $r = .34$, $p = .036$; extraversion, $r = .65$, $p < .001$; trustworthiness, $r = .76$, $p < .001$, health, $r = .34$, $p = .036$, parenting skills, $r = .57$, $p < .001$), this was not always the case for prosocial motivations. For example, participants who perceived faces as more attractive expressed a greater willingness to pick up hitch-hikers ($r = .49$, $p = .003$) and give people money ($r = .32$, $p = .048$), but had no preference to employ people ($r = .16$, $p = .25$) or provide them with help ($r = .25$, $p = .1$). While these latter two prosocial behaviour dimensions strongly correlated with one another ($r = .72$, $p < .001$), none of our other individual measures could explain their relationship. Our findings suggest individual differences in attractiveness perception contribute to social trait appraisals and some, but not all, feelings of altruistic motivation.

Development: Atypical

Sunday, May 19, 2:45 - 6:45 pm, Pavilion

36.422 **Learning and visual attention across neurodevelopmental conditions: Using Multiple Object-Tracking as a descriptor of visual attention**
Domenico Tullo[1](domenico.tullo@mail.mcgill.ca), Jocelyn Faubert[2], Armando Bertone[1]; [1]McGill University, [2]Université de Montreal

While most studies in Multiple Object-Tracking (MOT) have focused on understanding the mechanisms of visual tracking, recent work has suggested that MOT can be used to characterize individual differences in attention resource capacity (Tullo, et al., 2018).In the current study, we investigated whether repeated practice on an adaptive MOT task could explain the interplay between attention resource capacity and learning in relation to individuals diagnosed with neurodevelopmental conditions. Specifically, we investigated whether MOT performance would differ across neurodevelopmental conditions that are either defined by deficits in attention (e.g., ADHD), or exhibit clinically significant difficulties in attention among other deficiencies (e.g., Autism). We asked whether intelligence, our proxy for cognitive capability, and/or diagnostic profile (i.e., autism, ADHD, Intellectual Disability [ID], and Learning Disability [LD]) predicted learning on daily MOT performance across 15 sessions. Children and adolescents (N=106; Mage=13.51) with a diagnosis of either autism (n=32), ADHD (n=35), or ID/LD (n=39) visually tracked 3 of 8 spheres for 8 seconds. Task difficulty adapted to the participant's capability on a trial-by-trial basis. Performance was defined as the average speed in cm/s, where participants correctly tracked all target items. Results indicated that MOT performance mapped onto a logarithmic function, which resembled a typical learning curve at R2=0.87. Performance improved by 105% from the first to last day of testing. Moreover, day-one performance was predicted by intelligence: R2=0.28, and the rate of change in performance (i.e., learning) differed across diagnostic groups. Children and adolescents with autism (MsD1-1=1.11) demonstrated a greater standardized change than those with ADHD (MsD1-15=0.54) or ID/LD (MsD1-15=0.52). These differences highlight variability in learning capability and attention resource capacity, which vary by diagnosis and higher-level cognitive ability, such as fluid reasoning intelligence. Overall, these findings emphasize the promise and utility of MOT to define both attentional and learning capabilities across individuals.

Acknowledgement: Fonds de recherche du Québec – Santé (FRQS) doctoral fellowship

36.423 **Implicit learning of perceptual distributions in children with ASD**
Lisa Lemmens[1,2](lisa.lemmens@kuleuven.be), Sander Van de Cruys[1,2], Andrey Chetverikov[3], Laurie-Anne Sapey-Triomphe[1,2], Ilse Noens[2,4], Johan Wagemans[1,2]; [1]Laboratory of Experimental Psychology, Brain & Cognition, University of Leuven, Leuven, Belgium, [2]Leuven Autism Research (LAuRes), University of Leuven, Leuven, Belgium., [3]Donders Institute for Brain, Cognition, and Behaviour, Radboud University, Nijmegen, Netherlands, [4]Parenting and Special Education Research Unit, University of Leuven, Leuven, Belgium

Recent theories of autism spectrum disorder (ASD) based on the Predictive Coding framework hypothesize differences in implicit learning based on the statistical regularities of the environment in ASD. Previous studies indicate that children and adults with ASD are able to represent sets of low-level stimuli by its mean when assessed explicitly. However, it is unknown whether and how children with ASD implicitly represent sets of similar low-level stimuli. Chetverikov and colleagues (2016) found evidence for implicit learning of feature distributions' parameters (mean, variance and shape) in adults assessed by repetition and role-reversal effects in an odd-one-out search task. In this study, the odd-one-out search task (Chetverikov et al., 2016) was administered in an ASD group and a typically developing (TD) group of children (10-14y). We aimed for two groups of 25 children, matched for age, IQ and gender ratio. The task consisted of prime and test blocks and the children had to search for the odd-one-out in arrays of differently oriented lines. Within blocks, the orientations of the distractors were sampled from a Gaussian distribution with a constant mean and standard deviation of 10° or 5°. In the test blocks, target distance from the mean of the preceding prime distractor distribution (current-target-to-previous-distractors-distance; CT-PD) was manipulated. The internal model of the distractor distribution can be assessed by plotting reaction times (RTs) as a function of CT-PDs. Preliminary analyses on a subsample of the ASD (N=18) and TD groups (N=26) showed no significant difference in RTs or accuracy between groups. In addition, a significant decrease in RTs with repetitions in prime blocks was found in both groups. RTs in test blocks decreased as CT-PD increased in children with and without ASD. These preliminary results suggest that both children with and without ASD are able to implicitly learn the distractor distributions.

Acknowledgement: Lisa Lemmens is a doctoral fellow, and Sander Van de Cruys a postdoctoral fellow, both of the Research Foundation – Flanders (FWO).This work is supported in part by the Methusalem program by the Flemish Government (METH/14/02), awarded to Johan Wagemans.

36.424 **Learning during noisy vision in 3-year-olds at high and low risk for autism**
Emma K Ward[1](e.ward@donders.ru.nl), Jan K Buitelaar[1, 2], Sabine Hunnius[1]; [1]Donders Institute for Brain, Cognition and Behaviour, Radboud University, [2]Radboud University Medical Centre

Recent accounts of autism claim that due to altered predictive processing, autistic individuals cannot always identify signal from noise in sensory input, which leads to models of the world that are overfitted to specific experiences (Manning et al., 2015; van der Cruys et al., 2017). According to these accounts, information processing differences should be present at a very young age, even before autism can be reliably diagnosed. Due to the hereditary nature of autism, we can currently study the development of the condition by following younger siblings of autistic children. Here, we examined whether these younger siblings have difficulty in distinguishing signal from noise, by manipulating sensory noise in a touchscreen Serial Reaction Time Task (SRTT). In the task, a picture of a frog appeared in a sequence (see Figure 1), and the children were asked to press the frog. In block 1, the sequence was identical on every repetition, while in block 3, the frog's exact location included random jitter; it was possible to learn which lilypad the frog would appear on next, but not precisely where on the lilypad it would appear. According to Predictive Processing accounts of autism, high-risk siblings should show difficulty separating signal from noise, and should thus learn the pattern slower in the block with added jitter. This should be especially pronounced in the children who receive an autism diagnosis themselves. Data collection is ongoing, but so far the results suggest that high-risk children (N=12) do in fact learn the pattern when there is additional noise added to the signal. This is contrary to previous findings (Manning et al., 2015; van der Cruys et al., 2017) and raises questions around when autistic children's performance is and is not influenced by noise in the signal.

36.425 **Differences in Naturalistic Scene-Viewing in Individuals with Genetic Variations Linked to Autism** Jeff Mentch[1](jsmentch@mit.edu)**,** Caroline E. Robertson[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College

Sensory sensitivities are estimated to occur in 90% of individuals with autism, but little is known about the genetic underpinnings of these putative differences. Here, we sought to test how individuals with genetic conditions which are highly penetrant genetic causes of autism allocate visual attention in 360° real-world scenes using a traditional multi-level salience model.10 controls enrolled in this study, along with individuals with Fragile X condition (N = 8) and 16p.11.2 deletion syndrome (N = 4). Participants viewed 40 trials of real-world, 360° panoramic scenes using a head-mounted display. Viewing behavior was measured using an in-headset eye-tracker. During each trial (20s), participants actively explored one novel 360° scene, using head turns to change their viewpoint. We compared individuals' gaze behavior using a traditional multi-level salience model. Gaze-behavior in individuals with 16p.11.2 deletions was relatively less driven by feature-level salience (t=2.86, p=0.015) and relatively more driven by meaning-level salience (t=-2.19, p=0.048). However, this pattern of gaze behavior was not observed for individuals with Fragile X, who showed comparable attentional allocation to controls at both levels (feature-level: t=2.02, p=0.062; meaning-level: t=-0.50, p=0.62). Further, the observed differences in gaze behavior between individuals with 16p and controls were not driven by basic differences in fixation number (t=0.95, p=0.36) or duration (t=-0.16, p=0.88). Similarly, individuals with Fragile X exhibited comparable fixation numbers and durations as controls (both t>0.40, both p>0.13).Our results suggest that attention in real-world scenes is guided by different features for individuals with genetic conditions linked to autism and controls. Together, these results suggest that quantitative measurements of real-world viewing may help distinguish between genetic subgroups of autism.

36.426 **Pupil response trajectories as an index of visual processing across the autism phenotype** Antoinette Sabatino DiCriscio[1](asdicriscio@geisinger.edu)**,** Yirui Hu[2]**,** Vanessa Troiani[1]; [1]Geisinger Autism & Developmental Medicine Institute, [2]Geisinger Center for Health Research

Atypical global-local processing and heightened visual perceptual skill has been consistently described across autism spectrum disorders (ASD). In three eye tracking studies using hierarchical Navon stimuli, we assessed the utility of a novel trajectory-based analysis to quantify dynamic changes in pupil response in the context of visual selection and perception. As a critical first step, we implemented this analysis in healthy adults (N=33) to establish pupil response differences that underlie the selection of local versus global information (Study 1). Results indicated a characteristic constriction in the pupil waveform during the identification of local as compared to global information. In Study 2, we extended this research to a pediatric sample of children (N=34) with and without ASD. Using the combined trajectory patterns across global and local conditions, we identified three, task-induced pupil trajectory groups that may reflect different perceptual strategies. The proportion of children with a diagnosis of ASD was significantly larger in a 'Local-Focus' trajectory group, which was characterized by a narrowing of the pupil when identifying local information. The results from Study 1 and Study 2 indicate that pupil changes may serve as a visual filtering mechanism important for selection that may also underlie the atypical visual processing strategies of individuals with ASD. Finally, in Study 3, we used the same Navon stimuli in a modified task-switching paradigm that required increased cognitive effort, asking participants (N=33) to identify either global or local information based on a visual cue. Again, we identified three task-induced pupil trajectory groups and found higher scores on a quantitative measure of ASD traits associated with a particular trajectory group. Taken together, these results demonstrate the utility of individualized pupil response trajectories in understanding variations in visual selection and perceptual skill across the ASD phenotype.

36.427 **Visual temporal integration windows in 2-year-old toddlers with and without ASD** Julie Freschl[1](julie.freschl001@umb.edu)**,** David Melcher[1,2]**,** Alice Carter [1]**,** Sangya Dhungana[1]**,** Zsuzsa Kaldy[1]**,** Erik Blaser[1]; [1]University of Massachusetts Boston, [2]University of Trento, Center for Mind/Brain Sciences

Previous work on visual differences in autism spectrum disorder (ASD) primarily focused on spatial processing, suggesting a local bias in ASD. Recently, Van der Hallen et al. (2015) argued for a shift from a spatial to temporal explanation for this; individuals with ASD may take longer to construct global representations. A useful measure of temporal processing is the Temporal Integration Window (TIW): if two events fall within the same TIW, they are integrated, if they fall in different TIWs, they are segmented (Blake & Lee, 2005; Wutz & Melcher, 2013). We measured TIWs in 18-36-month-old typically developing (TD) toddlers (N=57), toddlers with ASD (N=51), and adults (N=28) using a visual search, eye tracking task. Each trial consisted of a 4s sequence of two displays (ABAB…), each exposed for a stimulus-onset asynchrony (SOA) of 33,67,133, or 267ms. Each display contained a 4x4 virtual grid of distractors and one target. On integration trials, each display viewed alone has no visible target, but if integrated over time, a 'pop-out' target (that captures gaze) becomes visible. On segmentation trials, the target becomes visible when displays are perceived individually. Shorter SOAs, then, facilitate finding the integration target, while longer SOAs facilitate finding the segmentation target. The 'crossover point' where these two performance functions intersect provides the estimate of the TIW. Toddlers in both groups have longer TIWs (M=138.3ms) than adults (M=55ms), indicating that TIWs decrease with development. While TIWs in toddlers with ASD were longer than TD toddlers' (ASD: M=151.2ms, TD: M=125.3ms), confidence intervals around the TIW estimates were large, meaning this difference was not significant. Analyses are ongoing, but this suggests that temporal processing, measured by the TIW, develops during early childhood but may not differ in ASD at this age.

Acknowledgement: This project was supported by a grant from the National Institute of Mental Health (R21MH117787)

36.428 **Motion sensitivity and perceptual decision making in developmental dyslexia** Gabrielle O'Brien[1](eobrien3@uw.edu)**,** Sung Jun Joo[2]**,** Jason Yeatman[1]; [1]Department of Speech and Hearing Sciences, Institute for Learning and Brain Sciences, University of Washington, [2]Department of Psychology, Pusan National University

A popular hypothesis holds that people with dyslexia have reduced sensitivity to visual motion, possibly originating in abnormalities in the magnocellular pathway. Recently, it has been proposed that dyslexics perform poorly on behavioral psychophysics in general for reasons unrelated to sensitivity, including suboptimal decision-making strategies. We revisit the question of sensitivity to visual motion in poor readers using the drift diffusion model as a tool to tease apart sensitivity from other aspects of decision-making. Seventy five children ages 8-12 with varying levels of reading skill participated in a motion direction discrimination task in which the coherence of the random dots varied from 6% to 48%. Accuracy and reaction times were collected from each participant on 240 trials. Psychometric functions fit to the accuracy data replicated the trend that dyslexic have, on average, slightly higher thresholds than their typically reading peers, although this finding was not significant ($\alpha = 0.053$, SE = 0.34, p =0.136; estimated Cohen's d = 0.5). Reaction time measures revealed a larger effect: median reaction time was negatively correlated with reading ability ($\alpha = -0.21$, SE = 0.055, $p < 0.001$), and a significant interaction of reading ability and response (correct or incorrect) revealed a tendency for poor readers to make relatively faster errors than strong readers ($\alpha = -0.15$, SE = 0.055, p = 0.007). After estimating the parameters of the drift diffusion model for each subject, we found not only that the quality of evidence amassed from dot motion is indeed lower in poor readers (lower drift rate), but also that dyslexics employ a less consistent decision boundary. Thus, some dyslexics may indeed be less able to extract evidence from moving stimuli, but a roughly equal fraction of variance in reading skill can be explained by suboptimal decision making factors unrelated to the stimulus.

36.429 **Action Video Games Improve Multi-sensory Perceptual Noise-Exclusion in Developmental Dyslexia** Simone Gori[1](simone.gori@unibg.it)**,** Sara Bertone[2]**,** Sandro Franceschini[2]**,** Andrea Facoetti[2]; [1] Department of Human and Social Sciences, University of Bergamo, Bergamo 24129, Italy., [2]Developmental and Cognitive Neuroscience Lab, Department of General Psychology, University of Padua, Padova 35131, Italy.

For about 10% of children reading acquisition is extremely difficult because they are affected by a heritable neurobiological disorder called developmental dyslexia (DD), mainly associated to an auditory-phonological disorder. The causal role of cognitive and perceptual deficits typically associated to DD can be investigated through intervention studies. Recently, it has been demonstrated that visual-attention, reading speed and phonological short-term memory could be simultaneously improved by using action video game (AVG) training both in shallow and deep alphabetic orthographies. Here, in a cross-over AVG and non-AVG experimental study, we investigated multi-sensory perceptual noise-exclusion mechanisms, manipulating the signal-noise ratio in a visual and an auditory search task. Our findings showed that after 12 hours of AGV training both visual and auditory perceptual noise-exclusion mechanisms were improved and phonological decoding speed was accelerated in children with DD. These findings suggest that the plasticity of the right multi-sensory fronto-parietal network could explain the reading improvements induced by the AVG training in children with DD.

36.430 **Selective loss of fMRI response to sustained chromatic stimuli In the Parvocellular Layers of the LGN and the Superficial Layer of the SC of Unilateral Adult Amblyopia** Yue Wang[1](844608997@qq.com), Wen Wen[2,3,4], Hong Liu[2,3,4], Peng Zhang[1]; [1]Chinese Academy of Sciences Institute of Biophysics, [2]Department of Ophthalmology & Visual Science, Eye & ENT Hospital, Shanghai Medical College, [3]Key Laboratory of Myopia, Ministry of Health, Fudan University, Shanghai, China, [4]Shanghai Key Laboratory of Visual Impairment and Restoration, Fudan University, Shanghai, China

Amblyopia or lazy eye is the most common cause of uniocular vision loss in adults, caused by a disruption to early visual development, such as monocular deprivation or abnormal binocular interaction. Histological abnormalities and reduced fMRI response have been found in the human lateral geniculate nucleus (LGN), suggesting functional deficits in the early subcortical visual pathways. As the key subcortical visual nuclei, the laminar responses of the human LGN and superior colliculus (SC) are difficult to detect, thus the subcortical neural mechanisms for amblyopia remain poorly understood. Using high resolution fMRI, we measured BOLD signals from the magnocellular and parvocellular layers of the LGN, as well as from different depth in the SC of unilateral amblyopia patients and healthy matched controls. Compared to normal controls and the fellow eye, the amblyopia eye showed a selective reduction of fMRI response to sustained chromatic stimuli in the P layers of the LGN, and in the superficial layers of the SC. No selective response loss was found in the M layers of the LGN. These results indicated a selective loss of parvocellular functions in the subcortical visual pathways of adult amblyopia patients.

36.431 **Intuitive psychophysics: designing new tests of contrast sensitivity, eye movements, and visual field asymmetry for children with cerebral visual impairment** Scott W.J. Mooney[1,2](swj.mooney@gmail.com), N. Jeremy Hill[1,2], Nazia M. Alam[1,2], Glen T. Prusky[1,2,3]; [1]Center for Vision Restoration, Burke Neurological Institute, [2]Blythedale Children's Hospital, [3]Weill Cornell Medical College

Cerebral visual impairment (CVI) classifies visual dysfunction in children arising from brain injury or developmental disorders, and is currently the leading cause of visual dysfunction in children in the developed world. CVI is more heterogenous than injury-induced vision loss in mature brains, is more ambiguous to characterize and treat, and commonly occurs alongside other sensory, cognitive, and motor deficits. Consequently, children with CVI often lack the ability to understand instructions or make the rational, volitional responses required by conventional tests of visual function typically used among high-functioning adults (e.g. acuity, contrast sensitivity, color vision, depth perception, visual fields). Diagnosis of CVI instead relies largely upon the neuro-opthalmological examination, which is designed only to detect overt departures from 'normal' function and cannot provide the resolution needed to differentiate categories of CVI or precisely grade separate dimensions of visual ability. Here, we present evidence that comprehensive psychophysical assessments of visual function can still be conducted in children with CVI by carefully designing tasks that minimize the influence of cognitive, attentional, and communicative deficits. Our novel tasks leverage predictable spatiotemporal patterns in eye movements that are contingent on the visibility and behavior of particular visual stimuli. We have successfully deployed these tasks among brain-injured children to reliably measure contrast sensitivity (see Mooney et al., 2018), quantify the kinematics of saccades and pursuits, and map asymmetries and abnormalities in spatial visual fields. Our findings suggest that non-verbal, intuitive tests of visual function can be conducted among brain-injured populations without sacrificing the precision and efficiency of the best conventional volition-based tasks (e.g. forced-choice paradigms). In some cases, our tasks appear no less efficient—and potentially less tiresome—than standard vision tests currently used among otherwise healthy adults.

Acknowledgement: Blythedale Children's Hospital

36.432 **Multisensory Perception for Action in Newly Sighted Individuals** Marc O. Ernst[1](marc.ernst@uni-ulm.de), Irene Senna[1], Sophia Pfister[1]; [1]Applied Cognitive Psychology, Ulm University, Germany

In our daily life we constantly integrate vision with other sensory signals to build knowledge of the world, and to guide actions. However, would we be able to integrate multisensory signals and to plan visually guided actions if we were deprived from vision during early development? I will here report on a set of studies conducted with Ethiopian children who were classified congenitally blind as they suffered from dense bilateral cataract during early post-natal development, and were surgically treaded years later (5-19 y). We assessed the ability of these individuals to integrate visual information with other senses, and to use visual feedback to guide actions. In one task, we asked participants to haptically explore objects while simultaneously looking at them through a magnifying lens, thereby inducing a discrepancy between senses. With such perturbation tasks, we tested whether newly sighted individuals are able to integrate multisensory signals and make use of this newly acquired visual sense. In another task, we asked participants to wear prism goggles that shifted the apparent location of the pointing target. With this task we tested whether newly sighted individuals are able to minimize the systematic errors by recalibrating the sensorimotor systems. This study provides important insights into their sensorimotor learning skills, which are essential for using vision to guide actions. Current results suggest that sight-recovered children weigh vision systematically less compared with typically developing-children, and are less able to recalibrate the sensorimotor system. This suggests that the newly sighted make use of the visual sense in the concert with the other senses, but also that they require month to years to fully exploit its potentials. In this regard, the use of vision for action seems to be affected particularly strongly by the deprivation in early childhood.

Acknowledgement: DFG DIP ER 542/3-1

36.433 **Visual cortex connectivity variability in congenitally blind individuals** Ella Striem-Amit[1], Smadar Ovadia-Caro[2,3], Ningcong Tong[4], Xiaoying Wang[5], Yanchao Bi[5], Alfonso Caramazza[1,6]; [1]Department of Psychology, Harvard University, Cambridge, MA 02138 USA, [2]Department of Neurology, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany, [3]Berlin School of Mind and Brain, Humboldt-Universität zu Berlin, Berlin, Germany, [4]Boston University, Boston, MA, USA, [5]State Key Laboratory of Cognitive Neuroscience and Learning & IDG/McGovern Institute for Brain Research, Beijing Normal University, Beijing 100875, China, [6]Center for Mind/Brain Sciences, University of Trento, 38068 Rovereto, Italy

Visual cortex organization is highly consistent across individuals, despite being driven by both innate and experience-dependent factors. To what degree does this consistency depend on sensory experience? When the visual cortex partly reorganizes as result of blindness, is the resulting pattern more variable across individuals? We tested this question regarding early (retinotopic) visual cortex functional connectivity patterns in people born blind. Functional connectivity data from people born blind shows large-scale preservation of connectivity patterns within the visual cortex which is consistent across individuals. In contrast to the consistency of the connectivity patterns within the visual cortex, we find inter-subject variability in the plasticity patterns resulting from blindness, for connecting visual and non-visual cortices. Variability is found in these pathways' connectivity not only in the blind, but also across the sighted individuals. These findings suggest that plasticity may operate at unmasking existing variable connectivity patterns in the absence of visual experience. Furthermore, they suggest that the link of such individual differences and variability to behavioral outcomes using different sensory aids and restoration approaches should be tested.

36.434 **Psychophysical Assessment of Contrast Sensitivity Functions in Surface and Hybrid Mexican Tetras** Ashley Rohacek[1](asrohace@utica.edu), Brittany Smith[2], Amy Lindsey[3]; [1]Neuroscience, Utica College, [2]Biochemistry, Utica College, [3]Psychology, Utica College

The Mexican tetra fish (Astyanax mexicanus) is an excellent model to study the genetics of developmental eye disorders because this single species has two distinct evolutionary forms. The surface-dwelling form is pigmented, eyed, and sees, whereas the cave-dwelling form is albino, eyeless, and blind. Hybrid progeny (surface x cavefish) display varying extents of eye/retinal development and pigmentation. Little is known about vision in hybrid Mexican tetras. To assess vision, psychophysical methods were used to determine the contrast sensitivity functions (CSFs) of surface (n=9) and hybrid (n=14) groups. Contrast threshold (T) was measured as a function of spatial frequency for 10 rotating (20rpm) black/white square-wave grating stimuli (10%-100% contrast; 0.25-4.23cpd). One fish at a time was placed in a cylindrical Plexiglas aquarium (d=20.32cm) in the center of a rotating drum (d=30.48cm) lined with one of the gratings. Optokinetic responses (saccadic eye movements of at least 5 seconds during stimulus presentation) were recorded by an observer blind to stimulus. A one-down one-up staircase procedure was used to measure T (P=0.50) for each grating. Results showed that surface fish had a typically shaped vertebrate CSF with maximal sensitivity (1/T) to a range of intermediate spatial frequencies and decreased sensitivity to low and high spatial frequencies. Hybrids had slightly reduced sensitivity at intermediate spatial frequencies and greater sensitivity at the lowest (U=4.50, p< 0.001) and highest (U=9.00, p< 0.001) spatial frequencies tested compared to surface fish. Decreased fall-off at low spatial frequencies observed in hybrids may be due to underdeveloped lateral inhibition mechanisms. Further research is necessary to explain specific mechanisms that underlie differences in vision at low and high spatial frequencies between surface and hybrid fish. These findings suggest that A. mexicanus may be a useful model to study the relationship between genetics and capacity for vision in humans with developmental eye disorders.

36.435 **Spatial and Temporal Visual Perception of Infantile Nystagmus** Avital Moshkovitz[1](1moavital@gmail.com), Inbal Ziv[1], Maria Lev[1], Uri Polat[1]; [1]School of Optometry and Vision Sciences, Faculty of Life Sciences, Bar-Ilan University. Ramat-Gan, Israel

Background: Infantile nystagmus (IN) is a form of spontaneous oscillation of the eyes, which results in excessive motion of images on the retina, accompanied by poor vision including reduction in visual acuity (VA) and contrast sensitivity (CS). The aim of the present work was to investigate the underlying mechanism of the deteriorated visual performance, which is still poorly understood. Methods: Contrast detection for Gabor patch was measured in ten IN and ten normally sighted subjects at a viewing distance of 60 cm and target presentation durations of 60, 120, 240, 320 and 480 ms under monocular and binocular conditions.The spatial frequencies of the Gabors were adjusted to be slightly lower than the cutoff threshold of each subject (IN~3 cpd; controls=9 cpd). Results: Differences in the VA between the eyes in IN were less than one line (0.1 logMar, p< 0.05), showing no amblyopia. Better or poor eyes were categorized based on the VA. Statistically significant differences (p< 0.001) were found between the CS of poor and better eyes for IN but not for the control subjects. The critical durations for the IN was significantly slower than the controls: binocular (369 vs 196), better eye (389 vs 250), poor eye (470 vs 294ms). The critical durations of the better and both eyes were similar highlighting the lack of binocular summation in IN. Finally, no significant differences were observed between the fixation abilities of the poor and better eyes. Conclusions: The observed significant differences in CS between eyes and the longer CD in the poor eye have similar features as in amblyopia. The patterns of eye movements of both eyes in IN are similar suggesting that the underlying cause of the perceptual impairment is due to abnormal cortical developmental of IN subjects rather than an ocular mechanism.

Acknowledgement: ISF(1825/16)

Scene Perception: Places, spatial structure, navigation, affordances

Sunday, May 19, 2:45 - 6:45 pm, Pavilion

36.436 **When a phone in a basket looks like a knife in a cup: Perception and abstraction of visual-spatial relations between objects** Alon Hafri[1](ahafri@gmail.com), Barbara Landau[1], Michael F Bonner[1], Chaz Firestone[1]; [1]Johns Hopkins University

Our minds effortlessly recognize the objects and environments that make up the scenes around us. Yet scene understanding relies on much richer information, including the relationships between objects—such as which objects may be in, on, above, below, behind, or in front of one another. Such spatial relations are the basis for especially sophisticated inferences about the current and future physical state of a scene ("What will fall if I bump this table?" "What will come with if I grab this cup?"). Are such distinctions made by the visual system itself? Here, we ask whether spatial relations are extracted at a sufficiently abstract level such that particular instances of these relations might be confused for one another. Inspired by the observation that certain spatial distinctions show wide agreement across the world's languages, we focus on two cross-linguistically "core" categories—Containment ("in") and Support ("on"). Subjects viewed streams of natural photographs that illustrated relations of either containment (e.g., phone in basket; knife in cup) or support (e.g., spoon on jar; tray on box). They were asked to press one key when a specific target image appeared (e.g., a phone in a basket) and another key for all other images. Although accuracy was quite high, subjects false-alarmed more often for images that matched the target's spatial-relational category than for those that did not, and they were also slower to reject images from the target's spatial-relational category. Put differently: When searching for a knife in a cup, the mind is more likely to confuse these objects with a phone in a basket than with a spoon on a jar. We suggest that the visual system automatically encodes a scene's spatial composition, and it does so in a surprisingly broad way that abstracts over the particular content of any one instance of such relations.

36.437 **Hole-in-the-wall: Perception of 3D shape and affordances from static images in humans and machines** Thomas S Wallis[1, 2](thomas.wallis@uni-tuebingen.de), Marlene Weller[1], Christina M Funke[1, 4], Matthias Bethge[1, 2, 3, 5]; [1]Center for Integrative Neuroscience, Eberhard Karls Universität Tübingen, [2]Bernstein Center for Computational Neuroscience, Tübingen, [3]Tuebingen AI Center, [4]IMPRS-IS Graduate School, [5]Institute for Theoretical Physics, Eberhard Karls Universität Tübingen

One popular toy for toddlers involves sorting block shapes into their respective holes. While toddlers require trial-and-error actions to sort blocks correctly, adults can rapidly see the appropriate solution through visual inspection alone. This feat requires an understanding of 3D shape and mental rotation. We study this task in a simplified vision-only setting by generating "shapes" of varying complexity using square matrices filled with connected binary regions, and "holes" by taking the negative region. "Fits" and "doesn't fit" conditions are created while ensuring that shapes do not match exactly and that the total filled area is the same in both conditions. These matrices are rendered into black-and-white images ("bw") and into more realistic rendered scenes. Human observers performed a single-interval fits / doesn't fit task for two complexity levels for bw and rendered scenes. Performance was high for both bw (average d' high complexity = 2.6, low complexity = 3.1) and rendered scenes (d' high = 2.7, low = 3.1), showing that indeed humans can perform this task well. To assess whether current machine vision systems can learn this task, we finetuned the weights of a convolutional neural network (CNN; ResNet-50) on 250k bw images at four complexity levels. The network achieved a (test) accuracy of 94% (same complexity) and 87% (generalisation on higher complexity). For the same images seen by humans, the network performs better than humans at both complexity levels (d' high = 3.5, low = 4.4), but there was no correlation between human response time and network logit. This suggests that the network is solving the task in a non-humanlike way. While this CNN can learn to exceed human performance at this particular task, we expect the model to fail further tests of generalisation because it does not understand the physical properties of the hole-in-the-wall task.

Acknowledgement: Funded by the German Federal Ministry of Education and Research (BMBF) through the Bernstein Computational Neuroscience Program Tuebingen (FKZ: 01GQ1002), the German Excellency Initiative through the Centre for Integrative Neuroscience Tuebingen (EXC307), and the German Science Foundation (DFG priority program 1527, BE 3848/2-1 and SFB 1233, Robust Vision: Inference Principles and Neural Mechanisms, TP03).

36.438 **Reachable or Not? Perceptual judgments of reachability along the object-scene continuum** Jeongho Park[1](jpark3@fas.harvard.edu), Emilie Josephs[1], Talia Konkle[1]; [1]Department of Psychology, Harvard University

Extensive work has shown that the visuo-motor system is critically sensitive to whether an object is in or out of reach, assessed typically using simple controlled stimuli (e.g. a dot on a desk). Here, we extend this framework, examining people's subjective reachability judgments using computer-generated pictures of everyday environments. To do so, we created 20 different indoor environments (e.g. kitchen, library) using virtual-reality software. All environments had the same physical dimensions, with an extended surface on the back wall (e.g. countertop, desk) containing both central and surrounding objects. A series of 30 snapshot views were taken along a continuum from a full-scale scene view to a close-up view of the central object. In Experiment 1, participants were presented with a set of views and for each view judged whether it was in or out of reach. A single set consisted of 20 views (1 from each environment at a randomized point on the continuum), and overall we obtained 45 judgments for each view of every environment. Over all environments, the average position of 50% reachability was consistently judged to be position 10.4 (out of 30 positions along object-scene continuum, SD = 1.7). In Experiment 2, different participants were presented with these views but instead judged whether they would step forward, backwards, or stay in place, to get a more comfortable view of the environment. Participants chose to step back from the close-up views and to step forward at the far views. Critically, the transition point between these options coincided with the transition point of perceived reachability (mean position=10.5, SD=2.4, t(19)=1.1, n.s). Overall, these results show that

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people can judge subjective reachability in pictures depicting everyday environments. Further, these results suggest that the perceived reachability of a view may automatically factor into perceptual judgments of the environment.

36.439 **Large-scale neural dissociations between views of objects, scenes, and reachable spaces** Emilie L Josephs[1](ejosephs@g.harvard.edu), Talia Konkle[1]; [1]Psychology Department, Harvard University

Space-related processing recruits a network of brain regions separate from those recruited in object-related processing. This dissociation has largely been explored using views of navigable-scale spaces compared to singleton objects.However, in naturalistic visual experience, we encounter spaces intermediate to these extremes, like the tops of desks and kitchen counters, which are not navigable but typically contain multiple objects. How are such intermediate "reachspaces" represented in the brain? Human participants underwent functional neuroimaging in which brain responses to reachspaces were compared with responses to scene and object views (Experiment 1, N=12). We found evidence for at least two regions that prefer reachspaces to both scenes and objects: one in ventral visual cortex (11/12 participants), one in occipito-parietal cortex (10/12 participants), with a potential third region in superior parietal cortex. Reachspace preferences were maintained in these regions even when all images were equalized in luminance, contrast and spatial frequency (Experiment 2a, N=12), indicating that low-level differences alone cannot account for these activation differences. Furthermore, these regions respond more strongly to views of multiple objects on blank backgrounds than to empty near-scale spaces (Experiment 2b), pointing to a role for multi-object processing. Finally, reachspaces elicited activity in both scene- and object-selective ROIs, driving each of these regions to an intermediate degree. Taken together, these results provide evidence for a neural distinction between reachspaces, full-scale scenes, and singleton object views. Broadly, the current evidence suggests that visual representations of reachable environments may draw on object-based and space- based computations, as well as recruiting additional regions to support multi-object processing.

Acknowledgement: Star Family Challenge Grant to TK, NIH Shared Instrumentation Grant S10OD020039

36.440 **Scene feature preferences found in scene selective cortex** Elissa Aminoff[1](eaminoff@fordham.edu), Howard Hughes[2]; [1]Psychology, Fordham University, [2]Integrative Neuroscience, Fordham University

The parahippocampal place area (PPA), retrosplenial complex (RSC), and occipital place area (OPA) have been established as regions of the brain that are more sensitive to processing scenes compared with other visual stimuli (e.g., faces). The current investigation sought to understand what about scenes was preferred by each of these areas. In a slow event related fMRI study, 100 scenes were presented to participants (Aminoff et al., 2015). Results demonstrated that the rank order of magnitude for the 100 scenes was strongly correlated across all regions of scene selective regions of interest (ROIs) but this rank order did not carry over to early visual cortex. We examined what features explained this rank order. Scenes are complex stimuli that vary in visual features such as line orientation and colors; attentional features such as where is someone's eye drawn to; and other features such as whether a social interaction is expected in the scene. Features were defined for each scene through a behavioral study of 20 participants. A linear regression was used to determine the variance accounted for by the range of features. Results demonstrated that the overall model with all the features included had an average r2 over .47. When explaining the rank order averaged across all scene ROIs, the feature that accounted for the most variance was the amount of right angles in the scene. The next strongest feature was the perception of navigation paths in the scene. Interestingly, color palette and whether a social interaction in the scene was expected also had prominent roles in accounting for variance in the rank order.Results will be discussed demonstrating differences across the various scene ROIs, suggesting a division of labor across these regions of the brain.

Acknowledgement: NSF BCS 1439237

36.441 **What lies beyond: Representations of the connectivity structure of the local environment** Rachel C Metzgar[1](rmetzgar@sas.upenn.edu), Michael F Bonner[2], Russell A Epstein[1]; [1]Department of Psychology, University of Pennsylvania, [2]Department of Cognitive Science, Johns Hopkins University

To navigate in a familiar environment, it is useful to have a representation of the relationship between the local perceptual scene and the broader spatial surroundings. It has been suggested that retrosplenial complex (RSC), a scene-selective region of the brain, plays an important role in this function. Here we use multivoxel pattern analysis (MVPA) of fMRI data to test the idea that RSC and other scene-selective regions represent memories of the connections between the local environment and adjacent parts of space. Before scanning, participants (N=18) learned the locations of 32 target objects within 4 environments by navigating through them in immersive virtual reality. Each environment consisted of a rectangular room with two visually identical doors, one of which led to a small closet, the other to an exterior space. We then scanned participants while they viewed snapshots of the corresponding rooms with all objects removed and reported whether the remembered locations of objects were on the left or right from the depicted view. MVPA revealed evidence for coding of the locations of the target objects as a function of their status as either within the local room or through the doors leading to the closet or exterior environment. These effects were most prominent in RSC, but a searchlight analysis suggested that this information was encoded throughout the anterior scene network consisting of RSC, anterior parahippocampal place area, and the caudal inferior parietal lobe (Baldassano et al. 2016; Silson et al. 2016). These findings suggest that anterior scene-selective regions, especially RSC, contain memory representations of the connectivity structure of navigable space. These representations may allow one to identify nearby spaces that are not visible in the current scene but have been encoded in memory through repeated navigational experience.

Acknowledgement: NIH R01 EY022350

36.442 **Scene semantics outperform center bias during scene memorization, image saliency models do not** Taylor R. Hayes[1](trhayes@ucdavis.edu), John M. Henderson[1,2]; [1]Center for Mind and Brain, University of California, Davis, [2]Department of Psychology, University of California, Davis

We must shift our attention to process the complex information in real-world scenes. How do we determine where to focus our attention in scenes? Image saliency theory proposes that our attention is 'pulled' to scene regions that differ in low-level image features (e.g., color, orientation, and/or luminance) from the surrounding regions. However, most image saliency models also produce substantial scene-independent spatial biases to help capture observer center bias. In the present study, we tested whether image saliency models explain scene attention based on scene-dependent image features or simply their scene-independent center bias. Participants (N=65) viewed 40 real-world scenes for 12 seconds while performing a scene memorization task. For each scene, a fixation density map was computed across all participant fixations to summarize scene attention. An image saliency map for each scene was then computed using three of the most cited image saliency models including the Itti & Koch model (Itti, Koch, & Niebur, 1998), the Graph-based Visual Saliency model (GBVS; Harel, Koch, & Perona, 2006), and the Attention Information Maximization model (AIM; Bruce & Tsotsos, 2007). For comparison, semantic feature maps ("meaning maps") were generated using human ratings of the informativeness of isolated scene patches (Henderson & Hayes, 2017). The average squared correlation (R2) between the scene fixation density maps and each image saliency model and its spatial bias were computed separately. The image saliency models on average explained 52% less variance in scene fixation density than their spatial bias alone (IttiKoch bias=0.45, IttiKoch=0.19; GBVS bias=0.46, GBVS=0.37; AIM bias=0.41, AIM=0.08). In comparison, the meaning maps explained on average 14% more variance than the spatial bias models. These results suggest that during scene memorization salient scene regions are weaker predictors of scene attention than a simple center bias model, whereas scene semantics explain additional variance beyond spatial center bias.

Acknowledgement: Supported by NEI/NIH R01EY027792

36.443 **A scene with an invisible wall - Does navigation experience influence scene perception?** Shi Pui Li[1](shipui2005@hotmail.com), Zhengang Lu[2], Soojin Park[1,3]; [1]Department of Cognitive Science, Johns Hopkins University, [2]Department of Psychology, University of Pennsylvania, [3]Department of Psychology, Yonsei University, Korea

Human navigation highly depends on scene perception as an input. However, does the scene perception depend on human navigation as well? Specifically, if you cannot navigate through a scene that is otherwise visually navigable, will it affect the way you perceive the scene? This study aimed to understand how navigation experience influences visual scene perception. Participants first navigated in a virtual reality (VR) outdoor environment and were asked to perform an object detection task at a particular location. In half of the environments, after performing the object detection task, they could walk through the scene to return to their starting point. Critically, in the other half, they could not walk through the scene although it was visually navigable, as if there was an invisible wall blocking their navigation. In this case, they had to turn back and choose another way back to the starting point. Participants navigated in each environment for four times to associate the visual experience with scenes. After the VR navigation phase, they performed a same/different task to judge whether the two scenes were visually the same. Stimuli were scenes captured from the VR environments. Within the 'different' trials where visually different scenes were presented, in half of the trials participants were shown a pair of scenes that had different navigability as experienced from the VR environments, and in the other half they were shown a pair of scenes that matched in navigability. Critically, there were no navigation component in this same/different task. We observed that participants were slower in RT and had higher error rate to answer 'different' when two visually different scenes but with same navigability were presented. These results suggest that past navigation experience with scenes affect the representational distance for scene perception.

36.444 **Learning to Integrate Egocentric and Allocentric Information using a Goal-directed Reward Signal** Arthur W Juliani[1](ajuliani@uoregon.edu), Joseph P Yaconelli[1], Margaret E Sereno[1]; [1]University of Oregon

Recent work in Deep Reinforcement Learning has demonstrated the ability for a parameterized model to learn to solve complex tasks from a sparse reward signal. A consequence of this learning is often a meaningful latent representation of the observational data. The composite nature of neural networks opens the possibility of learning joint representations between not just one, but multiple sensory streams of information. In this work, we train a neural network to learn a joint spatial representation that combines separate egocentric and allocentric visual streams, corresponding to a 3D first-person view and 2D map view. We used a simple 3D environment with a goal-driven navigation task. In order to fully explore the relationship between the two information streams, we employed multiple experimental conditions where each stream contained variable amounts of relevant spatial information, specified as follows. The egocentric perspective could contain one of three levels of information ("None", "Partial" - the goal is invisible, or "Full" - the goal is visible). Likewise, the allocentric perspective contained one of three levels of information: ("None", "Partial" - the goal is present, but self-location is not indicated, or "Full" both the goal position and self-location are indicated). We demonstrate the novel result that a goal-driven reward signal can be used to guide the learning of a joint representation between allocentric and egocentric visual streams. Additionally, in the condition involving imperfect information from both streams ("Partial" - "Partial") the network was able to learn to successfully combine the streams in a representation that contains near-perfect global self-location and orientation information, even when this information was not explicitly available in either visual stream, and allowed for near-optimal performance. We compare these learned representations to those prototypical of the mammalian "cognitive map," as well as compare behavior results between our trained models and human participants.

36.445 **Representation of scene navigability and structure in two distinct cortical pathways** Yoonjung Lee[1](yoonjung.lee812@gmail.com), Soojin Park[1]; [1]Department of Psychology, Yonsei University

Two distinct cortical pathways have been identified in monkeys and humans for visual processing—dorsal and ventral pathways. Previous studies have identified regions specified for processing visual scene information, one in a dorsal pathway, the Occipital Place Area (OPA) and another in a ventral pathway, the Parahippocampal Place Area (PPA). Here, we examined how neural representation of navigability in scenes arises along the brain regions in two different visual pathways, leading to the two scene-specific regions. We defined the regions extending from the primary visual cortex (V1) through the OPA as a dorsal stream, while those extending from V1 through the PPA as a ventral stream. During fMRI scans, participants (N=14) performed a one-back task while viewing natural outdoor scenes in a blocked design. The scenes were defined by the difference in level of navigability (more-navigable vs. less-navigable) and its global structural property (open vs. closed). Using Representational Similarity Analyses, we discovered that the neural RDMs in the regions of dorsal stream (V3, V3A and the OPA) and the PPA of ventral stream are highly correlated (Kendall's tau-a) with the model RDM of navigability than the model RDM of structure. For the neural RDMs in the regions of ventral stream (V1, ventral V2, VP and V4), we found higher correlation with the structure model than the navigability model. These results suggest differential contribution of the dorsal and the ventral stream in representing the navigability and structure of scenes. Importantly, navigability decoding index, computed by subtracting correlation coefficients of structure model from those of navigability model for each individual, was only significant for the OPA. These results suggest that OPA in the dorsal stream is at the apex of representing navigability in scenes, supporting a rapid computation of navigational affordance in visual scenes.

Acknowledgement: This work was supported by a grant from the National Eye Institute (NEI R01EY026042, to SP)

36.446 **A voxel-wise encoding model for VR-navigation maps view-direction tuning at 7T-fMRI** Matthias Nau[1](matthias.nau@ntnu.no), Tobias Navarro Schröder[1], Markus Frey[1], Christian F. Doeller[1,2]; [1]Kavli Institute for Systems Neuroscience, NTNU, Trondheim, Norway, [2]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

The brain derives cognitive maps from visual inputs, posing the important question how information is transformed and communicated across the neural systems involved. Inspired by the prior success of encoding models at characterizing the tuning and topography of responses in the visual cortex, we developed voxel-wise and multivariate encoding models to examine networks supporting spatial orienting during active navigation. We used 7T-fMRI to monitor brain activity at submillimeter resolution while participants freely navigated in a virtual environment. We combined their virtual view direction (vVD) with a variety of circular-gaussian vVD-basis functions that differed in kernel spacing and width. For each parameter set, we then estimated model weights using an iterative training procedure that maximized predictability to find the optimal parameters explaining each voxel's time course. Using the resulting model weights, we examined fMRI-responses in held-out data to show that vVD predicts activity in early visual, medioparietal and parahippocampal cortices involved in self-motion- and scene processing, as well as in mediotemporal regions known to support navigation, like the entorhinal cortex. The activity in each region was best predicted with distinct vVD-tuning widths that increased anteriorly from medioparietal to entorhinal cortices. Inverting the encoding model reconstructed vVD from fMRI responses also in regions with high-level mnemonic function, like the hippocampus, and revealed a vVD-tuning topology within the entorhinal cortex, akin to the topology of head direction representations previously observed in rodents. Our approach demonstrates the feasibility of using encoding models to study visual tuning during naturalistic behaviors, and sheds new light on how the currently viewed scene is encoded in the brain during active navigation.

36.447 **Why Uber Drivers Scare You: Detecting Road Hazards With Peripheral Vision** Benjamin A Wolfe[1](bwolfe@mit.edu), Ruth Rosenholtz[2]; [1]CSAIL, Massachusetts Institute of Technology, [2]Brain and Cognitive Sciences, Massachusetts Institute of Technology

Perceiving the gist of real-world static images is fast. At VSS2018, Wolfe and Rosenholtz showed similar rapid understanding of videos of driving. On road, the driver's environment changes quickly, requiring prompt hazard detection to avoid collisions, yet research in driving has argued that merely perceiving the environment requires seconds, not milliseconds. The Wolfe and Rosenholtz work demonstrated that drivers could detect pre-collision hazards in novel road scenes with as little as 200 ms of video. In addition, they showed that drivers could understand the scene sufficiently to evade the hazard with as little as 400 ms. However, these experiments did not constrain gaze. How might subjects' ability to detect hazards change if they were forced to use peripheral vision exclusively, fixating a location similar to where Uber drivers mount their smartphones? Using stimuli from Wolfe and Rosenholtz' 2018 work, drivers were required to maintain fixation at a location 20° below the center of the display and asked to detect hazards. This was done using a three down / one up staircase procedure to determine drivers' individual video threshold durations for detecting hazards with peripheral vision alone. When forced to use peripheral vision, drivers' mean thresholds rose significantly compared to free-viewing (787 ms in this experiment vs 468 ms in Wolfe and Rosenholtz' 2018 work), a 319 ms penalty, equivalent to 10 m at 104 kph. So: why do Uber drivers scare you? They trust their peripheral vision too much. It is useful, but not sufficient to keep everyone safe.

Acknowledgement: TRI-CSAIL Joint Partnership

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Temporal Processing: Duration

Sunday, May 19, 2:45 - 6:45 pm, Pavilion

36.448 **Time after time: Repeated failure to support the space/time claims of Casasanto and Boroditsky (2008)** Shelby N Billups[1](sbillup1@swarthmore.edu), Augustin Burchell[1], Elisabeth A Gillham[1], Maya Smith[1], Frank H Durgin[1]; [1]Department of Psychology, Swarthmore College

Casasanto and Boroditsky (2008) published an influential paper arguing for non-linguistic evidence of using space to think about time (asymmetrical dependence).In their task, a spatio-temporal event, such as a moving dot or growing line was used to present temporal durations and spatial extents. The two properties were uncorrelated across trials (though perfectly correlated, moment-to-moment within each trial).Across six experiments, they reported an asymmetrical effect of spatial extent on participants' reproductions of temporal duration. Their analysis of the effect of space on time involved collapsing their time estimation data by distance and reporting evidence of a trend for longer distances to produce longer times, but not vice-versa. The inappropriateness of this style of analysis is evident in their report of R2 values for time and distance predictors that summed to greater than 1. A series of carefully conducted replications revealed contamination of time judgments by distance in only a subset of our participants, resulting in an overall "reliable" trend when collapsed across participants (probably due to inattention rather than metaphor).When spatial parameters were modified so as to make the distances slightly less saliently different, symmetrical effects of time on distance were observed using these same measures, though none of these effects were reliable using more traditional mixed-effects models. Humans can perceive the magnitudes of short intervals of time perfectly well without recourse to perceived distance, so the observed contamination is more likely due to magnitude representation, and unlikely due to metaphor. The space/time asymmetries reported by Casasanto and Boroditsy were (1) likely due to inattention/magnitude interference, (2) may have been due to a subset of participants, and (3) were consistently produced in their experiments using exactly the same spatial and temporal parameters over and over. Small changes to those parameters are sufficient to remove or reverse the asymmetry.

36.449 **Duration of a time interval is perceived longer when you know when it ends** Seonggyu Choe[1](sgchoe@unist.ac.kr), Oh-Sang Kwon[1]; [1]Ulsan National Institute of Science and Technology

Knowledge of the ending time can affect how you perceive the remaining time (e.g. classroom lecture vs. church preaching). Despite the rich literature reporting the effects of various factors, which includes dynamicity of stimulus (Brown, 1995) and familiarity (Witherspoon, 1985), on the perceived duration, quantitative evidence showing how the knowledge about the time itself affects the time perception is lacking. Here, we examined how the perceived duration of a time interval changes when subjects know when the time interval ends. In Experiment 1, we presented a clock hand rotating at a constant speed and asked subjects to reproduce the perceived duration of the rotation by pressing a button. The duration of the rotation was randomly chosen from 10 linearly spaced time intervals ranging from 500ms to 3000ms. Angular speed (24 deg/s to 120 deg/s), starting angle, and rotating direction were randomized. A bar indicating the final angle of the clock hand was presented while the clock hand was rotating, which informed subjects of the ending time. The bar was not presented in a control condition. In Experiment 2, the bar indicating ending time was presented before the start of rotation and disappeared. All other experimental settings were identical to Experiment 1. In Experiment 1, the mean reproduced duration was 10% longer when a bar indicating the ending time was continuously presented ($F(1,13)=15.95$, partial eta squared=.55, $p=.001$) than in the control condition. In Experiment 2, the mean reproduced duration was 9% longer when a bar was presented and disappeared ($F(1,6)=9.67$, partial eta squared=.62, $p=.002$) than in the control condition. Results show that duration of a time interval is perceived longer when subjects know when the interval will end. It was not a critical factor whether the information of the ending time is visually presented or remembered in dilating perceived time.

Acknowledgement: UNIST grant, 2.180426.01

36.450 **Time (The 'Audiovisual Rulez' Remix)** Simon J Cropper[1](scropper@unimelb.edu.au), Liheng W Xu[1], Aurelio M Bruno[2], Alan Johnston[3]; [1]School of Psychological Sciences, University of Melbourne., [2]School of Psychology, University of York, UK., [3]School of Psychology, University of Nottingham, UK.

We are interested in how we perceive time and how we accumulate and use our internal representation of a temporal interval to improve that percept. The work described here continues to examine the perception of short periods of time in visual, auditory and audiovisual stimuli and the subjects' ongoing knowledge of their own performance over repeated trials. Subjects were presented with 2 intervals containing a stimulus of the same duration (1500ms or 3000ms). The stimuli were visual gratings or auditory tones or a combination of the two. Subjects initiated presentation of each interval with a button-press and released the button when they considered the stimulus to be half-way through; they then indicated their 'best estimate' of the pair. Each subject (n=8) performed 500 trails in the same order for 6 different stimulus conditions. Data was analysed in terms of first/second interval; 'best'/'worst' Actual Observer estimate; 'best'/'worst'Ideal Observer estimate. From this we were able to judge both the subject's performance on the task and their insight into their own decisional 'noise' within an Ideal Observer framework. In both sub- and supra-second conditions, audiovisual cues gave an estimation closer to the veridical bisection-point for all subjects compared to the single modality condition. This cannot be explained by simple probability summation across two cue-sources. There was no evidence for a scalar effect of duration in any condition and metacognition of performance was consistently good across conditions. Bayesian statistical modelling strongly supported optimal integration as an explanation of the data. Taken together (VSS 2017/18/19) our data suggest that subjects integrate effectively across modalities to generate an internal estimate of time close to, but subjectively different from, the actual time to be judged. This interval is learned rapidly but constantly updated throughout the observation period and is best explained within a Bayesian framework.

36.451 **Effects of the irrelevant duration information on duration perception** Hitomi Kawahara[1](hitomi@fechner.c.u-tokyo.ac.jp), Yuko Yotsumoto[2]; [1]Department of Integrated Sciences, College of Arts and Sciences, The University of Tokyo, [2]Department of Life Sciences, Graduate School of Arts and Sciences, The University of Tokyo

Human visual system processes information efficiently by selectively allocating attention to the information that is related to one's goal, inhibiting the irrelevant information at the same time. Studies investigating selective visual information processing often focus on space and/or features of the stimuli, however, how we inhibit irrelevant information in temporal domain remains unclear. In the present study, we examined characteristics of duration perception of a target with the presence of irrelevant information. In the experiment, distractor stimuli and a target stimulus were presented on a CRT monitor with various durations. A cue was briefly presented to indicate the location of the target stimulus, followed by presentations of the target and distractors. Subjects were instructed to reproduce the duration of the target by pressing a button while ignoring the distractors' durations. The target duration was either 450, 600, or 750 msec. The number of distractors was either 0, 3, 6, 9, or 11. The durations of the distractors were sampled from uniform distributions whose ranges were 0.8 – 1.2 times that of the target duration. In the analysis, we calculated the mean and the coefficient of variations (C.V.) of the reproduced durations. The results indicated that subjects accurately reproduced the target durations, regardless the number of distractors. On the other hand, C.V. monotonically increased as the number of distractors increased. These results suggest that irrelevant information interferes with duration perception by adding noise to the target representation. We will further discuss the mechanisms of duration perception and how interference occurs during the encoding of durations.

Acknowledgement: KAKENHI (Grant-in-Aid for Scientific Research on Innovative Areas) 17K18693 KAKENHI (Grant-in-Aid for Scientific Resarch (B))16H03749

36.452 **Ensemble perception for durations of visual stimuli** Teruaki Kido[1](tkido@fechner.c.u-tokyo.ac.jp), Yuko Yotsumoto[2]; [1]Graduate School of Arts and Sciences, The University of Tokyo, [2]Department of Life Sciences, The University of Tokyo

Whether our time perception is governed by a single timing system or multiple timing systems has been of interests to researchers. While studies have mainly focused on dedicated or intrinsic processes across modalities, how multiple time information is encoded and processed simultaneously within a modality remains unclear. How multiple visual items presented

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simultaneously are processed has been extensively studied under the name of ensemble perception. In the studies of ensemble perception, however, visual items are presented simultaneously with various spatial distributions with fixed stimulus durations; whether such ensemble perception is or is not possible in the temporal domain has not yet been studied. Here, we measured ensemble perception for durations of items. In the experiment, various numbers of discs were presented, with different durations at various onset times. Onset times of the discs were randomly determined so that the discs had some temporal overlaps with other discs. Participants were instructed to reproduce the mean duration of the discs by pressing a button. The number of discs was either 1, 2, 4, 8, or 16, and the actual mean duration of a set of discs was set to be either 0.5, 0.7, or 0.9 sec. In the analysis, we calculated (1) mean reproduced durations, and (2) coefficient variations (C.V.) of the reproduced durations. The results showed that the participants were able to reproduce the mean durations accurately regardless the number of items. However, C.V. increased monotonically as the number of the discs increased. These results indicate that our visual system is able to track multiple durations and extract ensemble statistics in the temporal domain, although the representation of the temporal information may be vulnerable to simultaneous processing.

Acknowledgement: KAKENHI (Grant-in-Aid for Scientific Research on Innovative Areas) 17K18693, KAKENHI (Grant-in-Aid for Scientific Research (B))16H03749

36.453 **Object substitution occurs when a masker and a target are presented to different eyes** Tomoya Nakamura[1](leventseleve0917@gmail.com), Sofia Lavrenteva[1], Ikuya Murakami[1]; [1]Department of Psychology, the University of Tokyo

Visual backward masking can be explained by two distinct processes, namely detection of low-level spatiotemporal correlations within a monocular pathway and object-level interference at a cyclopean stage. Here we investigated how these two potential mechanisms might impact on the phenomenon called "object substitution masking" that occurs due to the delayed delivery of four surrounding dots neither spatially adjacent nor similar to a target. We used a head-mounted display to compare dichoptic and monocular viewing conditions. In the dichoptic condition, four Landolt-C-like rings at the same eccentricity were presented to one eye, whereas a stimulus (referred to as a "masker") comprised of four dots surrounding one of the rings was presented to the other eye. In the monocular condition, all these stimuli were presented to the same eye. Observers were asked to indicate which part of the ring (referred to as a "target") surrounded by the dots was missing. For baseline conditions, only a single dot at the smallest eccentricity of the four dots was presented. We found a significant decline of correct responses from the baseline performances in some masker-target onset asynchronies as predicted from object substitution masking. This masking effect was quantitatively equivalent between the monocular and dichoptic conditions. Our results demonstrate that object substitution masking stems from interference at a cyclopean level, possibly in reentrant pathways from higher visual areas representing visual objects to lower areas representing images with high spatial resolution. In addition, we found that the single dot used in the baseline conditions deteriorated the performance to the same degree as the four dots did when it was presented at a nearer location to the missing part of the target, implying that multiple underlying mechanisms contribute to the visual masking in the current situation.

Acknowledgement: Supported by KAKENHI 18H05523

36.454 **Association between temporal perception and pupillary response in Red/Blue stimuli** Yuya Kinzuka[1](kinzuka17@vpac.cs.tut.ac.jp), Fumiaki Sato[1], Tetsuto Minami[2], Shigeki Nakauchi[1]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, [2]Electronics-Inspired Interdisciplinary Research Institute (EIIRIS), Toyohashi University of Technology

Background: Potential effects of color to temporal perception has not been sufficiently investigated, when the effect of color red and blue are still controversial. The perceived duration of time is reported to be overestimated induced by hue-arousing color red (e.g., Shibasaki and Masataka, 2014), however, few studies suggest blue was perceived longer (Thönes et al., 2018). Also, study involving monkeys has reported a close relation between perception of passing time and pupil diameter (Suzuki et al., 2016). To this end, this study aims to investigate how our perception of time is associated with pupillary response, which is closely linked to internal factors and neuronal activity in the locus coeruleus. Method: Experimental procedure was based on the latest temporal perception study (Thönes et al., 2018), combining with pupillometry to investigate the correlation between subjective time perception and the pupillary response. In a two-interval duration-discrimination task, two subjectively equiluminant color stimuli (red/blue) were presented continuously on the screen. On each trial, participant indicated which stimulus (former/latter) had been presented for a longer duration, using a numpad. Pupil diameter was recorded by EyeLink 1000PLUS while presentation of the two stimuli. Results and Discussions: The behavioral data suggests that the color red was significantly perceived longer compared to blue stimuli indicated by a shift of the PSE, even though the previous study reported the opposite result. Moreover, sampling trial with the same color condition and same duration condition (which means the two continuous stimuli is physically identical), constriction of the pupillary light reflex (PLR) was significantly larger for stimuli that were judged longer in blue condition, and also slightly larger with red stimuli. These results suggest that subjective temporal perception and pupillary response are somehow directly or indirectly connected, additionally, might be one factor to explain the inconsistent effects of color on time perception.

36.455 **Motor adaptation affects perception of time and numerosity** David Burr[1,2](dave@in.cnr.it), Giovanni Anobile[3], Irene Togoli[1,4], Nicola Domenici[1,5], Roberto Arrighi[1]; [1]Department of Neuroscience, Psychology, Pharmacology and Child Heath, University of Florence, via San Salvi 12, 50135 Florence, Italy, [2]School of Psychology, The University of Sydney, New South Wales, 2006, Australia, [3]Department of Developmental Neuroscience, Stella Maris Scientific Institute, Calambrone Pisa, Italy, [4]International School for Advanced Studies, 34136 Trieste, Italy, [5]Italian Institute of Technology, Genova, Italy

We investigated the effect of motor adaptation on the perception of event duration and numerosity. Participants were asked to tap in mid-air with their dominant hand, either slowly (around 1 Hz), or as fast as possible (5-6 Hz). After 6 seconds of motor adaptation, a test stimulus (high-contrast 1 c/deg grating, drifting at 10 Hz for 300-1000 ms) was presented to the spatial region where the participant had tapped, followed by a similar grating of fixed duration (600 ms) in the opposite visual field. Subjects judged the relative duration of the two stimuli in two-alternative forced-choice, leading to psychometric functions that estimated the apparent duration of the test. Fast tapping decreased the apparent duration of the test, slow tapping increased it, both by about 20%. The effect of hand tapping was spatially specific, confined to a region within 10° of the tapping hand (irrespective of where the hand was positioned), showing that the effect is perceptual rather than cognitive. Similar experiments were performed for estimation of stimulus numerosity, both for random spatial arrays and for temporal sequences of flashes. Fast tapping decreased numerosity of both spatial and temporal sequences, and slow tapping increased it, again by about 20% in each direction. And again, the adaptation effects were confined to a region of 10° around the tapping hand. Tapping had no effect on more basic perceptual aspects such as apparent speed, suggesting that it operates at relatively high levels of analysis, probably in parietal cortex. Finally, we showed that making an abrupt arm movement after the motor adaptation completely annuls the effect of adaptation, resetting the system. Our results reinforce studies suggesting that visual time perception is closely linked with action, and suggest the existence of multiple local visuo-motor clocks.

Acknowledgement: ERC grant ESCPLANE

Motion: Models, neural mechanisms

Sunday, May 19, 2:45 - 6:45 pm, Pavilion

36.456 **A motion aftereffect induced without motion: spatial, temporal and binocular properties, and a computational model** Mark A Georgeson[1](m.a.georgeson@aston.ac.uk), George Mather[2]; [1]School of Life & Health Sciences, Aston University, UK, [2]School of Psychology, University of Lincoln, UK

We describe and quantify an unusual motion aftereffect (MAE), induced by flickering the adapting pattern, not by moving it. Quite unlike the classic MAE, it reverses direction when the test contrast is inverted. Background. Adapting to an image patch ramping from dark to light over time ('brightening') makes a steady test patch appear to be dimming, and vice-versa (Anstis, 1967). Superimposing this temporal afterimage on a test edge makes the test image appear to move (Anstis, 1990). Methods. We adapted to sine-wave gratings (0.3 c/deg) with sawtooth contrast modulation (1-15 Hz), and we nulled the motion seen in a stationary test grating whose spatial phase was offset ±900 from the adapter. We used a 3-choice task to minimize response bias, and found the null point by maximum likelihood. Results. As an index of aftereffect strength, nulling contrast (i) increased nearly linearly with adapting contrast, (ii) varied little with test contrast, and (iii) was a band-pass function of sawtooth flicker rate, peaking at 4 Hz. (iv) It doubled when test duration doubled from 0.5 to 1s, implying that the key factor in nulling was the temporal gradient of the nulling stimulus. (v) In dichoptic viewing, aftereffect strength for the non-adapted eye was about 20% of the adapted eye, implying weak interocular transfer. Conclusions. Models for direction selectivity combine input filters that encode spatial & temporal luminance gradients. In our model these non-directional filters also adapt, and evoke negative afterimages that represent illusory temporal gradients. These combine with spatial gradients of the test image to form illusory motion signals. This model fits the data accurately, and suggests a fast temporal-derivative filter (peak 15 Hz) with tuning similar to M-cells in the primate retina or LGN. The site(s) of this non-directional adaptation may be largely in monocular pathways, before binocular combination.

Acknowledgement: The Leverhulme Trust

36.457 **Adaptation-induced changes to the 'intrinsic' occipital alpha rhythm** Wiremu D Hohaia[1](wiremu.hohaia@uq.net.au), Alan Johnston[2], Kielan Yarrow[3], Derek H Arnold[1]; [1]School of Psychology, The University of Queensland, [2]School of Psychology, The University of Nottingham, [3]Department of Psychology, City University of London

One of the longest-standing observations from human electroencephalographic (EEG) recordings has been that oscillatory power in the alpha frequency range (~7 to 13Hz) is enhanced when people close their eyes. This has been taken as evidence for a particular rhythm of activity intrinsic to visual cortex, which is disrupted by inhibitory interactions between input signals when people open their eyes. We have found that this effect can be modulated via motion adaptation. After adapting to radial motion, the increase in alpha power when people close their eyes is enhanced. This effect is broadly tuned, peaking for motion adaptation of ~10Hz, but it is robust for a range of adaptation frequencies about this value - ruling out a modulated frequency tag as a plausible explanation. The increase in alpha band activity is apparent when eyes are both open and closed. We also show that changes in alpha band activity while the eyes are closed predict the strength of 'stored' motion aftereffects, experienced when people reopen their' eyes. Our data are consistent with activity in visual cortex being entrained at an intrinsic rhythm, which is disrupted by inhibitory interactions. Visual adaptation would reduce inhibition from neural populations responsive to the adaptor, and thereby exaggerate both the intrinsic alpha rhythm, and create the inhibitory imbalance that generates perceptual aftereffects.

36.458 **Top-down Influence of Global Motion Patterns on Local Motion Patterns** Darwin Romulus[1](dromulus2016@fau.edu), Sang W Hong[1,2], Howard Hock[1,2]; [1]Center for Complex Systems, College of Science, Florida Atlantic University, [2]Psychology, College of Science, Florida Atlantic University

Purpose: During the formation of hierarchical motion patterns, the observation of global motion patterns can affect the perception of local motion patterns (Hock, Schöner, Brownlow and Taler, 2011). The purpose of this study is to determine whether global-to-local feedback is specific to areas where locally stimulated motion patterns exist within a global pattern, or whether this feedback generalizes to other spatial locations of the global pattern that are not locally stimulated. Hypothesis: If global-to-local feedback is not spatial location specific, we expect that exposure to a global motion pattern will affect the perception of a local motion that is presented at a location in the visual field that was not previously stimulated by the global motion pattern. Methods: Four motion quartets were organized into a diamond configuration to induce a global motion pattern described as global rotational rocking. After viewing the global motion pattern, participants viewed a single motion quartet which was present in one of two locations: the top portion of the previously presented diamond quartet or along the rotational arc between the top and left portion of the previously presented diamond quartet. After stimulus presentation, participants reported 1) whether they perceived rotational rocking with the four motion quartets, and 2) the direction of motion induced by the individual motion quartet that was presented after the global motion pattern. Results: For the single quartet presented after perception of rotational rocking motion, we found that participants were more likely to report motion as rotation consistent, irrespective of the location of the single motion quartet. Conclusion: Our results suggest the top-down influence of global motion patterns on local motion patterns is not spatial location specific.

36.459 **Decoding of retinal motion signals by cells in macaque MT** Ramanujan T. Raghavan[1], J. Anthony Movshon[1], E. J. Chichilnisky[2]; [1]Center for Neural Science, New York University, New York, 10003, [2]Departments of Neurosurgery and Ophthalmology, and Hansen Experimental Physics Laboratory, Stanford University, Stanford, California 94305

The perception of visual motion emerges from a cascade of computations along the magnocellular pathway, from retina through LGN, V1, and MT. Models of motion processing implicitly assume that a smooth and noiseless representation of the visual scene is conveyed by the retina. But the retinal signal is in fact noisy and discretely sampled in space (cells) and time (spikes), and no studies have investigated how efficiently central visual neurons extract information about visual motion from retinal activity. We have previously shown that populations of parasol (magnocellular-projecting) retinal ganglion cells in the macaque retina signal the speed of motion with a precision at least ten times higher than typical measures of behavioral speed sensitivity. This suggests that information is lost along the magnocellular pathway: central readout of the retinal signal fails to exploit all available information from the retina. To identify the origin of this inefficiency, we compared the fidelity of motion signals in neurons in area MT to that in populations of parasol ganglion cells. We used a common set of moving stimuli – drifting bars with Gaussian luminance profiles – to compare the precision of speed estimates obtained from retinal and cortical neurons. We displayed the bars at various speeds while recording from individual neurons or tens of neurons in MT, and computed a maximum posterior estimate of speed from populations of MT cells recorded individually or simultaneously in different experiments. The precision of the speed estimate derived from the MT populations was roughly ten times lower than the precision of speed estimates computed directly from retinal signals. Under the assumption that these recordings reveal the fidelity of the MT population's speed estimate, the results suggest that the limits on visual motion sensitivity underlying human speed perception arise between the retina and MT.

Acknowledgement: Simons Collaboration on the Global Brain

36.460 **Centre-surround Suppression of Contrast through the Form and Motion Pathways** Daisy J Phillips[1](daisy.phillips@research.uwa.edu.au), Thomas J McDougall[1], David R Badcock[1]; [1]School of Psychological Science, The University of Western Australia

Centre-surround suppression of contrast is the phenomenon where the perceived contrast of a central stimulus is reduced when presented with a surround. A number of stimulus features influence the amount of suppression the surround induces on the perceived contrast of the centre, with the focus of this study being on the orientation and direction of motion of the surround relative to the centre. Suppression declines as the similarity between centre and surround stimulus properties increases and this decline is thought to reflect multiple mechanisms of centre-surround suppression. However, this is yet to be established in the motion pathway in human participants. A two-mechanism model has been proposed involving a narrowly-tuned process, requiring very similar stimuli in the centre and surround, and a weaker, broadly-tuned process unselective for stimulus features. Five participants completed a two-interval forced choice contrast discrimination task relative to a 40% reference. Stimuli included both static and moving Gabor grating patterns whose high contrast (95%) surrounds had either parallel or orthogonal (90°) orientations relative to the centre. The motion manipulation included surrounds drifting in either the same or opposite direction to the centre. The results with static stimuli showed contrast suppression when surrounds were present and replicated the more substantial suppression when the centre and surround had the same orientation than when they were orthogonal. With motion stimuli all surround conditions were significantly more suppressed than the no-surround condition and the surround condition with the same orientation and direction of motion as the centre was significantly more suppressed than either the opposite direction of motion conditions or the orthogonal orientation conditions. There was no difference between the orthogonal orientation conditions and the opposite direction of motion conditions. These findings support the extension of the two mechanism model of contrast suppression to the motion pathways.

Acknowledgement: Grant: NHMRC 1081874

36.461 **Neural, functional, and aesthetic impact of spatially heterogeneous (multistable) flicker** Melisa Menceloglu[1](-mencel@u.northwestern.edu), Marcia Grabowecky[1,2], Satoru Suzuki[1,2]; [1]Department of Psychology, Northwestern University, [2]Interdepartmental Neuroscience Program, Northwestern University

Spatially heterogeneous flicker abounds in nature, fire flames, water surfaces, rustling leaves, etc., and are typically pleasant to observe. One way in which spatially heterogeneous flicker is special is that it is multistable, allowing sensory activation that conforms to the biases of the visual system, resulting in the perception of spontaneous motions and the calibration of the motion detectors. In this sense, heterogeneous flicker may provide especially "natural" signals to the visual system, engaging fluent processes with minimal engagements of top-down controls. Consistent with this idea, multistable flicker (relative to the control flicker with matching local and global temporal statistics) reduced posterior EEG beta power implicated in long-range neural interactions associated with top-down influences that impose constraints on sensory signals. Further, the degree of multistability, the amount of beta-power reduction, and the aesthetic rating of flicker were closely associated. These results are consistent with the idea that the pleasantness of spatially heterogeneous flicker in nature may derive from its multistability that affords fluent and self-calibrating visual processing.

36.462 **Temporal dynamics in MT during motion discrimination with varied temporal weighting strategies** Aaron J Levi[1,2](a-levi@utexas.edu), Alexander C Huk[1,2,3,4]; [1]Center for Perceptual Systems, University of Texas at Austin, [2]Institute of Neuroscience, University of Texas at Austin, [3]Department of Neuroscience, University of Texas at Austin, [4]Department of Psychology, University of Texas at Austin

Work on perceptual decision-making has used observations of time-varying weighting of sensory stimuli to make inferences about static decision mechanisms in the brain (e.g., the efficiency of integration and/or the form of decision bounds). However, recent work has also shown temporal weighting behavior during motion discrimination is flexibly adaptable to stimulus statistics (Levi et al., 2018). Here, we manipulate temporal weighting strategy to probe the flexibility of the time course of the sensory-driven and choice-correlated responses in the macaque middle temporal area (MT). In doing so, we test how various forms of signal and noise may (or may not) propagate through the visual system to impact downstream processing and behavior. We performed extracellular recordings in MT using linear electrode arrays while a macaque performed a motion discrimination task. The task was completed under three temporal stimulus conditions: (i) Flat, where motion strength had equal statistical expectation over time; (ii) Late, where motion expectation was higher during later stimulus pulses; and (iii) Early, where motion expectation was higher during early stimulus pulses. Psychophysical reverse correlation confirmed that the observer could change their temporal weighting strategy to match stimulus statistics. We could then evaluate changes in the time course of sensory and choice-correlated responses in MT. If temporal weighting strategy is implemented by decision mechanisms after feedforward sensory encoding, the sensory-driven response should not change. However, if choice probability indicates the readout of MT spikes, temporal weighting should be evident in its time course. We characterized these response components using a generalized linear model (GLM), which allowed for statistical dissection of sensory gain from choice-related activity. Across the three conditions, the time course of choice-related activity did not map straightforwardly onto the psychophysical weighting strategy. We discuss the implications for revisions to simple feedforward models of reading out MT.

36.463 **Apparent motion of double drift target originates from physical location at short delays but from closer to perceived location at longer delays** Jiahan Hui[1,3](hjh@ibp.ac.cn), Peng Zhang[1], Sheng he[1,2], Peter Ulric Tse[3], Patrick Cavanagh[3,4,5]; [1]State Key lab of brain and cognitive science, Institute of Biophysics, Chinese Academy of Sciences, Beijing 100101, China, [2]Department of Psychology, University of Minnesota, Minneapolis, MN 55455, [3]Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH, USA, [4]Department of Psychology, Glendon College, Toronto, ON, Canada, [5]Centre for Visual Research, York University, Toronto, ON, Canada

In the double-drift stimulus a gabor moves in one direction in the periphery while its internal texture moves in the orthogonal direction. In this case, the perceived trajectory deviates from its physical trajectory by as much as 45° or more (Tse & Hsieh, 2006; Shapiro et al, 2010; Kwon et al, 2015; Lisi & Cavanagh 2015). We tested the effective location of the gabor at the trajectory endpoint by presenting a brief test and having observers judge the the perceived direction of the apparent motion from the point of gabor offset to the point of test onset. On each trial, a double drift gabor moved upward along a 1 dva linear path tilted 22.5° to the left or right of vertical at 8 dva in the periphery. The internal motion of the gabor was set to make the perceived path appear tilted 22.5° on the other side of vertical. At the end of the trajectory, the gabor disappeared and after a random interval of 0-350 ms, a test gabor with no internal drift appeared for 200 ms 1.5 dva vertically above the start point of the initial path, so centered horizontally midway between the physical and illusory endpoints. At short intervals, the apparent motion appeared to originate from the physical location of the endpoint, but at longer intervals, it appeared to originate from about midway between the physical and perceived locations. This result is in agreement with previous reports that immediate saccades go to the physical location of double-drift targets whereas delayed saccades go more to their perceived locations (Massendari, Lisi, Collins, & Cavanagh, 2018; Ueda, Abekawa, & Gomi, 2018).

Acknowledgement: NSF EPSCoR Award #1632738

36.464 **Activity in human visual areas reflects the precision of motion perception** Andrey Chetverikov[1](andrey.a.chetverikov@gmail.com), Janneke F.M. Jehee[1]; [1]Donders Institute for Brain, Cognition, and Behavior, Radboud University

Any neural representation of a visual stimulus is necessarily uncertain, due to sensory noise and ambiguity in the inputs. Recent advances in fMRI decoding provide a principled approach for estimating the amount of uncertainty in cortical stimulus representations (van Bergen, Ma, Pratte & Jehee, 2015, Nature Neuroscience). However, these previous findings were limited to orientation perception. We here demonstrate that a similar decoding approach can be used to characterize the degree of uncertainty in cortical representations of motion. Participants viewed stimuli consisting of dots that moved coherently into a random direction, while their brain activity was measured with fMRI. Shortly after the dots disappeared from the screen, observers reported the direction of motion. Using a probabilistic analysis approach, we decoded the posterior probability distribution of motion direction from activity in visual areas V1-V4, and hMT+. We found that the decoded posterior distributions were generally bimodal, with two distinct peaks separated by roughly 180 degrees. One peak was reliably larger than the other, and centered on the true direction of stimulus motion. This bimodality suggests that the decoded distributions reflected not only motion, but also orientation information in the patterns of cortical activity. To assess the degree to which the decoded distributions reflected perceptual uncertainty, we computed the entropy of the decoded distributions. We compared this measure of uncertainty with behavioral variability, reasoning that a more precise representation in cortex should result in less variable (more precise) behavior. We found that uncertainty decoded from visual cortex was linked to participant behavior. Specifically, the entropy of the decoded distributions reliably predicted the variability in the observers' estimates of motion direction. This suggests that the precision of motion perception can be reliably extracted from activity in human visual cortex.

Acknowledgement: This work was supported by a Radboud Excellence Fellowship (A.C.) and ERC Starting Grant 677601 (J.J.).

36.465 **Evidence from amblyopia for shared processing of motion perception and stereopsis** Arijit Chakraborty[1,2](ari@midwestern.edu), Farnaz Javadian[1], Laurie M. Wilcox[3], Deborah Giaschi[1]; [1]Ophthalmology and Visual Sciences, University of British Columbia, [2]Chicago College of Optometry, Midwestern University, [3]Centre for Vision Research, York University

Amblyopia is a developmental disorder characterized clinically by decreased visual acuity in one eye that cannot be corrected with glasses; the fellow eye usually has normal visual acuity. Deficits on clinical measures of binocular vision, including stereoacuity are also common. Psychophysical measures have revealed 1) disruptions in motion perception, particularly at slow speeds, that affect both eyes, and 2) spared stereopsis for large disparities. Neuroimaging studies have implicated regions of the dorsal and ventral streams in both motion perception and stereopsis, but their shared processing has not been demonstrated. The aim of the current study was to determine whether behavioural measures of motion perception and stereopsis are correlated in typical or atypical vision. Accuracy on a stereoscopic depth discrimination task (0.2 – 3.5 deg disparity range), and coherence thresholds on global motion direction discrimination (0.3 – 30 deg/s dot speed) and motion-defined form orientation discrimination (0.1, 0.9, 5 deg/s dot speed) tasks were obtained from 369 participants (299 with healthy vision and 70 with amblyopia, age: 3-32 years). Visual acuity and stereoacuity were assessed using standardized tests. After controlling for age, significant correlations were

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found between stereoacuity and slow motion-defined form thresholds, and between small-disparity accuracy and slow global motion thresholds. Stereoacuity was shown to be a predictor, independent of visual acuity, of whether an individual has amblyopia. Overall, our results indicate an association between slow motion perception and fine stereopsis, suggesting a shared processing mechanism. There are also treatment implications; deficits in stereopsis and motion perception often persist following standard patching therapy for amblyopia. We hypothesize that these deficits contribute to treatment failure, to amblyopia recurrence, and possibly to the development of deficits in everyday activities such as hand-eye coordination and reading.

Acknowledgement: NSERC Discovery Grant Canada

36.466 **Enhanced auditory segregation in early blind individuals** Jasmine F Awad[1](awadj@uw.edu), Woon Ju Park[1], Ione Fine[1]; [1]Department of Psychology, University of Washington

Early loss of vision forces blind individuals to rely on auditory information to track the position and motion of objects in space. Here we examined whether early blindness leads to an enhanced ability to segregate moving and stationary auditory stimuli on the basis of frequency. Methods. Participants were seven EB individuals and three sighed controls (SC; matched by age and musical experience). Auditory segregation abilities were measured using a psychophysical notch paradigm. Stimuli consisted of three simultaneously presented non-overlapping broadband white noise stimuli. The target was a mid-frequency band (851-1691Hz). Masking notch width was manipulated by changing the width of two flanking masking noise bands. For the narrowest notch the low frequency noise band fell between 300Hz-776Hz, and the high frequency noise band fell between 1856-4800Hz. For the widest notch low and high frequency noise bands fell between 300Hz-534Hz and 2694-4800Hz respectively. In the static task subjects had to detect the presence of the target band, and in the motion task subjects had to report its direction of motion. Amplitude threshold was measured at each notch width and the slope of threshold as a function of notch width was used to characterize auditory filter widths. Results. As expected, thresholds decreased as a function of notch width for both sighted and blind participants, across both tasks (ANOVA, group x task x notch width: $F(4, 70) = 34.53$, $p< 0.0001$). Slopes were steeper in the static task, suggesting narrower filters for detection than motion direction judgments ($F(1, 70) = 11.07$, $p=0.0014$). EB participants showed steeper slopes than SC participants for both tasks, indicating narrower perceptual auditory filters as a result of early blindness $F(4, 70) = 34.53$, $p< 0.0001$). These results suggest that early blindness leads to an increased ability to segregate auditory objects based on auditory frequency.

Acknowledgement: NIH EY014645

36.467 **Theoretical predictions of the perceived motion-direction of same-spatial-frequency plaids** George Sperling[1](sperling@uci.edu), Dantian T. Liu[1], Peng Sun[1], Ling Lin[2]; [1]Department of Cognitive Sciences, University of California, Irvine, [2]AucFocus, Inc., Irvine CA

When two sinewave gratings of possibly different contrasts moving at possibly different velocities in different directions are superimposed (added point by point), the resultant looks like and is called a plaid. Whereas sinewave gratings viewed in circular apertures always appear to move perpendicularly to their stripes, their true motion is ambiguous because the motion component parallel to the stripes is invisible. However, every plaid has a unique representation as a moving rigid object, it can be equivalently produced by the translation of just a single frame. Here, we restrict the analysis of plaids to a narrow range of spatial frequency channels by considering only plaids composed of equal-spatial-frequency components, viewed foveally. The two plaid sinewave components vary independently in contrast (c1,c2), speed (temporal frequency, f1,f2), and angle (θ1,θ2), in an enormous 6-dimensional space. The theory assumptions are: (1) The first-order system processes plaid components of different angles independently and represents each component's direction as a 2-dimensional vector of length cj2/mj and direction θj ; mj is the component's modulation threshold; j=1,2. (2) The third-order system's components are: a rigid-direction plaid-component with amplitude 2ck2, ck=minimum(c1,c2), plus a sinewave component with amplitude |c1-c2|2 and direction θ~k, c~k=maximum(c1,c2). (3) For the first- and third-order motion systems, the output motion-direction vectors Θ1,Θ3 are the vector sums of each system's two component-direction vectors. Data: When both f1,f2≥10Hz (≥15Hz, one observer), only the first-order system is active. When f1=1Hz, f2 =2Hz, the third-order system dominates. (4) The net perceived direction Θ depends on the frequency-dependent relative strength α of the first- and third-order system outputs Θ 1, Θ 3: Θ = Θ 1+α Θ 3. This one-parameter-alpha-theory captures the essence of the data in full ranges of relative contrasts and of relative angles of the components, and a wide range of temporal frequencies. Precise data fits require more parameters.

36.468 **Dynamic non-linear interactions serving speed estimation inferred from channel interactions during ocular following** Guillaume S Masson[1](guillaume.masson@univ-amu.fr), Nikos Gekas[2,4], Andrew I Meso[1,3], Claudio Simoncini[1], Pascal Mamassian[2]; [1]Institut de Neurosciences de la Timone, CNRS & Aix-Marseille Université, France, [2]Laboratoire des Systèmes Perceptifs, CNRS & Ecole Normale Supérieure, France, [3]Department of Psychology, Bournemouth University, UK, [4]Department of Psychology, University of Notthingham, UK

Ocular following responses (OFR) are reflexive eye movements triggered in response to a brief coherent motion of a large area within the visual field. Initial phase of OFR reflects many properties of low-level motion processing. Herein, we probed speed estimation computations by presenting stimuli either from a set of 15 luminance noise stimuli spanning a range of spatiotemporal frequencies (Motion Clouds, MC) or a set of nine superimposed triplets of these components, defining Compound Motion Clouds (CMCs). Our rationale was to use the responses from MCs to predict OFR to MCMs, exploring a range of alternative combination rules. We recorded eye movements to MC/CMCs in 6 participants using a 1000 EyeLink video eyetracker. Volunteers were required to make a 10° centering saccade over a grey background. Large motion patterns (20° diameter) were presented for 400ms at the end of the saccade. Response latency was about 90ms, independent upon MC/CMC properties.We measured likelihoods of eye velocities at different points in time. Early eye velocities ([90-150ms] after motion onset) were best predicted by a linear superposition of responses to MCs (i.e. vector averaging). Beyond 200ms after stimulus onset, responses to CMCs were best predicted by an interaction model, where the contribution of different MCs unveils a pattern of inhibitory and excitatory interactions between the different channels. Similar to perception (Gekas et al Curr Biol 2017), we explored the shape of these spatiotemporal interactions, particularly looking at how information is combined across the orthogonal speed and scale axes. Inhibition of faster speeds was consistently seen, acting as a slow speed prior. Along the scale axis, there was a broad central excitatory pooling beyond which an inhibition whose pattern was more subtle, showing individual differences. We discuss how dynamic implementation of such inhibition influences OFR strength and variability.

Acknowledgement: Agence Nationale de la Recherche (France), Project SPEED

36.469 **Motion Integration and Disambiguation concerted by Feedforward-Feedback Interactions of V1-MT-MSTl** Maximilian P.R. Löhr[1](maximilian.loehr@uni-ulm.de), Daniel Schmid[1], Heiko Neumann[1]; [1]Institute of Neural Information Processing, Ulm University

Problem: Motion detection responds to items within restricted regions in the visual field. Representations are facilitated by more global integration of motion responses to reduce initial stimulus uncertainty (Born & Bradley, Ann Rev Neurosci, 2005). Early stages of cortical processing of motion advance the generation of spatio-temporal input responses in area V1 to build feature representations of direction and speed in area MT. The neural mechanisms underlying such processes are not yet fully understood. Method: We propose a neural model of hierarchically organized areas V1, MT, and MSTl, with feedforward and feedback connections. Each area is formally represented by layers of model cortical columns composed of excitatory and inhibitory neurons with conductance-based activation dynamics. Receptive field sizes increase from V1 to MSTl as feedback kernels decrease from MSTl to V1 in a reverse hierarchy (Hochstein & Ahissar, Neuron, 2002). Top-down feedback and lateral connections enhance activations by modulatory interaction. Together with pool normalization this realizes a distributed up- and down-modulating gain control mechanism. Results and Conclusion: Stimuli motivated by psychophysical experiments were used to probe the model. Model MT feedback modulation and lateral competition leads to de-emphasized normal flow responses in V1 and enhanced intrinsic terminator motions. The speed of component motion of shapes is estimated by maximum likelihood decoding of MT population responses of speed selective cells. Aperture motion was disambiguated by activation growth-cones spreading from feature points via recurrent model MT-MSTl interaction to adapt the populations' direction tuning generating coherent moving form representation. Its temporal signature depends on the boundary length (Pack & Born, Nature, 2001). Lesions of the model demonstrate that especially the feedback connection schemes were indispensable to feature enhancement

Sunday PM

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and shifts in feature coding. Our results suggest how V1, MT, and MSTl feedforward-feedback processing builds a coherent representation of moving forms using distributed representations of different spatio-temporal features.

Acknowledgement: Supported by Baden-Württemberg foundation (project no. NEU012).

36.470 **The construction of global shape with the Tusi and Not-Tusi configurations** Arthur Shapiro[1,2](arthur.shapiro@american.edu), Alex Rose-Henig[3]; [1]Department of Computer Science, American University, [2]Department of Psychology, American University, [3]BASIS Washington DC

Hypocycloids -- a geometrical construction in which a circle rolls inside the circumference of a larger outer circle -- have been studied by vision scientists (Rubin, 1919; Dunker, 1929; Johannson, 1950; Wallach, 1985) because the local motion does not always predict the global organization. Shapiro and Rose-Henig (2012, 2013) presented two versions of hypocycloids: in one, local elements oscillate in straight lines through the outer circle's center (we call this the Tusi configuration, after 13th-century astronomer Nasir al-Din al-Tusi); in another, local elements follow a circular path (the Not-Tusi illusion). The relative phase of the elements determines the global percept (that is, the local elements remain on the same paths, but changing the phases of the elements can lead to the emergence of a hypocycloid or other shapes). We demonstrate that the Tusi and Not-Tusi configurations address fundamental questions concerning interactions between color, motion, attention, and perceptual grouping: 1. Adding noise elements and perturbations to the hypocycloid's path disrupts static and dynamic configurations equally, suggesting (surprisingly) that motion does not add much to processes that create the global percept; 2. Attending to local elements shifts the percept between translational and rotational hypocycloids; 3. Changing a local element's luminance changes the perceived direction of motion, thus separating motion perception based on feature analysis from motion perception based on luminance motion energy; 4. Even though the elements follow the same path, identification of global organization can be disrupted by changing elements' colors and 5. we will discuss methods for translating the configurations into VR environments. Lastly, we will demonstrate other effects based on reverse-phi elements that show that local motion information can be used to create global percepts.

36.471 **Exploring how distance and duration information contributes to speed change discrimination** Abigail RI Lee[1](aril@st-andrews.ac.uk), Justin M Ales[1], Julie M Harris[1]; [1]School of Psychology and Neuroscience, University of St Andrews

Visual speed discrimination has been well studied. However, due to the relationship between speed, distance and time, it is difficult to determine which of these three cues is used for speed discrimination tasks. This problem can be avoided by using a speed change discrimination task, where participants discriminate a stimulus containing a step change in speed from one moving at a constant speed. Speed change discrimination tasks do not contain distance or duration cues, but these tasks are much more difficult than speed discrimination tasks (Lee, Ales & Harris, J Vis., 17(10):416, 2017; Monen & Brenner, Perception, 23(6):681-690, 1994; Snowden & Braddick, Vision Res., 31(5):907-914, 1992). One theory is that speed judgements actually involve the use distance and duration cues present, and this results in improved speed discrimination performance. Here we designed experiments that tease apart distance and duration from speed by carefully manipulating all three cues. The first experiment determined if participants' (n=9) performance in a speed discrimination task was influenced by duration or distance by using stimuli with identical ranges of speeds, but variable duration and distance cues. We found participants' speed discrimination performance depended only on stimulus speed, indicating participants discounted duration and distance and relied purely on speed information. In the second experiment (n=7), we tested whether adding distance or duration information improved speed change discrimination performance. We compared performance in conditions that only contained speed information with performance for stimuli that had additional distance or duration cues. We found no difference in performance between conditions. Our results suggest that speed is the cue used for speed discrimination, and the absence of distance and duration information is not what makes speed change discrimination difficult.

Acknowledgement: This work was supported by the Biotechnology and Biological Sciences Research Council (BBSRC) [grant numbers BB/M010996/1 and BB/M001660/1].

36.472 **Human sensitivity to task-relevant features in speed discrimination** Benjamin M Chin[1](bechin@sas.upenn.edu), Johannes Burge[1,2,3]; [1]Department of Psychology, University of Pennsylvania, Philadelphia, PA, United States of America, [2]Neuroscience Graduate Group, University of Pennsylvania, Philadelphia, PA, United States of America, [3]Bioengineering Graduate Group, University of Pennsylvania, Philadelphia, PA, United States of America

Many statistical methods exist for decomposing visual stimuli into collections of informative features. Which features contain information that human observers are sensitive to? We examine this question in the context of a speed discrimination task with naturalistic stimuli. Overall stimulus contrast impacts speed sensitivity, but it is less well known how the presence (or absence) of features defined by different contrast patterns modulates sensitivity. Here, we directly examine how different features impact human speed perception. To do so, we composed stimuli from two feature libraries learned from natural stimuli. The first library, determined using principal components analysis (PCA), emphasizes stimulus reconstruction; it consists of rank-ordered features that best account for contrast in natural image movies. The second library, determined using accuracy maximization analysis (AMA), emphasizes task-relevance; it consists of rank-ordered features that are most useful for estimating speed in natural image movies. We measured human foveal speed sensitivity in a two-alternative forced choice discrimination experiment. Experimental stimuli (~3º/s; 1x1º; 250ms) were composed by first filtering and then reconstructing natural stimuli with features from each library. Multiple results emerge. First, when stimulus contrast is held constant, stimuli with more task-relevant features yield better discrimination performance. Second, when contrast is mismatched between stimuli, lower contrast stimuli with more task-relevant features yield better performance than higher contrast stimuli that more closely approximate the original images. Third, when uninformative features are added to stimuli that already contain task-relevant features, discrimination performance decreases dramatically. Thus, task-relevance is a critical variable for predicting the outcome of additional information on performance. The current study draws an explicit link between human visual performance and principled statistical methods for assessing the task relevance of different stimulus features. Our data suggest that for speed discrimination, human observers are indeed sensitive to speed-relevant features identified by these principled methods.

Acknowledgement: R01-EY028571

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Attention: Models, neural mechanisms

Monday, May 20, 8:15 - 9:45 am, Talk Room 1

Moderator: Diane Beck

41.11, 8:15 am **Layer-specific modulation of top-down spatial attention in human early visual cortex** Peng Zhang[1,2](cheung870@gmail.com), Chengwen Liu[1,2], chencan Qian[1], Zihao Zhang[1], Sheng He[1,3], Yan Zhuo[1]; [1]State Key Lab of Brain and Cognitive Science,Institute of Biophysics,Chinese Academy of Sciences, Beijing, China, [2]University of Chinese Academy of Sciences, Beijing, China., [3]Department of Psychology, University of Minnesota, USA

Human visual cortex consists of six layers of neurons, with distinct roles in feedforward, feedback and lateral connections. The laminar circuits of attention in the human visual cortex remain largely unknown. Here we investigated how top-down spatial attention modulated layer-specific activities in the human visual cortex, using submillimeter-resolution fMRI at 7 Tesla (with 0.75mm 2d GE-EPI and 0.8mm 3d b-SSFP sequences). Two checkerboard patterns counterphase flickering at 7.5Hz were presented to the left and right side of fixation, at five contrast levels (2.5%, 6%, 14%, 35%, 83%). Subjects were instructed to either pay attention to the left or to the right checkerboards to detect occasional spatial frequency change of the stimulus. Results showed that compared to the middle layer activities, attention modulation was stronger in the superficial and deep layers of V1, and in the superficial layers of V2 and V3. Furthermore, contrast sensitivity was lower in the middle layer than in the superficial layer of V1, consistent with the feedforward input from the LGN. These findings suggest that top-down spatial attention mainly improves output neural signals in the superficial layers of visual cortex that project to higher cortical areas, and deep layer signals that project to the thalamus

Acknowledgement: This research was supported by grants from Bureau of International Cooperation, Chinese Academy of Sciences (153311KYSB20160030), the Project of State Key Laboratory of Ophthalmology, Optometry and Visual Science, Wenzhou Medical University, Wenzhou 325027, and The General Program of National Natural Science Foundation of China (31871107).

41.12, 8:30 am **A TMS-EROS investigation of the role of feedback to early visual cortex in visual awareness.** Ramisha Knight[1](rsknight@illinois.edu), Gabriele Gratton[1,2], Monica Fabiani[1,2], Diane M Beck[1,2]; [1]Beckman Institute, [2]Department of Psychology, University of Illinois at Urbana-Champaign

Although it is well established that early visual cortex (EVC) plays a critical role in visual awareness, it is less clear whether this is due purely to its critical role as input to the visual system or whether it is also necessary during continued cortical dynamics. These two possibilities have been difficult to assess, in part because it is difficult to dissociate input from later processing; that is, most visual experiences originate in the eye and enter the cortex via V1. Here, we bypass V1 input functions by using single-pulse transcranial magnetic stimulation (TMS) over left posterior parietal cortex (PPC) to produce visual experiences in the form of a phosphene. We simultaneously recorded activity in bilateral occipital cortex and under the TMS coil using the event-related optical signal (EROS) to ask whether activity in early visual areas or in PPC is predictive of visual awareness. Critically, since TMS to PPC served as the primary input of visual information into the cortex, any downstream activations in EVC that predict awareness would be due to feedback rather than feedforward mechanisms. TMS intensity was set, for each individual participant (N=12), to evoke a phosphene in 50% of the experimental trials. EROS activity predictive of phosphene perception was then identified by comparing phosphene-present versus phosphene-absent trials. Results indicate that visual cortex activity rather than PPC activity predicts the likelihood of perceiving a phosphene. EVC activity predicts awareness in two temporal intervals: 0-24 ms after the TMS pulse, activity in V1-V2 predicted phosphene perception, the timing of which is consistent with the state of EVC at the time of input being predictive of awareness. Additionally, 38-88 ms after the TMS pulse, activity in V3 predicted phosphene perception, consistent with a role of feedback dynamics in visual awareness.

Acknowledgement: NIH R01EY022605 to DMB MF and GG

41.13, 8:45 am **Pre-stimulation alpha phase/power and gamma power modulate the strength of feedback and feedforward in human visual areas** Lu Shen[1,2](lu.shen2013@gmail.com), Biao Han[1,2,3], Qi Chen[1,2], Rufin VanRullen[4,5]; [1]Center for Studies of Psychological Application and School of Psychology, South China Normal University, Guangzhou 510631, China, [2]Guangdong Key Laboratory of Mental Health and Cognitive Science, South China Normal University, Guangzhou 510631, China, [3]Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen 6500 HB, The Netherlands, [4]Centre National de la Recherche Scientifique, Unité Mixte de Recherche 5549, Faculté de Médecine de Purpan 31052, Toulouse Cedex, France, [5]Université de Toulouse, Centre de Recherche Cerveau et Cognition, Université Paul Sabatier 31062, Toulouse, France

Primate visual cortical areas are organized in a hierarchical manner. Recent laminar studies in monkey visual cortex showed that alpha oscillations tend to propagate in the feedback direction and gamma oscillations in the feedforward direction. Granger causality analysis in human magnetoencephalography showed that oscillations in these two frequency bands were similarly able to characterize the hierarchical cortical organization. Direct evidence for distinct frequency bands in feedforward and feedback information transfer in human cortex, however, is still lacking. Here, by studying stereoencephalography (sEEG) cortico-cortical evoked potential (CCEP) recordings from electrodes implanted in intact brain regions of epileptic patients, we investigated (1) whether alpha and gamma oscillations can characterize feedforward and feedback processing in human visual areas, and (2) if so, how they modulate the neural activities in lower or higher visual areas. Specifically, micro-stimulations were applied to sEEG electrodes in a stimulation site, while significant post-stimulation responses were measured at sEEG electrodes in response sites. Depending on the anatomical locations of the stimulation and response site electrodes, 406 feedforward pairs and 176 feedback pairs were tested in 8 patients. For all pairs, we measured Pearson correlation between pre-stimulation power in the stimulation site and CCEP amplitude in the response site, as well as circular-to-linear correlation between pre-stimulation phase and response amplitude. Results showed that pre-stimulation alpha power negatively modulates response amplitude in the feedback pairs, while pre-stimulation gamma power positively modulates response amplitude in the feedforward pairs. Furthermore, pre-stimulation alpha phase could also significantly modulate response amplitude in the feedback pairs, while no significant pre-stimulation phase effect could be observed at any frequency in the feedforward pairs. Altogether, our results show that alpha oscillatory phase and power and gamma power directly influence the strength of feedback and feedforward connections in human visual areas.

Acknowledgement: ERC Consolidator grant P-CYCLES Number 614244 to RV, Natural Science Foundation of China grant Number 31871138 to QC

41.14, 9:00 am **Biased neural coding of feature-based attentional priority along the visual hierarchy** Mengyuan Gong[1](gongmy@msu.edu), Taosheng Liu[1,2]; [1]Department of Psychology, Michigan State University, [2]Neuroscience Program, Michigan State University

Theories of neural information processing generally assume that sensory input is processed along hierarchical stages that start with analog representations and gradually transition to task-related, abstract representations. While the neural code of such abstract information remains unclear, neurophysiological findings suggest that a scalar code could be used to encode behavioral relevance. Here we test this hypothesis in human fMRI studies, using data from five feature-based attention tasks where participants selected one feature from a compound stimulus containing two features. We found that the majority of voxels in a cortical area showed consistently higher response when subjects attended one feature over the other. We examined this biased coding across brain areas, participants, and stimulus domains, and found robust bias within brain areas, consistent direction of such bias across areas for a given participant, and similar bias for multiple feature types (e.g. color, motion directions and objects). Using a receiver operating characteristics analysis to quantify the magnitude of the bias, we found stronger bias in frontoparietal areas than in visual areas, indicating more abstract representations in high-level areas. We also examined the contribution of this bias to multivariate decoding by removing the mean response from each condition before applying pattern classification. We observed decreased classification accuracies in frontal and parietal areas, but not in visual areas. Our results suggest a gradient coding mechanism along visual hierarchy, where high-dimensional coding in sensory cortex allows fine-grained representation of feature attributes, and low-dimensional (possibly one-dimensional scalar) coding in association cortex facilitates the simple read-out of decision and control variables.

Acknowledgement: R01EY022727

41.15, 9:15 am **Attention is a prerequisite for the neural effects of perceptual predictions** David Richter[1](d.richter@donders.ru.nl), Floris P. de Lange[1]; [1]Donders Institute for Brain, Cognition and Behaviour, Radboud University Nijmegen

Perception is often guided by predictions that we derive from previous experience. However, the automaticity of these perceptual predictions remains a topic of discussion. We and others have previously shown that neural responses to expected compared to unexpected object stimuli are suppressed throughout several cortical areas, including major parts of the ventral visual stream. In the current study, we examined whether these effects require attention to the predictable stimuli. Using fMRI in a sample (n=34) of healthy volunteers, we find that attention to the object stimuli is a prerequisite for the suppression of neural responses by expectation. Moreover, we show that while attention to the object stimulus is required for expectation suppression, the predictive relationship itself does not need to be task-relevant or attended. Our results indicate that predictions derived from previous experience do not always impact sensory processing, but rather emerge selectively when the predictable stimuli are attended.

41.16, 9:30 am **Pulvinar modulation of the contrast response function of cortical neurons along the ventral pathway** Christian Casanova[1](christian.casanova@umontreal.ca), Bruno Oliveira Ferreira de Souza[1], Cortes Nelson[1]; [1]School of Optometry, University of Montreal

The pulvinar has extensive reciprocal connections with the visual cortex, allowing the transthalamic cortico-cortical transfer of visual information. Little is known about the nature of these connections. Classically, neuronal signals are of two types: drivers, that determine the response of their target cells, and modulators, that provide contextual control of neural responses. In the visual system, previous studies characterized thalamocortical projections from the lateral geniculate nucleus as driver while those from the pulvinar, as either drivers or modulators. Here, we characterized the driver/modulatory nature of the thalamic input by their impact on the contrast response function (CRF) of neurons from two distinct cortical areas: areas 17 and 21a. Single-unit responses to gratings presented at different contrasts were recorded in both areas using linear probes before, during and after the GABA inactivation of the lateral (LPl) or medial (LPm) parts of the lateral posterior nucleus. Based on theoretical studies, driver effects may be distinguished as an additive or subtractive effect on the CRF, while modulator acts by a multiplicative or divisive change. In area 17, LPl inactivation modified mostly the Rmax with 63% of cells showing an increased and 37% a decrease of activity. Only 3 cells showed an increase of C50. In area 21a, LPl inactivation yielded an increase in Rmax for most cells (30/35), with only 2 neurons exhibiting changes in C50. Inactivation of the LPm yielded an increase in C50 and Rmax for 1/3 of 21a cells (11/31), while for the rest, only the Rmax increased. These findings indicate that the pulvino-cortical signals are mostly modulatory in area 17 and modulatory and driver in area 21a. The distinctive influence of pulvinar across the cortical hierarchy may play a central role in visual attention mechanisms.

Acknowledgement: CIHR

Monday AM

Object Recognition: Models, neural mechanisms

Monday, May 20, 8:15 - 9:45 am, Talk Room 2

Moderator: Biyu He

41.21, 8:15 am **Revealing the behaviorally-relevant dimensions underlying mental representations of objects** Martin N Hebart[1](martin.hebart@nih.gov), Charles Y Zheng[2], Francisco Pereira[2], Chris I Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, [2]Section on Functional Imaging Methods, National Institute of Mental Health

Humans can identify and categorize visually-presented objects rapidly and without much effort, yet for our everyday interactions with the world some object dimensions (e.g. shape or function) matter more than others. While these behaviorally-relevant dimensions are believed to form the basis of our mental representations of objects, their characterization typically depends on small-scale experiments with synthetic stimuli, often with pre-defined dimensions, thus leaving open the large-scale structure of the behavioral representations on which we ground object recognition and categorization. To fill this gap, we used large-scale online crowdsourcing of behavioral choices in a triplet odd-one-out similarity task. Based on natural images of 1,854 distinct objects and ~1.5 million behavioral responses, we developed a data-driven computational model (sparse positive embedding) that identifies object dimensions by learning to predict behavior in this task. Despite this dataset representing only 0.15% of all possible trials, cross-validated performance was excellent, correctly predicting 63% of individual human responses and approaching noise ceiling (67%). Further, the similarity structure between objects derived from those dimensions exhibited a close correspondence to a reference similarity matrix of 48 objects (r = 0.90).The model identified 49 interpretable dimensions, representing degrees of taxonomic membership (e.g. food), function (e.g. transportation), and perceptual properties (e.g. shape, texture, color). The dimensions were predictive of external behavior, including human typicality judgments, category membership, and object feature norms, suggesting that the dimensions reflect mental representations of objects that generalize beyond the similarity task. Further, independent participants (n = 20) were able to assign values to the dimensions of 20 separate objects, reproducing their similarity structure with high accuracy (r = 0.84). Together, these results reveal an interpretable representational space that accurately describes human similarity judgments for thousands of objects, thus offering a pathway towards a generative model of visual similarity judgments based on the comparison of behaviorally-relevant object dimensions.

Acknowledgement: Feodor-Lynen Fellowship by the Alexander-von-Humboldt Foundation

41.22, 8:30 am **Unique contributions of skeletal structure for object recognition in the visual system** Vladislav Ayzenberg[1](vayzenb@emory.edu), Frederik S Kamps[1], Daniel D Dilks[1], Stella F Lourenco[1]; [1]Emory University

Decades of research in the cognitive and neural sciences have shown that shape perception is crucial for object recognition. However, it remains unknown how object shape is represented to accomplish recognition. Here we used behavioral and neural techniques to test whether human object representations are well described by a model of shape based on an object's skeleton when compared with other computational descriptors of visual similarity. Skeletal representations may be an ideal model for object recognition because they (1) provide a compact description of a shape's structure by describing the relations between contours and component parts, and (2) provide a metric by which to compare the visual similarity between shapes. In a first experiment, we tested whether a model of skeletal similarity was predictive of human behavioral similarity judgments for novel objects. We found that the skeletal model explained the greatest amount of unique variance in participants' judgments (33.13%) when compared with other models of visual similarity (Gabor-jet, GIST, HMAX, AlexNet), suggesting that skeletal descriptions uniquely contribute to object recognition. In a second experiment, we used fMRI and representational similarity analyses to examine whether object-selective regions (LO, pFs), or even early-visual regions, code for an object's skeleton. We found that skeletal similarity explained the greatest amount of unique variance in LO (19.32%) and V3 (18.74%) in the right hemisphere (rLO; rV3), but not in other regions. That a skeletal description was most predictive of rLO is consistent with its role in specifying object shape via the relations between components parts. Moreover, our findings may shed new light on the functional role of V3 in using skeletons to integrate contours into complete shapes. Together, our results highlight the importance of skeletal descriptors for human object recognition and the computation of shape in the visual system.

41.23, 8:45 am **The representation of simultaneously-presented multiple categories in category-selective cortex** Libi Kliger[1](libi.stein@gmail.com), Galit Yovel[1,2]; [1]The School of Psychological Sciences, Tel Aviv University, [2]Sagol School of Neuroscience, Tel Aviv University

According to the normalization framework the neural response to multiple stimuli is normalized by the response of surrounding neurons. Here we attempt to assess the contribution of object-category selectivity - a fundamental feature of high-level visual cortex – to the normalized response to simultaneously-presented multiple categories. Taken together the normalization model and the spatial proximity of category-selective areas, we predicted that the representation of multiple categories would be influenced by the selectivity to all of its components. Particularly, we hypothesized that the relative contribution of each category would be correlated with the selectivity to each of the categories, but in an opposing manner. In an fMRI study, participants were presented with a compound stimulus made of two components: face+body or face+object as well as with isolated face, body and object stimuli. We used a linear model to estimate the relative contribution of each component to the representation of the compound stimulus. Results show that the response to the compound stimuli in face, body and object-selective areas is a weighted mean of the response to each of the isolated components, consistent with a normalization model. The response to the compound stimulus was dominated by the preferred category, but was also influenced by the non-preferred category. A searchlight analysis further shows that the contribution of each isolated component to the compound stimulus was positively correlated to the voxel's selectivity to that component and negatively correlated to the selectivity to the other component in category selective cortex but not in early visual cortex . The same pattern was observed for the face-body and for face-object compound stimuli. We conclude that spatial proximity among category-selective areas together with a normalization mechanism enables a representation of a compound stimulus that preserves the information of each of its categories while maintaining the neural response within the dynamic range.

41.24, 9:00 am **Scene Clutter and Attention Differentially Affect Object Category and Location Representations** Monika Graumann[1,2](monikag@zedat.fu-berlin.de), Caterina Ciuffi[1], Radoslaw M Cichy[1,2,3]; [1]Department of Education and Psychology, Freie Universitaet Berlin, Berlin, [2]Berlin School of Mind and Brain, Humboldt Universitaet Berlin, Berlin, [3]Bernstein Center for Computational Neuroscience, Berlin

Object perception requires the neural representation of both object identity independent of viewing conditions, and the representation of viewing-dependent properties such as location. The seminal view is that such representations emerge respectively in the ventral and dorsal streams. Recent research in monkeys (Hong et al., 2016) has questioned this division observing both types of information in high-level ventral visual cortex when objects are shown in cluttered scenes. However, how such representations emerge over time, how they emerge in the processing cascade of the ventral visual stream, and whether they depend on attention remains unknown. To investigate this, we conducted three experiments in humans using EEG and fMRI, and analyzed data with multivariate pattern classification methods. Experiment 1 (EEG, N=27) investigated the emergence of object category and location representations in time, dependent on clutter level of the background. We found that object location information emerged later when objects were presented in cluttered versus uncluttered scenes. Further analysis of object location and category information showed that the brain carried out the same processing steps with and without scene clutter, but shifted in time. Experiment 2 (fMRI, N=14) corroborated the previous result in space. In particular, when objects were presented in cluttered versus uncluttered scenes, location information emerged in higher regions of the ventral stream hierarchy. Experiment 3 (EEG, N =25) investigated whether disentangling object-specific information from cluttered scenes might require top-down attention. The emergence of location representations depended strongly on attention for cluttered scenes but was independent of attention in uncluttered scenes. In contrast, category representations were affected by attention independent of whether the background was cluttered or not. Together, our results provide a new perspective on the role of ventral visual cortex in object perception and show how attention impacts the underlying neural processing.

Acknowledgement: German Research Foundation CI-241/1-1

41.25, 9:15 am **A dual role of spontaneous neural activity in object recognition** Ella Podvalny[1](ellapodvalny@gmail.com), Matthew W Flounders[1], Leana E King[1], Tom Holroyd[2], Biyu J He[1]; [1]Neuroscience Institute, New York University School of Medicine, New York, New York 10016, [2]Magnetoencephalography Core Facility, National Institute of Mental Health, Bethesda, Maryland 20892

Object recognition relies on both specific knowledge of object categories and general brain states, such as arousal. Here, we hypothesized that these distinct phenomena, "specific" and "general", are reflected in spontaneous fluctuations of neural activity and independently influence recognition of forthcoming object stimuli. We recorded magnetoencephalographic (MEG) activity in participants (N=24) who viewed images of objects presented at recognition threshold. The stimuli were presented briefly at a contrast that was titrated individually for each subject, and, as a result, the subjects reported successful recognition in ~50% of the repeated trials. Using multivariate pattern analysis applied to whole-brain neural signals recorded before stimulus onset, we found two neural processes influencing subjective recognition of forthcoming stimuli: a general process, which ignored stimulus category and correlated with pupil size, and a specific process, which influenced recognition in category-specific manner. We employed Signal Detection Theory (SDT) measures to delineate a role of each spontaneous neural activity process in object recognition behavior. We found that the two processes are doubly dissociable: the general process shifted the criterion of recognition but had no effect on sensitivity, whereas the specific process enhanced sensitivity with no effect on criterion. These findings reveal a dual role of spontaneously-emerging neural activity patterns in object recognition. Furthermore, they shed light on a mechanism of interaction between spontaneous brain activity and sensory input - a fundamental process underlying perceptual inference.

Acknowledgement: This research was supported by National Science Foundation (BCS-1753218, to BJH). BJH further acknowledges support by Klingenstein-Simons Neuroscience Fellowship.

41.26, 9:30 am **Low-frequency oscillations track the contents of visual perception and mental imagery** Siying Xie[1](seeing.xie@gmail.com), Daniel Kaiser[1], Polina Iamshchinina[1], Radoslaw Cichy[1,2,3]; [1]Department of Education and Psychology, Freie Universität Berlin, Berlin, Germany, [2]Berlin School of Mind and Brain, Humboldt-Universität Berlin, Berlin, Germany, [3]Bernstein Center for Computational Neuroscience Berlin, Berlin, Germany

Mental imagery of objects is phenomenologically similar to veridical perception. Agreeing with phenomenology, fMRI studies showed that visual perception and imagery of objects share neural representations. However, the temporal dynamics with which these representations emerge remain elusive. To investigate this, we performed an EEG experiment, which included three conditions: participants either saw one of 12 everyday objects (visual condition) or heard the corresponding words while being instructed to imagine the object (mental imagery condition) or not (auditory-only condition). We performed multivariate classification on oscillatory responses to reveal the time courses of perception and imagery. We conducted two key analyses. Firstly, using time- and frequency-resolved classification, we found that in all three conditions object representations emerged rapidly (from around 110ms) in oscillatory components at 5Hz and 30Hz. Comparing these representations across conditions revealed higher classification in the imagery condition, compared to the auditory-only condition in low frequencies (in the theta and alpha range), indexing additional imagery-specific processing. Secondly, using time-generalization analysis, we found that imagery and visual perception share content-specific representations in the theta and alpha frequencies, which emerge in imagery at around 1000ms and in visual perception from 400ms onwards. Altogether, our results indicate that low-frequency oscillations track the contents of visual perception and imagery in a shared neural format, suggesting that mental imagery is supported by an activation of oscillatory mechanisms also recruited during visual perception.

Acknowledgement: The work was supported by the DFG Emmy Noether Grant (CI-241/1-1) and Chinese Scholarship Council Award (201706750004).

Object Recognition: Reading, domain-specific expertise

Monday, May 20, 10:45 am - 12:15 pm, Talk Room 1

Moderator: Geoffrey Boynton

42.11, 10:45 am **Domain-specific experience determines individual differences in holistic processing** Isabel Gauthier[1](isabel.gauthier@vanderbilt.edu), Kao-Wei Chua[2]; [1]Department of Psychology, Vanderbilt University, [2]Department of Psychology, New York University

Most people process faces holistically and there is great variability in how well they can recognize faces, but individual differences in holistic processing do not predict face recognition ability. The relationship between experience and holistic processing is difficult to uncover in a domain where experience is as high as for faces. To address this, we developed the Vanderbilt Holistic Processing Tests for novel objects (VHPT-NOs), to measure individual differences in holistic processing with artificial stimuli. We found that congruency effects in VHPT-NOs are not contaminated by domain-general effects and that overall part matching performance on these tests taps the same ability as whole object learning on tests of Novel Object Memory (NOMTs, Richler et al., 2017). In a large training study we combine an individual differences approach with an experimental approach and parametrically manipulate experience with novel objects to examine the determinants of holistic processing. Fifty participants each received 10 hours of training to individuate novel objects from 3 categories. Participants received a variable amount of training which was matched for two categories, and the remainder of 10 hours for a third category. At post-test we used the VHPT-NOs to measure holistic processing for each category and assessed object recognition ability with the NOMT. While domain-general visual ability is a predictor of the ability to match object parts, we find that it is the amount of experience people have individuating objects of a category that determines the extent to which they process new objects of this category holistically. This work highlights the benefits of dissociating the influences of domain-general ability and domain-specific experience, typically confounded in measures of performance or "expertise". Individual differences in holistic processing arise from domain-specific experience and these effects may be related to similar effects of experience on other measures of selective attention.

Acknowledgement: This work was supported by the NSF (SBE-0542013 and SMA-1640681).

42.12, 11:00 am **Linking occipital callosal white matter to cortical responses and reading skill** Elizabeth Huber[1,2](ehuber@uw.edu), Emily C Kubota[1,2], Jason D Yeatman[1,2]; [1]Institute for Learning and Brain Sciences, University of Washington, Seattle, WA, [2]Department of Speech and Hearing Sciences, University of Washington, Seattle, WA

A counterintuitive finding in the diffusion MRI literature is the presence of higher radial diffusivity and lower fractional anisotropy in the posterior callosal connections of individuals with greater reading proficiency. These data suggest increased density of inter-hemispheric connections in struggling versus skilled readers, and they have been linked to the hypothesis that reading related functions are not as strongly left-lateralized in struggling readers. However, this relationship has not been tested directly in a single participant group. Further, since callosal connections continue to mature throughout childhood and adolescence, it is unclear how reading experience and maturational factors shape the observed anatomy-behavior relationships. Here, we used diffusion MRI to examine the structure of posterior callosal connections in 55 children (age 6-12) with a range of reading levels. Two modeling approaches were used to estimate axonal water fraction (AWF) from the diffusion MRI data. Participants also completed functional MRI scans designed to localize word-, face- and object-selective responses. A subset (n=36) participated in an intensive reading intervention, with longitudinal behavioral and MRI measurements taken at regular 2-week intervals. In a cross-sectional analysis (n=55), AWF was found to increase with age, consistent with previous work showing maturational changes in myelination. Posterior callosal AWF predicted reading skill, after controlling for age effects: Struggling readers had higher AWF than skilled readers, consistent with increased axonal density and/or greater myelination of inter-hemispheric connections. Word-selective regions localized with fMRI were strongly left lateralized in skilled readers and more bilateral or right-lateralized in struggling readers. Finally, over intervention, AWF remained stable, even as reading skills improved. We therefore suggest that differences in the structure of axons connecting left and right visual cortex emerge early in life and shape subsequent reading development. Other portions of the network remain more malleable, perhaps supporting compensatory mechanisms that can emerge with educational experience.

Acknowledgement: NSF/BSF BCS #1551330 to JDY

42.13, 11:15 am **A precursor of reading: Neural responses to letters strings in the untrained primate inferior temporal cortex predict word recognition behavior** Rishi Rajalingham[1,2](rishi.rajalingham@gmail.com), Kohitij Kar[1,2], Sachi Sanghavi[1,2], Stanislas Dehaene[3,4], James J DiCarlo[1,2]; [1]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, [2]McGovern Institute for Brain Research Massachusetts Institute of Technology, [3]Collège de France, [4]Cognitive Neuroimaging Unit, CEA DSV/I2BM, INSERM, Université Paris-Sud, Université Paris-Saclay, NeuroSpin Center

Skilled human readers can readily recognize written letters and words. This domain of visual recognition --- known as orthographic processing --- is critical to human reading abilities, but it is unclear how such behaviors are supported by neural populations in the human brain. A dominant theory is that the existing representations known to support general object recognition, i.e. the ventral visual pathway, could be "recycled" to support orthographic processing. Importantly, recent work has shown that non-human primates (baboons) can learn to distinguish written English words from pseudowords (lexical decision task), successfully generalizing to novel strings, and exhibiting behavioral error patterns that are consistent with humans. These observations demonstrate that non-human primates, while not capturing the entirety of human reading abilities, provide a unique opportunity to investigate the neuronal mechanisms underlying orthographic processing. Here, we investigated the representation of letters and letter strings in the ventral visual stream of naive macaque monkeys, and asked to what extent these representations could support word recognition. We recorded the activity of hundreds of neurons in V4 and IT while monkeys passively viewed images of letters, English words and non-word strings. We then used biologically plausible linear decoders to test these neuronal populations on word recognition. We found that decoders trained on the IT population responses achieved relatively high performance on this lexical decision task. Importantly, the pattern of errors obtained from the IT population was highly correlated with the corresponding primate behavioral pattern. This behavioral pattern was also reproduced by leading artificial neural network models of the ventral stream, but not by low-level representations. Taken together, these results suggest that, even in untrained non-human primates, the population of IT neurons forms an explicit representation of written words that could be "recycled" to support orthographic processing behaviors, serving as a precursor of reading acquisition in humans.

42.14, 11:30 am **Visually driven reading deficits: The role of object perception and visual attention** Heida M Sigurdardottir[1](heidamaria@gmail.com), Alexandra Arnardottir[1], Eydis T Halldorsdottir[1], Hilma R Omarsdottir[1], Anna S Valgeirsdottir[1]; [1]Icelandic Vision Lab, Department of Psychology, School of Health Sciences, University of Iceland

Several factors could contribute to reading problems, and interest in the contribution of visual processes has recently resurfaced. According to the dorsal view, reading problems could stem from a selective visual attentional disorder. According to the ventral view, reading deficits could stem from problems with specific visual object perception mechanisms. The aim of the current study was threefold. First, to investigate if reading problems are associated with specific deficits in feature-based processing (ventral view), as previous research points to intact holistic processing in dyslexic readers. Second, to replicate previous findings on a relationship between attentionally demanding visual search and reading problems (dorsal view). Finally, to see if these potential problems with object perception and visual attention are linked or largely independent. 60 people participated in the study. All were undergraduate students or had graduated within the past two years. Their history of reading problems and their current reading speed and accuracy were assessed. Featural processing and holistic or global form processing of faces was measured with a face matching task. Visual conjunction search, thought to be attentionally demanding, was measured using lines with a specific combination of orientation and brightness, and visual feature search was measured using a pop-out task. Reading problems appear to be associated with both task-specific problems in feature-based face matching accuracy and slower visual search, especially conjunction search. However, the association between task-specific problems in feature-based face matching

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accuracy and reading problems does not seem to be driven by attentional problems. There is evidence for both the ventral and dorsal view in visually driven reading deficits, but they do not seem to be connected. This indicates that reading problems have more than one underlying factor.

Acknowledgement: This research was supported by grants from the University of Iceland Research Fund and the Icelandic Research Fund (grant number: 174013-051).

42.15, 11:45 am **Word and face recognition in posterior stroke – behavioural patterns and lesion lateralization** Randi Starrfelt[1](randi.starrfelt@psy.ku.dk), Ro J Robotham[1], Sheila J Kerry[2], Grace E Rice[3], Matthew A Lambon Ralph[3], Alex P Leff[2]; [1]Department of Psychology, University of Copenhagen, Denmark, [2]Institute of Cognitive Neuroscience, University College London, UK, [3]Cognition and Brain Sciences Unit, University of Cambridge, UK

Most neuropsychological evidence for category specific deficits in reading and face recognition comes from small-N studies of patients recruited on the basis of selective deficits. Taking a different approach, we recruited patients based on lesion location (Posterior Cerebral Artery-stroke) rather than symptomatology. 58 patients and 31 controls were included. We used a novel paradigm assessing recognition and memory for words, objects, and faces (the WOF-test), as well as typical tests of face recognition (CFMT) and reading aloud (RTs and word length effect). In a case series design, we analyse both group performance (left vs right hemisphere lesion), and single subject deficits, focusing on hemispheric differences in performance with faces and words. For the WOF-test and the CFMT, there were no significant differences in performance between lesion groups. Also, the proportion of patients in the left and right hemisphere groups with face recognition deficits and visual word processing deficits, respectively, did not differ. However, the severity of impairments in reading out loud was greater in the left hemisphere group. Four patients fulfilled the statistical criteria for a dissociation with impaired reading and preserved face recognition performance. These results suggest that face and word processing may be more bilaterally distributed than indicated by single case neuropsychological studies and functional imaging in neurotypicals. However, the observed dissociations indicate that word recognition may rely in part on (left) lateralized processes not involved in face recognition. This complements previous evidence that face recognition may be selectively impaired by right hemisphere stroke.

Acknowledgement: Independent Research Fund Denmark (Sapere Aude)

42.16, 12:00 pm **Parallel spatial channels for word recognition converge at a bottleneck in anterior word-selective cortex** Alex L White[1,2](alexlw@uw.edu), John Palmer[3], Geoffrey M Boynton[3], Jason D Yeatman[1,2]; [1]Institute for Learning & Brain Sciences, University of Washington, [2]Department of Speech & Hearing Sciences, University of Washington, [3]Department of Psychology, University of Washington

In most environments, the visual system is confronted with many relevant objects simultaneously. This is especially true during reading. However, recent behavioral experiments demonstrate that a fundamental processing bottleneck prevents recognition of more than one word at a time (White, Palmer & Boynton, Psychological Science 2018). Here, we used functional magnetic resonance imaging (fMRI) to investigate the neuronal basis of that bottleneck. Fifteen observers viewed masked pairs of words (one on either side of fixation) and performed a semantic categorization task during fMRI scanning. On each trial they were cued to attend selectively to the right word or the left word, or to divide attention between both words. Responses in retinotopic visual cortex were consistent with unlimited capacity parallel processing: the two words were processed by parallel spatial channels, one in each contralateral hemisphere. Responses were higher to attended words than ignored words, but were not reduced when attention was divided, although behavioral performance suffered greatly. We then analyzed responses in word-selective patches of ventral occipito-temporal cortex, which have been termed the "visual word form area(s)". A relatively posterior patch in the left hemisphere responded to words on both sides of fixation but nonetheless, and quite surprisingly, appeared to process them in two spatial channels that can be independently modulated by spatial attention. Therefore, like retinotopic cortex, this area also supports parallel processing prior to the bottleneck. In contrast, a more anterior word-selective region in the left hemisphere showed no spatial or attentional selectivity, consistent with processing after the bottleneck. Our interpretation is that the visual system can process two words in parallel up to a relatively late stage in the ventral stream. Beyond this point there are no longer separable neural populations for the two words, leading to behavioral deficits when dividing attention between words.

Acknowledgement: K99EY029366 to AW and R01 EY12925 to GB and JP

Multisensory Processing

Monday, May 20, 10:45 am - 12:15 pm, Talk Room 2

Moderator: Shinsuke Shimojo

42.21, 10:45 am **Visual Judgements of Grasp Optimality** Guido Maiello[1](guido_maiello@yahoo.it), Marcel Schepko[1], Lina K Klein[1], Vivian C Paulun[1], Roland W Fleming[1]; [1]Department of Experimental Psychology, University of Giessen

Humans strongly rely on vision to guide grasping. Visual grasp selection is highly systematic and consistent across repetitions and participants, suggesting that humans employ a common set of constraints when visually selecting grasps. We formalized these constraints as a set of grasp-cost functions related to torque, grasp axis, grasp aperture, and object visibility, which we have shown predict grasping behavior with striking fidelity. Here, we test if humans can explicitly estimate grasp optimality derived from these grasp-cost functions. We additionally ask whether vision alone is sufficient to compute grasp optimality, or whether sensorimotor feedback is required to link vision to action selection. Stimuli were novel objects made of 10 cubes of brass and wood (side length 2.5 cm) in various configurations. On each object, an optimal and a sub-optimal grasp were selected based on one of the cost functions, while cost for the other constraints was kept approximately constant or counterbalanced. Participants were visually cued as to the location of the grasps on each object via colored markers. In a vision-only session, participants were required to judge which of the two grasps they believed to be better, without ever having grasped the object. In a vision-plus-grasp session, participants were required to attempt both grasps on each object, and again indicate which of the two grasps they judged to be better. Participants (N=11) were already able to judge grasp optimality above chance in the vision-only session (65+/-13% correct, p= 0.0035). Additionally, participants were significantly better at judging grasp optimality in the vision-plus-grasp session (77+/-7% correct, p=0.0081). Together, these findings show that humans can consciously access the visuomotor computations underlying grasp selection, and highlight the fundamental role of sensorimotor feedback in linking visual perception to motor control.

Acknowledgement: This research was supported by the DFG (IRTG-1901: 'The Brain in Action' and SFB-TRR-135: 'Cardinal Mechanisms of Perception'), and an ERC Consolidator Award (ERC-2015-CoG-682859: 'SHAPE'). Guido Maiello was supported by a Marie-Skłodowska-Curie Actions Individual Fellowship (H2020-MSCA-IF-2017: 'VisualGrasping' Project ID: 793660).

42.22, 11:00 am **The Ventriloquist Illusion in the Blind with Retinal Prostheses: Are Auditory-Visual Interactions Restored After Decades of Blindness?** Noelle R B Stiles[1](nstiles@caltech.edu), Vivek R. Patel[1], James D. Weiland[2,3]; [1]Department of Ophthalmology, University of Southern California, 1450 San Pablo Street, Los Angeles, CA, 90033, USA, [2]Department of Biomedical Engineering, University of Michigan, 2800 Plymouth Road, Ann Arbor, MI, 48109, USA, [3]Department of Ophthalmology and Visual Sciences, University of Michigan, 1000 Wall Street, Ann Arbor, MI, 48109, USA

Background: In most individuals, auditory and visual perception have strong interactions and influence over each other.Blindness acquired in adulthood alters these multisensory pathways.During blindness, it has been shown that the senses functionally reorganize, enabling visual cortex to be recruited for auditory processing.It is unknown whether this reorganization is permanent, or whether auditory-visual interactions can be re-established in cases of partial visual recovery. Retinal prostheses restore visual perception to the late blind and provide an opportunity to determine if those auditory-visual connections and interactions are still viable after years of plasticity and neglect. Methods: Participants were seated about 20 inches away from an iMac 27-inch computer.The computer was placed on a black felt covered table and wall.Visual stimuli presented were vertical white rectangles (2.75 inches by 13 inches) on a black background (0.5 second duration). The auditory beeps were 0.07 seconds long and delivered via headphones (auditory location conveyed via intensity differences). Results: We tested Argus II retinal prosthesis patients (N=7) for the auditory-visual illusion, the ventriloquist effect, where the perceived location of an auditory stimulus is modified by the presence of a visual stimulus.These patients showed a significant modification of the auditory perception by the restored prosthetic visual

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perception (N=7; t(6)=4.59, p=0.004) that was not significantly different from sighted participants (N=10; t(15)=1.62, p=0.13).Furthermore, the strength of this auditory-visual interaction in prosthesis patients was significantly partially-correlated to patient's age and their duration of prosthesis use (Age of Argus II user: rho=-0.95, p=0.004, Duration of Argus II use: rho=0.86, p=0.03). Discussion: This result indicates that auditory-visual interactions can be restored after decades of blindness, and that auditory-visual processing pathways and regions can be re-engaged. Furthermore, it indicates the resilience of multimodal interactions to plasticity during blindness.

Acknowledgement: We are grateful for support from the National Institutes of Health, the Philanthropic Educational Organization Scholar Award Program, and Arnold O. Beckman Postdoctoral Scholars Fellowship Program.

42.23, 11:15 am **Spatiotemporal neural representations in high-level visual cortex evoked from sounds** Matthew X Lowe[1](mx-lowe@mit.edu), Yalda Mohsenzadeh[1], Benjamin Lahner[1], Santani Teng[1,2], Ian Charest[3], Aude Oliva[1]; [1]Computer Science and Artificial Intelligence Lab, MIT, [2]Smith-Kettlewell Eye Research Institute, [3]School of Psychology, University of Birmingham

It is well established that areas of high-level visual cortex are selectively driven by visual categories such as places, objects, and faces. These areas include the scene-selective parahippocampal place area (PPA), occipital place area (OPA), and retrosplenial cortex (RSC), the object-selective lateral occipital complex (LOC), and the face-selective fusiform face area (FFA). Here we sought to determine whether neural representations in these regions are evoked without visual input, and if so, how these representations emerge across space and time in the human brain. Using an event-related design, we presented participants (n = 15) with 80 real-world sounds from various sources (animals, human voices, objects, and spaces) and instructed them to form a corresponding mental image with their eyes closed. To trace the emergence of neural representations at both the millisecond and millimeter level, we acquired spatial data from functional magnetic resonance imaging (fMRI) and temporal data from magnetoencephalography (MEG) in independent sessions. Regions of interest (ROIs) were independently localized in auditory and visual cortex. Using similarity-based fusion (Cichy et al., 2014), we correlated MEG and fMRI data to reveal correspondence between temporal and spatial neural dynamics. Our results reveal neural representations evoked from auditory stimuli emerge rapidly in the face-selective FFA, in addition to voice-selective auditory areas (< 100ms). In contrast, representations in scene- and object-selective cortex emerged later (>130ms). We found no evidence for neural representations in early visual cortex, as expected. By tracing the emergence of neural representations in cascade across the human brain, we therefore reveal the differential spatiotemporal neural dynamics of these representations in high-level visual cortex evoked in the absence of visual input. Our findings thus support a multimodal neural framework for sensory representations, and track these emerging neural representations across space and time in the human brain.

Acknowledgement: Vannevar Bush Faculty Fellowship program funded by the ONR grant number N00014-16-1-3116. The experiments were conducted at the Athinoula A. Martinos Imaging Center at the McGovern Institute for Brain Research, Massachusetts Institute of Technology.

42.24, 11:30 am **Vision in the Extreme Periphery (1a):Auditory Modulation of Flicker Perception** Shinsuke Shimojo[1](sshimojo@caltech.edu), Daw-An J Wu[1], Kensuke Shimojo[2], Eiko Shimojo[1], Takashi Suegami[3,1], Mohammad Shehata[4,1], Noelle R Stiles[5], Christopher C Berger[1], Armand R Tanguay Jr.[6,1]; [1]California Institute of Technology (Biology and Biological Engineering), [2]Chandler School, [3]Yamaha Motor Corporation U.S.A., [4]Toyohashi University of Technology, [5]University of Southern California (Keck School of Medicine, Institute for Biomedical Therapeutics), [6]University of Southern California (Departments of Electrical Engineering, Chemical Engineering and Materials Science, Biomedical Engineering, Ophthalmology, and Physics and Astronomy and Neuroscience Graduate Program)

Background: Peripheral vision (20 to 40˚ eccentricity) has been extensively characterized, but there has been little study of the extreme periphery (40 to 95+˚). Extreme peripheral vision is important for behavioral fitness, both in evolutionary history and in modern contexts such as driving and sports.The extreme periphery is also subject to the greatest signal ambiguities, and thus requires the most inferential processing to be effective.We are conducting a series of psychophysical studies to test a general "compensation hypothesis" whereby the ambiguity in the extreme periphery is compensated for by sources such as unambiguous signals from the fovea or another sensory modality. We investigated the perception of flicker rate in the fovea vs. in the extreme periphery, and report a new synchronized sound modulatory effect. Methods: Two targets flickering in synchrony (5 Hz) were presented, one at foveal fixation and the other at various eccentricities (15 to 55˚). Observers (N = 7) reported whether the peripheral stimulus appeared to be faster, at the same frequency but out-of-phase, or in sync. Sounds synchronized with the flickering targets were added in one block. Results: (1) The peripheral flicker appears faster (and/or out-of-phase) compared to the fovea. The effect is stronger in the more extreme periphery. (2) The synchronized sounds suppressed the fast-flicker illusion, causing the two stimuli to be perceived in sync with the foveal flicker. Higher frequency sounds (8 to 10 Hz) retrieved the original effect (apparent faster peripheral flicker).These basic observations were confirmed at the VSS 2017 demo night (N > 150). Discussion: The findings suggest that basic visual properties (e.g., flicker) can be perceived quite differently in the extreme periphery even with stimuli that are well above threshold and well below flicker-fusion limits, indicating that competing integrational weights drive binding among foveal vision, peripheral vision, and auditory inputs.

Acknowledgement: Yamaha Motor Corporation U.S.A., CREST(JST), Tyohashi University of Technology

42.25, 11:45 am **Are you the sort of person who would like this? Quantifying the typicality of aesthetic taste across seeing and hearing** Yi-Chia Chen[1](yi-chia.chen@fas.harvard.edu), Andrew Chang[2], Monica Rosenberg[3], Brian Scholl[3], Laurel J. Trainor[2]; [1]Department of Psychology, Harvard University, [2]Department of Psychology, Neuroscience & Behaviour, McMaster University, [3]Department of Psychology, Yale University

Aesthetic experience seems both regular and idiosyncratic. On one hand, there are powerful regularities in what we tend to find attractive vs. unattractive. (For example, most of us prefer images of beaches to images of mud puddles.) On the other hand, what we like also varies dramatically from person to person: what one of us finds beautiful, another might find distasteful. What is the nature of such differences in aesthetic taste? They may in part be arbitrary—e.g. reflecting the random details of highly specific past judgments (such as liking red towels over blue ones because they were once cheaper). But they may also in part be systematic—reflecting deeper ways in which people differ from each other in terms of their perceptual and/or cognitive processing. We assessed the systematicity of aesthetic taste by exploring its typicality across seeing and hearing. A large group of people rated the aesthetic appeal of wide ranges of both visual images of scenes and objects (e.g. beaches, buildings, and books), and common environmental sounds (e.g. doorbells, dripping, and dialtones). Each person's 'taste typicality' for each modality was quantified by correlating their individual ratings with the mean ratings for each stimulus—thus capturing how similar each individual's aesthetic preferences are to those of the group as a whole. We discovered that these typicality scores were reliably correlated across seeing and hearing in multiple independent samples—even when controlling for rating reliability and differences in how peoples used the scales. In other words, if you're the sort of person who has (a)typical aesthetic preferences for visual images, you're more likely to also be the sort of person who has (a)typical aesthetic preferences for sounds. This suggests that one's 'taste typicality' is not entirely arbitrary, but rather reflects deeper factors that operate across multiple sensory modalities.

42.26, 12:00 pm **Motor and vestibular self-motion signals drive perceptual alternations of opposed motions in binocular rivalry** David Alais[1](david.alais@sydney.edu.au), Chris Paffen[2], Robert Keys[1], Hamish MacDougall[1], Frans Verstraten[1]; [1]School of Psychology, University of Sydney, [2]Experimental Psychology & Helmholtz Institute, Utrecht University

Using opposed drifting gratings (left vs. right) to trigger binocular rivalry, we investigated whether motor and vestibular self-motion signals would modulate rivalry alternation dynamics. Rivalry dynamics in vision-only conditions were compared with two observer-rotation conditions – passive and active. Passive: Observers viewed motion rivalry on a motion platform undergoing sinusoidal yaw oscillations (range=±24°, sine period=4s). Active: Observers wore a virtual reality headset and made trunk rotations to reproduce the same sinusoidal oscillations. Perceived direction in rivalry correlated with rotation direction. The 64s trials were modelled by the best-fitting sinewave, then epoched by the sine period and averaged into one cycle. Sinewave fits to epoched data for each participant showed perceived direction in

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motion rivalry correlated with direction of yaw rotation. Passive data: Group mean sine period was 3.88s, indicating entrainment of rivalry dynamics to the self-motion oscillation. Mean absolute amplitude was 0.37. The sine fit was generally in-phase (perceived motion matched self-motion direction); for 2/10 it was in anti-phase. Active data: All observers showed in-phase oscillations, all had a period very close to 4s (3.98s), and all showed greater amplitude (0.53) than for passive rotation. Rivalling up/down motions showed no effect of yaw rotation (active or passive), ruling out response bias linked to oscillation rate or direction reversals. Head and eye movements: head position was stable throughout trials and timing of any eye movements showed no correlation with rotation profile (turning points or peak velocities) and thus cannot explain the entrainment of dominant rivalry direction to rotation direction. We conclude both motor and vestibular self-motion signals input to vision and can help resolve perceptual ambiguity. The visual uncertainty in rivalry amplifies the role of these crossmodal influences and facilitates their study. In both cases, perceived visual direction follows the rotation direction, with active self-motion (vestibular+motor) signals particularly salient.

MONDAY MORNING POSTERS

3D Perception: Models, mechanisms

Monday, May 20, 8:30 am - 12:30 pm, Banyan Breezeway

43.301 **Monocular depth discrimination in natural scenes: Humans vs. deep networks** Kedarnath Vilankar[1](kedarpv@yorku.ca), Hengchao Xiang[1], Krista Ehinger[1], Wendy Adams[2], Erich Graf[2], James Elder[1]; [1]Centre for Vision Research, York University, [2]Psychology Department, University of Southampton

Objective. Humans use a number of monocular cues to estimate depth, but little is known about how accuracy varies with depth, nor how we compare to recent deep network models for monocular depth estimation. Here we measure and compare monocular depth acuity for humans and deep network models. Methods. Stimuli were drawn from natural outdoor scenes of the SYNS database of spherical imagery with registered ground truth range data. From each spherical image we extracted 62x49 deg sub-images sampled at regular intervals along the horizon. Four observers viewed randomly-selected images monocularly. Two points on the image were indicated by coloured crosshairs; observers were asked to judge which was closer. The difference in depth was varied to sweep out psychometric functions at four mean depths. Four deep network models were run on the same task. Results. Absolute JNDs were found to increase with mean depth faster than a Weber law for humans and most models, possibly due to the increased foreshortening of the ground surface with depth. While humans outperformed deep network models, a kernel regression model that uses only the elevation angle (height in the image) outperformed both for nearer depths, and we found that both humans and the networks struggled when the two points were fixed to have the same elevation. This suggests that both humans and deep networks may rely largely upon this simple elevation cue, although superior human performance at greater depths indicates that humans can recruit additional image cues. While luminance, colour and spatial frequency cues were all correlated with depth, most of the variance is shared with elevation and adding these cues to the kernel regression model failed to improve its performance. Conclusions. While human monocular depth acuity surpasses current state-of-the-art deep networks, both appear to rely heavily upon gaze elevation to estimate depth.

Acknowledgement: Vision: Science to Applications (VISTA), and Intelligent Systems for Sustainable Urban Mobility (ISSUM)

43.302 **Optimal spatial integration: How to pool local estimates into a global percept** Seha Kim[1](sehakim@sas.upenn.edu), Johannes Burge[1,2,3]; [1]Department of Psychology, University of Pennsylvania, [2]Neuroscience Graduate Group, University of Pennsylvania, [3]Bioengineering Graduate Group, University of Pennsylvania

Human visual systems integrate information across space to improve estimates about the environment. But the optimal strategy for integrating spatially correlated signals in natural scenes is not fully understood. We derive the optimal strategy for integrating local estimates from neighboring locations in space to compute a "global" estimate of a local scene property. Our framework is inspired by ideas from the cue combination literature. In cue combination, single-cue estimates are combined in a reliability-based weighted average. It is often assumed i) that measurement noise is independent, ii) that single-cue signals come from the same source (i.e. they are perfectly correlated), and iii) that single-cue estimates are unbiased. Here, we generalize these ideas to the problem of optimally pooling multiple local estimates from different nearby spatial locations. We assume i) that local estimates provide unbiased information and ii) that signals are only partially correlated at neighboring locations (as they are in natural images). The model specifies that local estimates should be linearly combined with weights that depend both on the reliability of local estimate and on the pattern of signal correlation across space. We applied this model to the problem of estimating 3D tilt. First, from a database of co-registered photographs and groundtruth distance maps of natural scenes, we sampled a large set of stimuli and validated that the model assumptions are approximately correct in natural scenes. Then, we computed the Bayes-optimal local tilt estimates from local image cues in the natural images. Finally, we combined the local estimates into global estimates using the optimal pooling model described above. Optimal global tilt estimates are better than optimal local tilt estimates at recovering groundtruth tilt in natural scenes. We also examine whether global estimates better predict human performance. The model provides a principled way to integrate local signals in real-world settings.

Acknowledgement: NIH R01-EY011747

43.303 **A Realistic Cue Combination Rule for Multi-Cue Depth Perception** Christopher W Tyler[1,2](cwt@ski.org); [1]Smith-Kettlewell Eye Research Institute, San Francisco, [2]Division of Optometry & Vision Sciences, City University of London

Introduction. A key issue in the encoding of the 3D structure of the world is the neural computation of the multiple depth cues and their integration to a unitary depth structure. This cue integration is often conceptualized as a reliability-weighted summation of all the depth cues to each other, scaled to the unitary world metric for effective action. Analysis. A simple linear weighted summation rule required for weak cues to combine to a strong depth percept would massively overestimate the perceived depth in cases where each cue alone provides a strong depth estimate. For example, if each depth cue alone provided, on average, 0.3 of the veridical depth in the scene, the linear summation of ten depth cues would overestimate the total depth by a factor of three. On the other hand, a Bayesian averaging, or 'modified weak fusion', model of depth cue combination would not provide for the enhancement of perceived depth from weak depth cues that is observed empirically. Results. These problems can be solved with an asymptotic, or hyperbolic Minkowski, weighted combination rule, providing for stronger summation for the first few depth cues with progressively weaker summation as the number of cues increases towards the veridical level. However, this rule does asymptote far too slowly to account for classic depth cue summation data. An accelerated asymptotic rule is therefore proposed to fit the empirical strength of perceived depth as the number of depth cues is increased. Conclusion. Despite a substantial literature on the topic, the theoretical analysis of depth cue combination remains drastically incomplete, and some form of accelerated asymptotic cue combination will be required to capture the quantitative phenomenology of human depth perception.

43.304 **TMS induced slowing of pursuit and depth from motion parallax** Mark Nawrot[1](mark.nawrot@ndsu.edu), Andrew Heinz[1], Shanda D Lauer[2], Jeffrey S Johnson[1]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University, [2]Institutional Research and Assessment Division, The Army University

The unambiguous perception of depth from motion parallax (MP) relies on the neural integration of retinal image motion with a pursuit eye movement signal. Transcranial Magnetic Stimulation (TMS) was used to investigate underlying neural mechanisms, particularly the slow eye-movement region of the Frontal Eye Fields' (FEFsem) role in generating the pursuit signal necessary to disambiguate MP. If TMS of FEFsem increases pursuit latency for contralateral movements, and if FEFsem provides the necessary pursuit signal for perception of depth from MP, then TMS of FEFsem should increase the presentation duration needed for depth from a MP stimulus translating in the contralateral direction. FEF was localized to individual anatomy (T1-weighted MRI) and functionally refined as the region of FEF that, when stimulated, produced an increase in pursuit latency. Following localization, single-pulse TMS was applied to right FEFsem 50 msec after stimulus motion onset during: i) pursuit, ii) motion perception, and iii) MP depth perception tasks. In the MP task, observers reported perceived depth phase (2AFC) upon viewing a computer-generated random-dot MP stimulus making a single translation of duration (t). Between trials, t varied in two interleaved staircases, one for each direction of stimulus translation. Stimuli were presented on a 120 Hz CRT and eye position was monitored with remote optics eye-tracking. Overall, TMS produced an average 25 msec increase in pursuit latency in the contralateral direction, but not in the ipsilateral direction. As hypothesized, TMS also produced direction and task-specific effects on performance; there was an average 25 msec increase in the MP presentation duration required for depth perception with stimulus translations in the contralateral direction. The temporal magnitude of the pursuit and MP effects were significantly correlated. These results indicate that FEFsem has a role in the production of the pursuit signal needed for the unambiguous perception of depth from MP.

Acknowledgement: NIGMS P30 GM114748

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43.305 **Neural correlates of contextually modulated depth perception** Nicole Wong[1](nicole26@connect.hku.hk), Dorita H.F. Chang[1,2]; [1]Department of Psychology, The University of Hong Kong, [2]The State Key Laboratory of Brain and Cognitive Sciences, The University of Hong Kong

The neural mechanisms underlying the perception of depth from disparity information are not well understood. In previous work (Wong & Chang, 2018 JOV 18(1): 994), we have shown that behavioural sensitivities to depth position are affected by object context, defined in terms of the conformity of the stimulus with natural physical laws (i.e., physically plausible versus implausible geometric shapes).Here, we asked how the plausibility of complex 3D objects affects neural responses to disparity information. Stimuli were disparity-defined geometric objects rendered as random dot stereograms (RDS), presented in plausible and implausible variations (e.g. a normal versus a physically implausible Penrose triangle). Observers were asked to complete a signal-in-noise task (SNR task), judging whether the object was in front or behind of a reference plane, while BOLD responses were measured using fMRI (3T, 2 mm3 iso voxels). Task difficulty was manipulated adaptively via the QUEST staircase procedure, varying the percentage of signal dots that defined the target. Comparisons of the multivariate fMRI response patterns indicated that contextual modulations of depth sensitivity are reflected in both dorsal and ventral areas. Specifically, areas V3a, V7 and LO can distinguish between response patterns of plausible and implausible triangles. In subsequent functional connectivity analyses (Granger causality), we observed context-driven (plausibility-based) modulations of connections along the dorsal and ventral stream for the implausible triangle only, signalled by stronger feedforward connections from V3a to higher-order dorsal areas as compared to the ventral areas. Our data suggest substantial modulation of disparity responses along cortex based on object context, indicating an intrinsic relationship between object perception and depth-related mechanisms.

43.306 **Contribution of stereopsis and motion parallax to fear response in the pit room environment** Siavash Eftekharifar[1](16se16@queensu.ca), Nikolaus Troje[1,2,3]; [1]Centre for Neuroscience Studies, Queen's University, Kingston, ON, Canada, [2]Department of Psychology, Queen's University, [3]Centre for Vision Research, York University

Stereopsis and active motion parallax are two of the main perceptual factors provided by head mounted displays to create a sense of presence in virtual environments. However, their relative contribution to create the sense of presence is not clear and existing results are somewhat controversial. Here, we study the contribution of stereopsis and active motion parallax using variants of the classic pit room paradigm in two experiments. In the first, participants were required to cross a deep abyss between two platforms on a narrow plank. They completed the task under three experimental conditions: (1) Standard VR (both motion parallax and stereopsis were available); (2) The lateral component of motion parallax was disabled; (3) Stereopsis was disabled. Participants responded to a presence questionnaire after each condition and their electrodermal activity (EDA) was recorded as a measure of stress and anxiety in a threatening situation. Results revealed a main effect of condition and the importance of motion parallax ($F[2,54] = 6.71$; $p< 0.005$). Questionnaire results, on the other hand, did not show an effect of experimental condition ($F[2,54]=0.04$; n.s.). In the second experiment, we applied a similar paradigm in a less stressful context. Participants were standing on the ledge over the pit and dropped a ball trying to hit a target on the ground. Experimental conditions and dependent measures were similar to experiment 1. Both EDA ($F[2,36] = 4.70$; $p< 0.05$) and presence questionnaire ($F[2,36] = 5.73$; $p< 0.01$) revealed a main effect of condition. Motion parallax affected the EDA and questionnaire scores more than stereopsis. The results from this study suggest that in VR, motion parallax is a more efficient depth cue than stereopsis in terms of fear response which was measured by EDA. Presence questionnaires also showed the importance of motion parallax in the second experiment.

43.307 **Generalized representation of shapes from different cues in parts of IPS areas** Zhen Li[1](li_zhen22@qq.com), Hiroaki Shigemasu[2]; [1]Graduate School of Engineering, Kochi University of Technology, [2]School of Information, Kochi University of Technology

In this study, we adopted fMRI to provide evidence whether ROIs are involved in representation of convex-concave 3D shapes from binocular disparity or perspective by assessing classification accuracy of distinguishing 3D shapes using multi-voxel pattern analysis, and further investigated relationships of these representations: whether generalized representation of 3D shapes from different cues is involved in each ROI. The ROIs were defined by standard retinotopic mapping in early visual areas and localizers for higher areas. Stimuli depicted convex-concave 3D shapes formed by two slanted planes. Three types of stimuli were used: (I) Shapes from disparity using random dot stereogram. (II) Shapes from disparity using black-white dotted lines. (III) Shapes from perspective cue using black-white dotted lines. Two different types of stimuli of disparity were used in order to check whether shapes from disparity using different elements shares generalized representation with shape from perspective cue. Linear support vector machine was used for classification. Two types of classification were performed to investigate 3D shape representation: (1) Same-type stimuli classification which trained and tested classifier on the shapes from the same type of cue. (2) Transfer classification on shapes from different types of cues which includes: training on type I and testing on type III and vice versa; training on type II and testing on type III and vice versa. Results showed that for same-type stimuli classification, classification accuracy had a tendency to be higher in early visual areas than in intraparietal sulcus (IPS) areas, while for transfer classification, classification accuracy had a tendency to be higher in parts of IPS areas than early visual areas. These results indicate that parts of IPS areas may be related to more generalized representation of 3D shapes formed by slanted planes irrespective of cue types while early areas are related to low level process of cue information.

43.308 **Characterizing a snapshot of perceptual experience** Michael A Cohen[1](michaelthecohen@gmail.com), Caroline Ostrand[1], Nicole Frontero[1]; [1]Amherst College, Department of Psychology

What can we perceive in a single glance of the visual world? To answer this question, we used an inattentional blindness paradigm to measure how much and in what ways we could alter the periphery of an image without observers noticing? For 10 trials, participants viewed a stream of images (288ms/item, 288ms SOA) and reported if the last image had a face in the middle. On the 11th trial, a modified image was unexpectedly presented at the end of the sequence. Our images were modified in several ways. In Experiment 1, we used a texture synthesis algorithm to generate images that were matched on several first- and second-order statistics within a series of receptive field-like pooling windows (Rosenholtz, 2016). By increasing the size of the pooling windows, we created a series of images that looked progressively more "scrambled." How much could we scramble images before observers notice? When scrambling the images the least (Freeman & Simoncelli, 2011), 100% of participants failed to notice. In the most extreme case, when using one large pooling window to scramble the entire image while preserving only the center/foveal part (Portilla & Simoncelli, 2001), 48% of participants failed to notice. In Experiment 2, we put the unscrambled peripheral part of one image (e.g., a skyline) around the center/foveal part of another (e.g., a dog). In this case, 75% of participants failed to notice. The only situation in which virtually every observer noticed our modifications (5%) was when the periphery of the image was completely blank. However, in cases when participants did not notice the modifications, they still successfully identified the last image in the stream (i.e., "I saw this dog, not that dog"). Together, these results highlight how a snapshot of perceptual experience is surprisingly impoverished when observers are attending to one location in space.

Acknowledgement: National Science Foundation

43.309 **Does experience of stereoblindness change use of texture cues in slant perception?** Pin Yang[1](18321556180@163.com), Zhongting Chen[1], Jeffrey Allen Saunders[2]; [1]East China Normal University, [2]the University of Hong Kong

People with normal visual systems use both stereo and monocular cues for 3D perception. However, about 10% of the population are stereoblind and have to rely on other cues. Does stereoblindness change how monocular cues are processed? We investigated this question for the case of stereo and texture cues to 3D slant. For normal people, slant estimates from monocular texture are a highly nonlinear function of slant, with large bias toward frontal at low slants, while slant estimates from binocular texture are close to linear. Slant discrimination from monocular texture is also highly dependent on slant, with poor sensitivity at low slants, while discrimination from binocular texture is more uniform. If biases and poor sensitivity of slant from texture is due to fundamental limitations ability to extract information from texture, then stereoblind people would show the same effects. Alternatively, long-term experience with stereoblindness might cause some adaptive changes, such as increased sensitivity to texture cues or rescaling of the relation between texture cues and perceived slant. We tested this by comparing slant estimation and discrimination performance of stereoblind and normal observers (N=48) for textured surfaces presented both monocularly and binocularly. In the monocular conditions, we found no difference between groups for either task; both groups showed the same biases in slant estimation and equivalent discrimination thresholds. Experience with stereoblindness does not appear to have changed interpretation of slant from texture nor improved sensitivity. As expected, binocular viewing improved slant discrimination for normal observers but not for stereoblind observers. However, the stereoblind observers showed a small but significant reduction in frontal biases in the binocular conditions, which is likely due to some phenomenal difference between monocular and binocular viewing. In conclusion, we found no evidence that stereoblindness produces of adaptive changes in use of texture information for 3D perception.

Acknowledgement: China Postdoctoral Science Foundation (NO. 2018M630410)

43.310 **The face narrowing caused by the Mona Lisa effect**

Marie Morita[1, 2](marie.mrt1092@gmail.com), Yoshitaka Fujii[3], Takao Sato[4]; [1]Department of Psychology, Ritsumeikan University, [2]Research Fellow of Japan Society for the Promotion of Science (DC2), [3]Research Organization of Open Innovation and Collaboration, Ritsumeikan University, [4]College of Comprehensive Psychology, Ritsumeikan University

A person depicted in a portrait painting does not become slanted even when observers move around. The gaze is also fixed to the observer. This effect is called the Mona Lisa effect. In addition, the face appears thinner when the Mona Lisa effect occurs. In this study, we examined this face narrowing to explore relationship between the Mona lisa effect and depth perception. The face narrowing is a break-down of shape constancy and suggests the information about the physical orientation of the painting/photography or the face/body is not obtained by the observer. If the slant of the portrait is obtained by the observer, the face width should be perceived wider than that implied by the width of the retinal image because of shape constancy. In experiment 1, we presented 2D portraits generated from CG 3D model as test stimuli and a line-drawing oval as references. Rotation angles of -30 deg to + 30 deg were used. Binocular disparity was given to the 2D portrait to represent the slant and presented with mirror stereoscope. Observers were asked to compare the face and flat oval and to judge which appeared wider. The results showed that facial width was perceived narrower with increasing rotation angle and indicated that the Mona Lisa effect occurred. Moreover, intensity of the effect was stronger when edges of background were blurred by Gaussian mask to reduce binocular disparity cues. Following these experiments, we investigated whether the Mona Lisa effect is specific for human face by using inverse and negative/positive portraits. The results showed that changing of facial width became smaller than upright portrait. However, intensity of positive portrait also became smaller. These results indicate that the Mona Lisa effect occurs from conflict between face specific cues (occlusion) and binocular disparity cues.

Monday AM

Perception and Action: Walking, driving, navigating

Monday, May 20, 8:30 am - 12:30 pm, Banyan Breezeway

43.311 **The span of visible terrain for walking over multiple raised obstacles**

Brett Fajen[1](fajenb@rpi.edu), Scott T Steinmetz[1], Mark J Uszacki[1], Sean L Barton[2], Gabriel J Diaz[3]; [1]Cognitive Science Department, Rensselaer Polytechnic Institute, [2]Computational Information Sciences Directorate, Army Research Laboratory, [3]Center for Imaging Science, Rochester Institute of Technology

When humans walk along a path with predefined foot targets, visual information about the location of an upcoming target is maximally important during the latter half of the preceding step (Matthis et al., 2017). However, strategies for visual sampling and control may differ when footholds are not predefined. When potential footholds are all regions that do not contain obstacles (e.g., a trail with small puddles), choices have to be made about where to place the feet. Furthermore, when obstacles are elevated, walkers may try to find footholds for one foot that allow the other foot to swing between rather than over obstacles (Fajen et al., VSS 2018). This may require visual information from a wider span of the upcoming terrain. In this study, subjects walked along a short path while stepping over or around virtual obstacles, which were projected onto the floor by a 3d-capable projector (Binaee & Diaz, 2018) and appeared as an array of randomly distributed blocks. There was also a condition in which obstacles were flat. The terrain was visible only when it fell within a donut-shaped region centered on the subject. We manipulated both the inner radius and the span (difference between inner and outer radii) of the visibility donut. With flat obstacles, collisions were infrequent and minimally affected by the visibility manipulations. When obstacles were 3d, performance was comparable to full vision only when the visibility donut spanned one to three step-lengths ahead. When the visibility span was smaller than two step-lengths or when obstacles disappeared more than one step-length in advance, collisions increased. The findings suggest that when obstacles are elevated, the region of visible terrain must be large enough to span two potential footholds. This may allow walkers to evaluate potential footholds in pairs, which could facilitate safer and more efficient locomotion.

Acknowledgement: NSF 1431078

43.312 **A role for stereopsis in walking over complex terrains**

Kathryn Bonnen[1,2](kathryn.bonnen@nyu.edu), Jonathan S Matthis[3], Agostino Gibaldi[4], Martin S Banks[4], Dennis Levi[4], Mary Hayhoe[3]; [1]Center for Neural Science, College of Arts & Science, New York University, [2]Howard Hughes Medical Institute, [3]Departments of Neuroscience & Psychology, University of Texas at Austin, [4]Department of Vision Science, School of Optometry, University of California Berkeley

When walking across complex terrains, humans gather information about the structure of the path ahead in order to support locomotion.Several studies have established the importance of stereopsis for natural visuomotor control tasks, particularly for tasks involving the arms (e.g., reaching and grasping). We examined the role of stereopsis for walking over complex terrains, a visuomotor control task involving foothold selection and the modulation of gait. Using methods developed by Matthis et al (2018), we recorded the eye and body movements of subjects walking over terrains of varying complexity (pre-designated as flat, medium, or rough).Eight subjects performed the experiment twice, once with their normal or corrected-to-normal vision, and once with a Bangerter foil (0.2, 20/100) over one eye to blur vision and impair stereopsis. In both conditions, subjects adjusted their gaze strategy to accommodate the different difficulties of terrain, allocating more fixations to closer footholds as the terrain became more difficult.The effect of removing stereo-information (using the Bangerter foil) was evident in the medium terrain, where subjects allocated more of their gaze to earlier footholds, indicating that the transition to the rough terrain gaze strategy happens earlier in the absence of stereo-information.Preliminary data from subjects with permanently impaired stereopsis (due to amblyopia and strabismus) indicates a similar strategy, with subjects allocating even more of their gaze to closer footholds in both the medium and rough terrains. The degradation of stereopsis has measurable effects on the gaze strategies used during walking across complex terrains, suggesting that stereopsis is an important source of information for the visuomotor control of locomotion.

Acknowledgement: NIH EY05729, ARVO/VSS Fellowship, Harrington Fellowship

43.314 **Both optical expansion and depth information are used to control 2D pedestrian following**

Gregory C Dachner[1](gregory_dachner@brown.edu), William H Warren[1]; [1]Cognitive, Linguistic & Psychological Sciences, Brown University

Collective motion in human crowds emerges from local interactions between individuals, in which pedestrian follows their near neighbors (Rio, Dachner, & Warren, PRSB, 2018). In previous work, we found that a follower's speed and heading are controlled by nulling the optical expansion and angular velocity of a leader, depending on the leader's position. This model explains following one neighbor (Dachner & Warren, VSS 2017; Bai & Warren, VSS 2018, 2019) and following crowds (Dachner & Warren, VSS 2018), based on visual information. However, our previous experiments isolated optical expansion and angular velocity, removing distance information. Here we add depth information (vergence, binocular disparity, declination angle from the horizon), and put it in conflict with optical expansion. 10 participants walked in a virtual environment while head position and orientation were recorded at 90 Hz. They were instructed to follow a virtual target (speckled pole, 40 cm diameter) that rested on a textured ground plane. The target appeared in three initial positions relative to the participant (0˚, 30˚, 60˚ from straight ahead), two initial distances (1m, 4m), and moved forward in the walking direction at 0.8 m/s. After 5 seconds, the pole changed its expansion rate, heading direction (+/- 35˚), or both. Although its position and motion on the ground plane were consistent with its trajectory, the pole's width expanded or contracted as if it changed speed (+/- 0.2 m/s). Participants changed speed in response to this expansion; this effect was significantly reduced by the inclusion of depth information (36% less compared to control, $t(9)=3.77$, $p< 0.01$). As well, head pitch angle indicated that participants centered their field of view at the target's base. These results imply that following is controlled by both optical expansion and declination angle of neighbors. We plan to integrate this into our visual model of crowd behavior.

Acknowledgement: Supported by NSF BCS-1431406 & the Link Foundation Modeling, Simulation, and Training Program

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43.315 **Retinal optic flow and the control of locomotion** Jonathan Samir Matthis[1](matthis@utexas.edu), Karl S Muller[1], Mary M Hayhoe[1]; [1]Center for Perceptual Systems, University of Texas at Austin

A long history of research on the visual control of locomotion has explored the role of optic flow in the regulation and guidance of human walking. It is generally agreed that the head-centered Focus of Expansion (FoE) lies in a stable location in the walker's direction of travel, and that humans use this feature to control heading. We used optic flow estimation algorithms to measure head-centered optic flow recorded from the head-mounted camera of a mobile eye tracker of subjects walking in real-world environments. Contrary to the traditional view, we found natural head oscillations during locomotion cause the FoE to move constantly at high velocities within the walker's field of view. Thus strategies that suggest the FoE is used for heading could not be implemented on the basis of naturally occurring optic flow. In contrast, we found that retinal optic flow contains information that may be used for the control of locomotion. Fixation nulls motion at the fovea, resulting in regular patterns of outward flow across the retina that encode information about the walker's movement relative to the fixated location. Analyzing retinal flow fields using the curl and divergence operators from vector calculus reveals features that are directly applicable for the control of locomotion. For instance, the sign of retinal curl (which corresponds clockwise/counter clockwise rotation) indicates whether the walker will pass to the left or right of the point they are fixating. In addition, the walkers' instantaneous, world-centered velocity vector may be derived directly from the divergence across the retinal flow field. These features provide a much richer and more stable source of information for the control of locomotion than the FoE. Furthermore, this information can be extracted directly from retinotopic visual motion, so a coordinate transform into head-centered coordinates is unnecessary.

Acknowledgement: K99EY028229, R01EY021462

43.316 **The role of optic flow and visual direction in locomotion** Daniel P Panfili[1](dan.panfili@utexas.edu), Jonathan Samir Matthis[1], Mary M Hayhoe[1]; [1]Center for Perceptual Systems, University of Texas at Austin

When optic flow patterns are measured during natural outdoor locomotion, the head-centered focus of expansion (FOE) of the resulting optic flow patterns are highly unstable as a consequence of head oscillations in all three axes during locomotion (Matthis et al, 2018). This suggests that the head-centered FOE is unsuitable for controlling heading during locomotion, and visual direction could serve this purpose instead (Rushton et al, 1999). However, Warren et al (2001) pitted visual direction against the FOE in a virtual environment and found comparable influences from flow and visual direction. To further explore exactly how optic flow is used in locomotion we devised a similar experiment to that of Warren et al in a virtual environment using an HTC Vive Pro running on Unity. We simulated a prism rotation to separate visual direction and the FOE. We found similar effects to those reported by Warren et al, where optic flow combines with visual direction cues to result in straighter walking paths in more structured environments. However, the way that flow exerts this influence is unclear in light of the instability of the FOE in the natural optic flow stimulus. It is possible that the curl signal introduced in retinal flow from the ground plane drives walking trajectories rather than the FOE. We are exploring this possibility by independently manipulating flow from the ground plane vs the surrounding scene structure.

Acknowledgement: NIH grant EY05729 and K99EY028229

43.317 **Invisible social space alters human walking behaviours** Chen Zhou[1](c.zhou.psy@gmail.com), Ming-Cheng Miao[1], Yi-Fei Hu[1], Shu-Guang Kuai[1,2]; [1]Shanghai Key Laboratory of Brain Functional Genomics, Key Laboratory of Brain Functional Genomics, Ministry of Education, School of Psychology and Cognitive Science, East China Normal University, [2]NYU-ECNU Institute of Brain and Cognitive Science, New York University Shanghai

Human walking behaviours are influenced by other people in daily lives. People usually make a detour to keep a certain distance from others in a social scene. There are two hypotheses that explain the behaviour of a detour. The first hypothesis claims that human requires a physical buffer space during walking to avoid collisions with others. The second hypothesis claims people might need a social space to keep a comfortable distance with others during walking. In the current study, we conducted two experiments to compare these two hypotheses. In Experiment 1, participants were asked to steer towards a door which was five meters away in a virtual environment, while a virtual human would be standing at the middle point between the start point and the destination. Participants tended to take a larger detour when the virtual human was facing them, to keep a distance from the virtual human. The results highlighted the importance of social features in guiding walking behaviours. In Experiment 2, participants were asked to bypass a pair of virtual humans. When the two virtual humans were interacting, participants made a larger detour to keep a farther distance from them. The social force model which only considered the physical factors of people, such as spatial position, failed to explain our data. Thus, we built a social interaction field model which quantified the strength of social interaction between people in a social scene. We further combined our model with the social force model. The combined model reached a good fitting performance of our experimental data. These results show that people's detour behaviours are influenced by the social features of humans and support the hypothesis of invisible human social space.

Acknowledgement: This research was supported by the National Natural Science Foundation of China Grants (No. 31771209, No. 31571160), the National Social Science Foundation of China Grants (No. 15ZDB016), the Fundamental Research Funds for the Central Universities and the JRI Seed Grants NYU-ECNU Institute of Brain and Cognitive Science at NYU Shanghai.

43.318 **How do people drive a car to cross a road intersection between incoming vehicles?** Huaiyong Zhao[1](huaiyongzhao@gmail.com), Dominik Straub[1]; [1]Technical University Darmstadt

It is a challenging task for people to drive a car to cross a road intersection while avoiding collision with lead and trail vehicles. It has been proposed that drivers' speed regulation in this task can be explained as they intercept a gap of the train of incoming traffic. This explanation turns the task from an avoidance task to an interception task. It raises a question about the difference between interception of a physical object and interception of a gap; it concerns an ontological issue because a physical object is an entity, but a traffic gap is not. To test this explanation, we asked participants (N = 12) to adjust a car's speed to cross an intersection in a virtual environment. We manipulated the size of the traffic gap and the time of arrival of the traffic gap at the intersection. In comparison conditions, the traffic gap was replaced with a box with the same dimensions with the traffic gap. The box appeared and moved either alone or between incoming vehicles as the gap appeared. In each trial, the participant initially adjusted the car's speed to a fixed value while approaching the intersection; then a train of vehicles and/or the box appeared on the other road and approached the intersection; then the participant needed to adjust the car's speed to pass through the traffic gap or the box while avoiding other vehicles or the two ends of the box. We analyzed participants' speed regulation and examined whether they used the constant bearing strategy to intercept the traffic gap or the box. We did not find any consistent evidence for it such as a constant bearing angle computed with respect to the interception point of the gap or the box. Participants' eye movements will be examined and discussed.

43.319 **The Influence of Space Semantics on Navigational Choices in Virtual Settings** Serena De Stefani[1](sd911@rutgers.edu), Davide Schaumann[2], Xun Zhang[2], Jacob Feldman[1], Mubbasir Kapadia[2]; [1]Psychology, Rutgers University, [2]Computer Science, Rutgers University

When navigating complex environments, humans are exposed to social and spatial cues produced by the built environment and by the presence and movement of other people in the space. In this work, we focus on space semantics cues, which denote how space can be used by people at a given time. We use the term space semantics to mean the ensemble of the psychological and behavioral properties implicit in the configuration and visual appearance of environments (Franz & Wiener, 2006). For example, space semantics differentiate an "office" from a kitchen", or a "nurse station" from a "patient room", by enabling different kinds of users' behaviors. Semantic properties may be conveyed by a combination of geometric properties, the configuration of equipment, and the presence and activities of specific users. To understand how people are affected by space semantics, we built a virtual hallway that our subjects can navigate and explore through a desktop computer. We created four versions of the same setting, manipulating aspects of the scene such as the presence of objects or people, while leaving unaltered the geometry of the pathway available to subjects. We evaluated the navigational choices of the subjects and their chosen pathway in a virtual setting, asking them to find a way out of an enclosure. Results show how it is possible to direct people's behavior through the way space communicates meaning, rather than using overt signage.

43.320 **Spatial learning from navigation in a virtual environment: effect of previewing a top-down map** Jie Ding[1](jieding11@gmail.com), Jeffrey A Saunders[1]; [1]Department of Psychology, The University of Hong Kong

Previous evidence suggests that cognitive maps have an orientation; for example, judgments of relative direction (JRD) are better when the imagined facing direction is aligned with the dominant orientation of an environment. We tested whether briefly viewing a top-down map before exploring an environment can induce the orientation of a cognitive map. Subjects navigated in a virtual village environment to find a sequence of targets, and then performed a JRD task to test their spatial knowledge. In separate sessions, we tested conditions with and without a map preview. In the map preview condition, subjects viewed a top-down image of the environment with targets removed for 30 seconds before exploration. The village environments were constructed to have one longer path that would be a natural intrinsic axis, which was oriented to be diagonal on the preview maps. The map orientation and intrinsic structure therefore predict different alignment effects. JRD trials had four facing directions: aligned or perpendicular to the map orientation, and aligned or perpendicular to intrinsic axis. We found that JRD accuracy varied as a function of facing direction, and that the alignment effect depended whether the map was previewed. With no map, mean errors were lowest when the JRD facing direction was aligned with the intrinsic axis of the environment, while with a map preview, the mean errors were lowest when the facing direction was aligned with the upward direction of the map. The map preview did not produce any overall improvement in accuracy in judgments, which suggests that most of the spatial learning was from exploration, and that the map primarily determined the orientation of the cognitive map. Our results demonstrate that a brief preview of a map is enough to change how spatial knowledge acquired from navigation is encoded.

Acknowledgement: Supported by Hong Kong Research Grants Council GRF17407914

43.321 **Effects of degraded vision on the use of landmarks in spatial learning** Holly C Gagnon[1](holly.gagnon@psych.utah.edu), Erica M. Barhorst-Cates[1], Sarah H. Creem-Regehr[1]; [1]Psychology, University of Utah

Previous research indicates that landmarks aid in spatial learning and navigation. What is not known is how the degree to which landmarks are detectable or recognizable influences their usefulness in spatial cognition. This is especially relevant to those with low vision, who may rely on residual visual capabilities to accomplish daily goals. In the present study, participants (n = 16) were guided through four paths in a real-world maze wearing goggles that simulated degraded visual acuity and contrast sensitivity. For each participant, three landmarks (furniture items) were present at distances that were previously determined to allow for recognizability, in some paths but not others. Participants were instructed to attend to four targets in the maze (capital letters), but they were not told about the landmarks. At the end of each path participants completed a pointing task measuring their memory for target locations. Upon completion of the study participants were asked to indicate whether they saw any other objects in the maze besides the targets. If they did see other objects, they were asked to name them. Preliminary results show that the presence of landmarks tended to result in smaller pointing error, even when participants did not report seeing any landmarks. Thus, the mere presence of a landmark, even if it is not overtly detected, may be enough to aid in spatial learning while navigating. These results have implications for the low vision community, suggesting that landmarks may not need to be fully recognized in order to be useful in spatial learning. The results also suggest a gender by landmark presence interaction, indicating that males might receive more benefit from landmarks compared to females. Additional studies using more severe simulated blur level and manipulating explicit instructions about landmarks are currently underway.

Acknowledgement: NIH/NEI BRP 2 R01 EY017835-06A1

43.322 **Where did I park my car? Influence of visual landmark permanency on navigation** Charlotte E. Roy[1](charlotte.roy@uni-ulm.de), Dennis Wiebusch[1], Marc O. Ernst[1]; [1]Ulm University, Ulm 89081, Germany

Visual landmarks provide crucial information for human navigation. But what defines a landmark? To be uniquely recognized, a landmark should be distinctive and salient, while providing precise and accurate positional information (Chan, FrontiersPsychology, 2012). However, it should also be permanent, e.g., to find back your car, a nearby church seems a better landmark compared with a truck, as you learned the truck likely might move. However, if you are only in the shop for a minute you may as well use the truck as a landmark because it is likely still there upon return. To this end, we here investigate the learning of landmark permanency while treating permanency as a probabilistic feature for human navigation. Particularly we study the learning behavior when exposed to landmarks whose permanency characteristics are probabilistically defined and hypothesize that humans will be able to learn these characteristics and assign higher weight to more permanent landmarks. To test this hypothesis, we used a homing task where participants had to return home, while the home position was surrounded by three landmarks. In the learning phase we manipulated the permanency of one landmark by secretly repositioning it prior to returning home. The statistics of repositioning was drawn from a normal distribution. In the test phase we investigated the weight given to the non-permanent landmark by analyzing its influence on the homing performance. The results of two studies with different permanency statistics confirmed our hypothesis. Participants learned the non-permanent characteristics and consequently weighted these landmarks less upon returning home. We conclude that landmark permanency is a probabilistic feature used by humans for navigation.

Faces: Expressions, speech

Monday, May 20, 8:30 am - 12:30 pm, Banyan Breezeway

43.323 **Discrimination of facial expressions and pain through different viewing distances** Isabelle Charbonneau[1](isabellecharbonneau8@gmail.com), Joël Guérette[1,2], Caroline Blais [1], Stéphanie Cormier[1], Fraser Smith [3], Daniel Fiset[1]; [1]Département de Psychoéducation et de Psychologie, Université du Québec en Outaouais, [2]Département de Psychologie, Université du Québec à Montréal, [3]School of Psychology, University of East Anglia

Due to its important communicative function, a growing body of research has focused on the mechanisms underlying the recognition of the facial expression of pain. A study suggested that pain recognition relies on the use of low spatial frequencies (SFs; Wang et al., 2015) although another study has highlighted the importance of mid-SFs (Guérette et al., VSS 2018). With the aim of clarifying these contradictory results, we manipulated the effect of distance, a method that better reflects the reality of clinicians who may have to recognize pain from a near or a far distance. Importantly, changes in viewing distance modulate the available SFs by progressively removing high-SFs as the stimulus moves further away. With a concern to replicate previous findings (Smith & Schyns, 2009), the six basic emotions and neutral were also included in the experiment which consisted of an 8-expression categorization task (16 participants; 2400 trials per participant). The Laplacian Pyramid toolbox (Burt & Adelson, 1983) was used to create six reduced-size images simulating increasing viewing distances (3.26, 1.63, 0.815, 0.41, 0.20, 0.10 degree of visual angle). Unbiased hit rates (Wagner, 1993) were calculated to quantify the participants' performance at each distance. A 6 x 8 (Distance x Emotion) repeated-measures ANOVA revealed a significant interaction $F(8.54,128.22)=15.97$, $p< .001$ ($\eta2=0.516$). Separate repeated-measures ANOVAs looking at the effect of Emotion for each Distance were conducted and follow-up paired sample t-tests (corrected $p=0.05/28$) revealed significant differences between expressions. Most importantly, recognition of pain decreased with increasing viewing distances and was not recognized above chance level at further distances, whereas surprise and happiness were the best two recognized expressions at these distances (all p's< .05). These results support the central role of mid-SFs for the recognition of pain.

Acknowledgement: NSERC

43.324 **Spatial frequencies underlying the detection of basic emotions and pain** Joël Guérette[1,2](joel.guerette@uqo.ca), Isabelle Charbonneau[1], Caroline Blais[1], Stéphanie Cormier[1], Daniel Fiset[1]; [1]Université du Québec en Outaouais, [2]Université du Québec à Montréal

Many studies have examined the role of spatial frequencies (SFs) in facial expression perception. However, although their detection and recognition have been proposed to rely on different perceptual mechanisms (Sweeny et al., 2013; Smith & Rossit, 2018), the SFs underlying these two tasks have never been compared. Thus, the present study aimed to compare the SFs underlying the detection and recognition of facial expressions of basic emotions and pain. Here, we asked 10 participants (1400 trials per participant) to decide if a stimulus randomly sampled with SF Bubbles (Willenbockel et al., 2010) corresponded to an emotion or a neutral face. Classification vectors for each emotion were computed using a weighted sum of SFs sampled on each trial, with accuracies transformed in z-scores as weights. We then compared the SFs used in this task to those obtained in a previous study using the same stimuli and method but during a recognition task (Charbonneau et al., 2018). Overall, accurate detection of emotions

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was significantly associated with the use of low-SFs (ranging from 3.33 to 6 cycles per face (cpf); Zcrit=3.45, p< 0.05). Happiness was the only emotion relying on similar low-SFs for both tasks. Other emotions were associated with the use of higher SFs in the recognition task. Interestingly, the detection of fear (ranging from 1.67 to 7 cpf, peaking at 4 cpf) and surprise (ranging from 1.33 and 6.33 cpf, peaking at 3.33 cpf) was associated with the lowest SF information. These results are consistent with the idea that low-SF represent potent information for the detection of emotions, especially those with a survival value such as fear. However, the contribution of higher SFs is needed to discriminate between emotions for their accurate recognition.

Acknowledgement: NSERC

43.325 **The Peripheral View Melts Facial Emotion into a Blur: Investigating the Role of Spatial Frequency in Younger and Older Adults' Peripheral Emotion Detection** Andrew Mienaltowski[1](andrew.mienaltowski@wku.edu), Alyssa R Minton[1], Connor Rogers[1], J. Farley Norman[1]; [1]Department of Psychological Sciences, Ogden College of Science and Engineering, Western Kentucky University

Facial emotion detection declines when stimuli are presented in more distal peripheral relative to more central foveal and parafoveal locations. Younger and older adults display similar decline in facial emotion detection with increased display distance from the center of the visual field when the stimuli used include a broad range of spatial frequencies. The current study examined younger and older adults' emotion detection performance when low or high spatial frequencies have been filtered from the facial stimuli. Younger (n = 37, ages 18-29) and older (n = 40, ages 61-80) adults observed either angry and neutral or happy and neutral facial expressions presented at 5, 10, and 15 degrees from the center of the visual field. Spatial frequency filters were applied to the images so that participants observed stimuli consisting of broad, low, or high spatial frequencies at each location. Happiness was more easily detected than anger, and, as a result, happiness detection was more greatly impacted by stimulus distance from the center of the visual field than was anger. Likewise, emotion was more easily detected in broad and low spatial frequency stimuli at peripheral locations than in high spatial frequency stimuli. Younger adults outperformed older adults at detecting happiness and anger in high spatial frequency facial stimuli presented at 5 and 10 degrees from the center of the visual field, but not at 15 degrees, where both age groups were equally poor at detecting emotion. Younger and older adults did not differ in their ability to detect anger and happiness in broad and low spatial frequency expressions. Overall, these findings suggest that peripheral emotion detection relies more heavily on low spatial frequency information in facial images, and that this tendency is maintained throughout adulthood.

Acknowledgement: Western Kentucky University Graduate School

43.326 **The discrimination ability of human visual system for facial expression, identity and gender** Hui Zhang[1](hui.zhang@buaa.edu.cn), Zixiang Wei[2], Xueping Wang[2], Yunhong Wang[3]; [1]Beijing Advanced Innovation Center for Big Data and Brain Computing (BDBC), Beihang University, [2]School of Computer Science and Engineering,Beihang University, [3]State Key Laboratory of Virtual Reality Technology and Systems School of Computer Science and Engineering,Beihang University

Facial expression, identity and gender discrimination are crucial for effective social functioning. Previous neuroimaging studies have examined the discrimination abilities of human face-selective regions for each kind of facial attribute in independent experiment, which caused conflicting results. Here we carried out an fMRI experiment to quantitatively evaluate how the discriminate abilities for facial expressions, identities and gender are represented in human visual system. Subjects participated in a slow event-related fMRI experiment in which they were shown 56 faces belonging to eight different identities and portraying seven different expressions: fear, anger, disgust, sadness, neutral, surprise and happiness, half of individuals were male and half were female. The one-versus-six Support Vector Machine (SVM) and leave-one-identity-out cross-validation was used on the patterns of the fMRI response to determine how well each class of facial expression was decoded from all other expressions; the one-versus-seven SVM and leave-one-expression-out cross-validation was used on the same patterns of the fMRI response to determine how well each class of facial identity was decoded from all other identities; the one-versus-one SVM and leave-one-expression-out cross-validation was used to determine how well gender was decoded. All decoding accuracies were permutation tested, normalized, and entered into a "decoding preference index analysis (DPI)", which was calculated as DPI=[D1-0.5×(D2+D3)]/(D1+D2+D3), where Di (i=1,2 and 3) is one of the three decoding accuracies in one identified brain location. Of all the identified face-selective regions as well as V1, amygdala and posterior superior temporal sulcus showed significantly higher discrimination ability for facial expressions than for identities and gender, aIT and FFA (fusiform face area) showed significantly higher discrimination ability for facial identities than for expressions, but not for gender. Taken together, our results suggest that different face-selective regions in the human brain play distinct roles in discrimination of facial expression, identities and gender.

Acknowledgement: This work was supported by the Chinese Academy of Sciences under Grant No. 81871511.

43.327 **The importance of stimulus variability when studying face processing using Fast Periodic Visual Stimulation: A novel 'Mixed-Emotions' paradigm** Rebecca Brewer[1](Rebecca.brewer@rhul.ac.uk), Michel-Pierre Coll[2], Jennifer Murphy[3], Caroline Catmur[4], Geoffrey Bird[2]; [1]Department of Psychology, Royal Holloway, University of London, [2]Experimental Psychology Department, University of Oxford, [3]Social, Genetic and Developmental Psychiatry Centre, Institute of Psychiatry, Psychology & Neuroscience, King's College, London, [4]Department of Psychology, Institute of Psychiatry, Psychology & Neuroscience, King's College London

Fast Periodic Visual Stimulation (FPVS) with oddball stimuli has been used to investigate discrimination of facial identity and emotion, with studies concluding that oddball responses indicate discrimination of faces at the conceptual level (i.e. discrimination of identity and emotion), rather than low-level perceptual (visual, image-based) discrimination. However, because previous studies have utilised identical images as base stimuli, physical differences between base and oddball stimuli, rather than recognition of identity or emotion, may have been responsible for oddball responses. This study tested two new FPVS paradigms designed to distinguish recognition of expressions of emotion from basic detection of visual change in adult participants (N = 42, 24 male). In both paradigms, the oddball emotional expression was different from that of the base stream images. However, in the 'fixed-emotion' paradigm, stimulus image varied at every presentation but the emotion in the base stream remained constant, and in the 'mixed-emotions' paradigm, both stimulus image and emotion varied at every presentation, with only the oddball emotion (disgust) remaining constant. In the fixed-emotion paradigm, typical inversion effects were observed at occipital sites. In the mixed-emotions paradigm, however, inversion effects in a central cluster (indicative of higher level emotion processing) were present in typical participants, but not those with alexithymia (who are impaired at emotion recognition), suggesting that only the mixed-emotions paradigm reflects emotion recognition rather than lower-level visual processing or basic detection of change. These results have significant methodological implications for future FPVS studies (of both facial emotion and identity), suggesting that it is crucial to vary base stimuli sufficiently, such that simple physical differences between base and oddball stimuli cannot give rise to neural oddball responses.

43.328 **Natural brief facial expression changes detection at a single glance: evidence from Fast Periodic Visual Stimulation** Stéphanie Matt[1,2](stephanie.matt@univ-lorraine.fr), Milena Dzhelyova[3], Louis Maillard[4], Joëlle Lighezzolo-Alnot[2], Bruno Rossion[3,4], Stéphanie Caharel[1]; [1]Laboratoire 2LPN (EA7489) - Université de Lorraine (France), [2]Laboratoire INTERPSY (EA4432) - Université de Lorraine (France), [3]Institute of Research in Psychological Science, Institute of Neuroscience, University of Louvain (Belgium), [4]CRAN (UMR 7039 CNRS) - CHU de Nancy - Université de Lorraine (France)

The processing of emotional facial expressions has been studied mainly with stereotypical face stimuli, but contextual information leads to drastic modulation in the categorization of facial expressions (Aviezer et al., 2017). In the human brain, brief facial expression changes are quickly read from faces (Dzhelyova et al., 2017). Yet, how reliably these changes are detected with realistic faces embedded in a natural context remain unknown. In this study, faces varied in viewpoint, identity, gender, age, ethnic origin and background context. We recorded 128-channel EEG in 17 participants while they viewed 50s sequences with a neutral-expression face at a rate of 5.99 Hz (F) at two faces orientations (upright, inverted). Every five faces, the faces changed expression to one of the six basic expression (fear, disgust, happiness, anger, surprised or sadness; Ekman, 1993), one emotion per sequence (e.g ANeutralANeutralANeutralANeutralANeutralBExpressiveANeutral …). EEG responses at 5.99 Hz reflect general visual processing, while the EEG responses at F/5 = 1.1998 Hz and its harmonics (e.g., 2F/5 = 2.3996, etc.)

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index detection of a brief change of natural facial expression. Despite the wide variety across images, a F/5 response was observed for each individual participant, pointing to robust facial expression categorization processes. At the group-level, the categorization response was measured over occipito-temporal sites and was largely reduced when faces were inverted, indicating that it reflects high-level processes. Despite evidence (Leleu et al., 2018; Hinojosa et al., 2015) suggesting that sad expressions are more subtle and thus lead to weaker responses than other emotions, our observations with natural expressions highlight a stronger response for this emotion, especially over the left hemisphere. Moreover, we observed a right hemisphere dominance for a shift from neutral to fearful faces and a left hemisphere dominance for a shift from neutral to happy faces.

43.329 **The Neural Underpinning of Abstracting Emotion from Facial Expressions** Yi-Chen Kuo[1](alex830625@gmail.com), Ya-Yun Chen[1], Gary C.-W. Shyi[1,2]; [1]Department of Psychology and Center for Research in Cognitive Sciences, National Chung Cheng University, Chiayi, Taiwan, [2]Advanced Institute of Manufacturing with High-tech Innovations, National Chung Cheng University, Chiayi, Taiwan

Abstraction bridges the perception and cognition, minimizing the storage of information, while speeding up processing. In our previous study (Kuo, Shyi, & Chen, 2017, VSS), we found behavioral evidence suggesting that people applied the abstraction strategy of image-label-conversion (ILC) when they were asked to judge others' facial expressions. Some neuroimaging studies have revealed brain regions related to labeling, and others have demonstrated areas underneath the processing of facial expression. However, cortical representations underlying facial expression labeling have not been probed directly. In the present study, we compared cortical activations in three conditions, including BaseFace, BaseLabel, and BaseFace, to investigate the brain regions that are involved in the process of ILC. In the BaseFace condition, participants were to match facial expressions from the same identity. In the BaseLabel condition, they had to choose between a pair of affective labels the one that matches a previously displayed facial expression, which presumably would prompt them to apply the ILC strategy. Finally, in the FaceCue condition, participants were to match two faces of different identities but exhibiting the same expression, which may adopt the ILC twice. The contrasts of brain activation between the three conditions showed that the right ventral lateral prefrontal cortex (rVLPFC), left fusiform gyrus, dorsal lateral prefrontal cortex (DLPFC), and anterior cingulate cortex (ACC) were significantly activated when participants applied the ILC. Moreover, the ROI analyses showed that (a) the rVLPFC was negatively correlated with the accuracy under the conditions where the ILC was used, (b) the rDLPFC was negatively correlated with the accuracy of BaseLabel condition under the contrast of BaseLabel > BaseFace, and (c) the activation of lFFG negatively predicted the performance of both the FaceCue and the BaseLabel conditions. Taken together, these findings highlight a network of cortical representations that may underpin the emotional abstraction of facial expressions.

43.330 **The acute effects of intranasal oxytocin on EEG mu responses to emotional faces** Laila E Hugrass[1,2,3](l.hugrass@latrobe.edu.au), Ariane Price[2], Eveline Mu[2], David P Crewther[2]; [1]School of Psychology and Public Health, La Trobe University, Bundoora, Australia, 3086, [2]Centre for Human Psychopharmacology, Swinburne University, Melbourne, Victoria, Australia, 3122, [3]3. Cognition and Emotion Research Centre, Australian Catholic University

Oxytocin (OT) is a neuropeptide that is well known for its effects on social cognition (Ebert & Brüne, 2017). Suppression of oscillatory activity in the mu/alpha and beta bands is associated with social cognitive processes, such as the perception of biological motion (Perry et al., 2010) and facial emotions (Moore et al., 2012). It has been shown that intranasal OT delivery enhances both mu and beta desynchronisation in electroencephalography (EEG) signals during the viewing of biological motion (Perry et al., 2010). Here, we investigated whether OT influences EEG oscillatory responses to emotional faces. In a double-blind, placebo-controlled, within subjects design, thirty healthy, young males were administered intranasal sprays of 24 IU of OT and placebo. After a delay of 45 minutes, participants viewed images of faces with fearful, neutral and happy expressions. In the 100-300ms time window after viewing neutral and fearful faces, desynchronisation in the low (8-10 Hz) and high (10-12 Hz) alpha/mu ranges was significantly stronger after OT than placebo delivery for a frontal, left-lateralised cluster of electrodes. However, OT did not significantly affect oscillatory responses to happy faces, nor did it affect oscillatory responses in the beta band (15-20 Hz). These results suggest that even at relatively early stages of visual processing, OT can affect facial emotion processing, and it may mediate the allocation of cortical processing resources towards socially relevant information.

Acknowledgement: LH and DC were supported by the Australian Research Council (ARC) (150104172). Nasal sprays were purchased with funding from Swinburne University of Technology and the Australian Catholic University.

43.331 **Visual context in emotion recognition is more powerful, prevalent and efficient than we thought** Zhimin Chen[1](mandy_chen@berkeley.edu), David Whitney[1,2,3]; [1]Department of Psychology, University of California Berkeley, Berkeley, California 94720, USA, [2]Vision Science Program, University of California, Berkeley, Berkeley, CA 94720, USA, [3]Helen Wills Neuroscience Institute, University of California, Berkeley, Berkeley, CA 94720, USA

Emotion recognition is a core perceptual ability critical for social functioning. It is widely assumed that recognizing facial expressions predominantly determines perceived emotion, and contextual influences only coarsely modulate or disambiguate interpreted faces. Using a novel method, 'Inferential Emotion Tracking,' we isolated and quantified the contribution of visual context versus face and body information in dynamic emotion recognition. Independent groups of observers tracked the valence and arousal of a chosen character in a silent Hollywood movie clip in 3 different conditions in real-time: 1) fully-informed, where everything in the video was visible. 2) character-only, where the face and body of the target character were visible but the visual context (everything else except the target) was masked and invisible. 3) context-only, where the face and body of the target were masked and invisible but the context was visible. Using regression models, we found that context-only affect ratings contributed a significant amount of unique variance (14.6%) to fully-informed ratings, comparable to that by character-only ratings (20.5%; p > 0.05). Importantly, we replicated the essential contribution of context with a different set of movie clips in which no other character is present (context: 14.4%, character: 20.5%), and another different set of non-Hollywood videos (e.g. home videos, documentaries; context: 23.2%, character: 17.8%). A meta-analysis over all 34 videos shows that context contributed as much as the face and body (p > 0.05). Strikingly, temporal cross-correlation analyses (with milliseconds precision) revealed that emotion information from context is available just as fast as emotion from faces. Furthermore, when observers tracked the emotion of the target using discrete emotion categories, the context still contributed significantly (12%), although less than the character did (35%; p < 0.01). Our results demonstrate that emotion recognition is, at its heart, an issue of context as much as it is about faces.

43.332 **Investigating the contribution to emotional response of facial information in the context of natural scenes** Cristina-Bianca Denk-Florea[1](c.denk-florea.1@research.gla.ac.uk), Professor Frank Pollick[1]; [1]The University of Glasgow

Responses to affective images are organised around the dimensions of valence, arousal and approach-avoidance motivation (Watson et al., 1999). These dimensions are mapped onto specific physiological systems (e.g. startle blink responses) and drive the emotional response differently. Apart from these dimensions, another major factor driving emotional response is provided through the phenomenon of emotional mimicry and more specifically through facial mimicry (Moody et al., 2017). Despite this effect, the contribution to emotional response of facial information and affective scene response have mostly been studied separately. To bridge the gap between these two areas, we are investigating the effect of facial information in the context of complex scenes. We are collecting data from 40 participants. During the experiment, participants are presented with images from 5 categories (neutral, erotic, mutilation, threat and positive people scenes). These images are presented in their intact form (intact condition) and in an altered form (pixelated condition) where facial information of people in the scenes has been pixelated. The participants' task is to rate the valence and arousal of the pictures with the Self-Assessment Manikin (Bradley & Lang, 1994). We are also collecting participants' physiological responses to the images using facial electromyography and electrodermal activity. We are measuring the activity of the corrugator supercilli, zygomaticus major and orbicularis oculi muscles to assess responses of valence and finger electrodermal activity to assess responses of arousal. Preliminary gamma GLM analyses of 5 participants indicate a significant main effect of condition (chi2=74.903, df=1, p=0.0009) in the zygomaticus and a significant main effect of image category (chi2=325.43, df=4, p< 0.001) in the corrugator. Overall, this study will provide a better understanding of the contribution of facial information in the context of complex scenes and will inform professional organisations of practices which can improve workplace emotional well-being in employees exposed to distressing images.

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43.333 **The effect of auditory semantic cues on face expression processing: An EEG investigation** Anna Hudson[1](a3hudson@uwaterloo.ca), Heather Henderson[1], Roxane Itier[1]; [1]Psychology, University of Waterloo

The context under which we view emotional face expressions modulate their interpretation. Of particular importance are the spoken words of a social partner, providing immediate contextual changes that guide socio-cognitive processing. Despite the salience of auditory cues, prior work has mostly employed visual context primes. These works demonstrate that language-driven semantic context modulates the perception of facial expressions at both the behavioural and neural level. While previous auditory context cues include interjections and prosodic manipulations, auditory situational semantic sentences have not yet been used. The current study investigated how such auditory semantic cues modulate face expression processing. In a within-subjects dynamic design, participants categorized the change in expression of a face (happy; angry) following congruently (e.g. positive sentence-happy face) and incongruently paired (e.g. positive sentence-angry face) auditory sentences presented concurrently with the neutral expression of the face. Neural activity was recorded, and Event Related Potential (ERP) components time-locked to the onset of the face expression included the P1 (70-120ms), N170 (120-220ms), Early Posterior Negativity (EPN: 200-400ms), and the Late Positive Potential (LPP; 400-600ms). Consistent with previous work, congruent trials elicited faster reactions times and fewer errors relative to incongruent trials. Typical emotion effects were found, whereby the EPN and LPP were enhanced for angry relative to happy faces. Interestingly, the N170 was enhanced for happy relative to angry faces, a finding opposite to typical results in the literature, although reported in previous visual context priming studies. No effects on the P1 and no interaction between sentence valence and face expression, were found. Thus, despite auditory semantic cues modulating the categorization of face expressions at the behavioural level, no interaction at the neural level was seen. Findings are discussed in the framework of distinct neural networks for processing auditory semantic cues and visual face expressions in dynamic audio-visual designs.

Acknowledgement: NSERC Discovery Grant

43.334 **Dorsal face-movement and ventral face-form regions are functionally connected during visual—speech recognition** Kamila Borowiak[1, 2, 3](kamila.borowiak@tu-dresden.de), Katharina von Kriegstein[1, 2]; [1]Technical University of Dresden, [2]Max Planck Institute for Human Cognitive and Brain Sciences, [3]Berlin School of Mind and Brain, Humboldt University of Berlin

Facial emotion perception involves functional connectivity between dorsal-movement and ventral-form brain regions (Furl et al., 2014, Cereb. Cortex; Foley et al., 2012, J. Cogn. Neurosci.). Here, we tested the hypothesis that such connectivity also exists for visual-speech processing and explored how it is related to impaired visual-speech recognition in high-functioning autism spectrum disorder (ASD) (Borowiak et al., 2018, Neuroimage Clin.; Schelinski et al., 2014, Neuropsychologia). Seventeen typically developed adults (control group) and seventeen adults with high-functioning ASD (ASD group) participated. Groups were matched pairwise on age, gender, handedness and intelligence quotient. The study included a combined functional magnetic resonance imaging (fMRI) and eye-tracking experiment on visual-speech recognition, a functional localizer and behavioral assessments of face recognition abilities. In the visual-speech recognition experiment, participants viewed blocks of muted videos of speakers articulating syllables. Before each block, participants were instructed to recognize either the articulated syllable (visual-speech task) or the identity of the articulating person (face-identity task). Functional connectivity was assessed using psycho-physiological interaction analysis (PPI) based on the contrast "visual-speech task > face-identity task". The functional localizer was used to localize seed regions in the individual dorsal-movement regions (visual motion area 5 (V5/MT), temporal visual speech area (TVSA)) and target regions in the ventral-form regions (occipital face area (OFA), fusiform face area (FFA)). In both groups, dorsal-movement regions were functionally connected to ventral-form regions during visual-speech vs. face-identity recognition ($p < .0125$ FWE corrected). Part of this connectivity was decreased in the ASD group compared to the control group (i.e., right V5/MT- right OFA, left TVSA – left FFA). The results confirmed our hypothesis that functional connectivity between dorsal-movement and ventral-form regions exists during visual-speech processing, but parts of it are reduced in ASD.

Acknowledgement: Max Planck Research Group grant, ERC-Consolidator Grant (SENSOCOM, 647051)

43.335 **The relationship between facial speech cues and vocal tract configuration** Alan Johnston[1,2](alan.johnston@nottingham.ac.uk), Christopher Scholes[1], Ben B Brown[1], Jeremy Skipper[2]; [1]School of Psychology, University of Nottingham, [2]Experimental Psychology, University College London

Exposure to visual facial cues during speech improves speech recognition, especially when the speech is embedded in auditory noise. However, the neural mechanisms underlying integration of visual and auditory speech cues are unclear and relatively little work has been devoted to understanding how visual facial cues provide information about speech. Do we have an internal model of speech production that links facial cues with articulation? To start to address this question, we investigated what information was available from videos of facial motion that might support an internal representation of the vocal tract during speech perception.We video-recorded 13 'actors' simultaneously from 5 angles (ranging from front-on to profile view) as they repeated 10 different sentences 20 times, and then separately took high-acquisition-rate sagittal magnetic-resonance imaging (MRI) scans as the actors repeated the same sentences (replayed through headphones). Principal components analysis (PCA) was performed on hybrid profile face video and MRI vocal tract scans to identify co-variation between the two modalities. First, separate PCAs were performed for all combinations of the 20 video and MRI repeats for a given subject and sentence. By projecting only the part of the input vector describing change in one modality into the bimodal PCA space the other modality was 'reconstructed'. Pearson correlations between the original and reconstructed PCA scores were broadly distributed, reflecting natural variation in spatiotemporal registration between the video and MRI. Importantly, MRI reconstruction coefficients were generally close to 1, indicating that vocal tract motion could be predicted from facial motion, without the need for precise alignment of the two modalities in either space or time.This shows that the shared variability between facial speech and MRI representations of speech production can be extracted by PCA as a first step in understanding how facial cues might be used to understand speech.

Acknowledgement: EPSRC, NIHR BRC

Perceptual Learning: adaptation, neural mechanisms

Monday, May 20, 8:30 am - 12:30 pm, Banyan Breezeway

43.336 **The transfer of perceptual learning to a physically and orientation different stimulus requires triple training** Jun-Yun Zhang[1](zhangjunyun@pku.edu.cn), Guo-Zhen Liu[1], Cong Yu[1]; [1]School of Psychological and Cognitive Sciences, Peking University

Perceptual learning becomes completely transferrable with double training when the observers receive additional exposure of the transfer stimulus via an irrelevant task. However, we noticed that Vernier learning transferred to a new location after double training only when the training and transfer stimuli shared the same orientation. A second exposure to a suprathreshold orthogonal Vernier was necessary to enable cross-orientation learning transfer (Wang_et_al._2012). Here we investigated whether orientation learning transfer between orthogonal gratings and symmetric dot patterns also requires such triple training (training plus double exposures). Observers learned orientation discrimination of a grating or symmetric dot pattern, and the learning transfer to the other, orthogonal, stimulus was tested. We found (1) Baseline: Grating orientation learning (35o/125o) had little effect on orthogonal dot-pattern orientation discrimination; (2) Double training: Additional exposure to the orthogonal dot patterns via a brightness discrimination task produced incomplete learning transfer to orthogonal dot patterns, since further dot-pattern orientation training induced extra performance gain; (3) Triple training: Observers received exposure of both new orientation and new stimulus via two separate tasks: grating brightness discrimination at the orthogonal orientation, and dot pattern brightness discrimination at the same or orthogonal orientation. After triple training, dot-pattern orthogonal orientation discrimination was improved, and continued training produced no further gains, indicating complete transfer of grating orientation learning to the orthogonal symmetric dot patterns. (4) Control: The above double exposures by themselves had little impact on dot-pattern orientation discrimination. (5) The same patterns of learning transfer results were replicated from dot-patterns to gratings. These results suggest that the brain performs two remapping to transfer perceptual learning. One remaps learning to an

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orthogonal orientation of the same stimulus, which is enabled by exposure of the same but orthogonal-oriented stimulus. The other remaps learning to a physically distinct stimulus by exposure of the new stimulus.

Acknowledgement: Natural Science Foundation of China Grant (31470975 & 31230030

43.337 **Adaptive Changes in the Visuocortical Contrast Response to Spatial Frequency Stimuli: Dissociation Between Alpha-band Power and Driven Oscillations.** Wendel M Friedl[1](wfriedl@ufl.edu), Andreas Keil[1]; [1]Department of Psychology, University of Florida

The current work investigated adaptive visuocortical changes in spatial frequency tuning using electrophysiology and a classical fear conditioning paradigm in which the spatial frequency of Gabor gratings differentially predicted a noxious sound.Fifty-five undergraduate students (MAGE = 18.69, SDAGE = 0.91, 36 female) at the University of Florida participated in the study. High-density (128 channel) EEG was continuously recorded while participants viewed 400 total trials of individually presented Gabor patches of 10 different spatial frequencies (40 total trials per frequency). Gabor stimuli were flickered to produce sweep steady-state visual evoked potentials (ssVEPs) with a temporal frequency of 13.33 Hz. Stimulus contrast was ramped up from 0 to 100% Michelson over the course of each trial. In the second half of the experimental session, a selected range of Gabor stimuli (either with the lowest or highest spatial frequencies, manipulated between-participants) were paired with an aversive 90 dB white noise auditory stimulus.The amplitude envelope of the sweep ssVEP response at 13.33 Hz was extracted via Hilbert transformation and Alpha band (7.93 – 12.07 Hz) activity was isolated through wavelet transform, with differences between paired and unpaired gratings before and after conditioning evaluated statistically using permutation-controlled mass-univariate t-tests. Ongoing analyses indicate that amplitude reduction in the alpha band (alpha blocking) was more pronounced when viewing spatial frequencies paired with aversive stimuli, compared with when viewing non-paired Gabors. Notably, alpha blocking did not follow the contrast increase across the trial, but the Hilbert envelope of the sweep-ssVEP did, suggesting that alpha reflects a detection/attention mechanism rather than a contrast-tracking mechanism. Results suggest that higher-order attention network responses to fear-conditioned stimuli may operate independently of low-level stimulus feature processing in primary visual cortex as indexed by ssVEPs.

43.338 **Rapid reorganization in the adult human primary visual cortex following non-invasive and reversible visual cortical deprivation in healthy subjects** Yaseen A Jamal[1](yaseen.jamal@emory.edu), Daniel D Dilks[1]; [1]Department of Psychology, Emory University

Neural and behavioral evidence of reorganization in the adult human primary visual cortex (V1) has been reported in patients following long-term deprivation (i.e. months to years) due to stroke or Macular Degeneration. By contrast, reorganization following short-term deprivation (i.e. seconds to minutes) is far less clear: neural evidence is absent, behavioral evidence is sparse, and studies combining neural and behavioral evidence have not been reported. Here we provide the first converging neural and behavioral evidence of rapid reorganization in healthy adult V1. Specifically, we patched one eye, thus noninvasively and reversibly depriving the cortical representation of the other eye's blind spot (BS), and then tested for reorganization using functional magnetic resonance imaging (fMRI) and psychophysics. Within minutes of eye patching, the cortical representation of the BS in V1, which normally responds to stimuli presented inside the BS in the visual field, began responding to stimuli presented outside of the BS, consistent with evidence from patients with long-term visual cortical deprivation. Crucially, these same stimuli were perceived as elongated (i.e. squares were perceived as rectangles) following deprivation. This rapid reorganization was specific to the deprived cortex only, and is too fast to be the result of structural changes (e.g., the growth of new connections), instead implicating the unmasking of preexisting connections as the underlying neural mechanism. These findings constitute the strongest evidence to date that human V1 retains the capacity for change in adulthood, and that such reorganization can occur in just minutes following the loss of normal visual input.

43.339 **Sharpness discrimination as an effective perceptual training task for presbyopia** Suraiya Jahan Liza[1](jahan@unist.ac.kr), Liana Nafisa Saftari[1], Hyun-Jun Jeon[1], Oh-Sang Kwon[1]; [1]Human Factors Engineering Department, School of Design and Human Engineering, Ulsan National Institute of Science and Technology (UNIST)

Background: Despite the growing body of evidence demonstrating that perceptual learning (Chung and Susana, 2011; Levi et al., 2009; Polat et al., 2012; Tan & Fong, 2008) and eye-training (Horwood et al., 2014; Kang et al., 2016) can improve visual functions, it is still controversial whether those improvements are practically significant enough to treat maladies such as myopia and presbyopia (Allen, et al., 2009; Deveau & Seitz, 2014). We devised a novel training task where participants discriminated the sharpness of a grating stimulus and measured the effects of training for presbyopia. Methods: Three female participants (age: 70, 51 and 50 years) completed pre-tests, 20-day training, and post-tests. In pre- and post-tests, participants' visual acuity, comfortable viewing distance, and motion sensitivity were measured. In training, a grating stimulus with sine/square wave (orientation randomized) was alternately presented on a far (280 cm) or near-screen (2-70 cm). The spatial-frequency of the far-screen stimulus and the viewing distance of the near-screen changed adaptively depending on participant's performance. Participants reported the grating's sharpness (i.e. sine or square wave) by pressing a sharp-edged/a blunt-edged button within 5 seconds after the stimulus onset (stimulus duration:1 second). Participants ran 800 trials per day for about 35 minutes. Results: Participants' performances in both near and far-screen tasks gradually improved over 20 days of training. Mean comfortable viewing distance for near-screen decreased from 27.0 cm to 8.8 cm. Spatial frequency threshold for far-screen stimulus increased from 8.6 cycle/degree to 20.7 cycle/degree. In post-test participants' VA (pre-test=0.9; post-test=1.07, p=0.04) and comfortable viewing distance (pre-test=28.83 cm; post-test=6.63 cm, p=0.04) improved significantly. However, motion sensitivity (large-sized stimuli: p=0.12; small-sized stimuli: p=0.09) didn't improve significantly. Conclusions: Results suggest that sharpness discrimination can be an effective training task for presbyopia, although additional experiments with control conditions are necessary to clarify the effects of the task.

43.340 **Single-session expertise training leads to competition between object and face representations in visuo-cortical processing** Gabriella Silva[1](gabriella.silva@ufl.edu), Lisa S Scott[1], Andreas Keil[1]; [1]Department of Psychology, University of Florida

Previous research examining perceptual expertise shows that experience alters sensory processing, including in visual cortical areas. There is also evidence that neural processing of non-face objects of expertise interferes with the processing of faces in experts (Gauthier & Curby, 2005).However, the emergence of visuo-cortical competition during early object learning has not yet been examined. The present investigations used steady state visual evoked potential (ssVEP) frequency tagging while adults (n= 24) viewed novel objects superimposed with human faces before and after a brief expertise training period.Faces served as comparison stimuli, given their ability to engage expertise-related brain regions without training. The novel objects were generated to represent exemplars of two species, based on distinctive physical characteristics. In the training phase, participants learned to distinguish exemplars of Species 1 from exemplars of Species 2. They also completed a forced choice gender discrimination task for the faces, to keep exposure to faces and objects comparable. During the pre- and post-training phases, pictures of human faces and pictures of novel objects were periodically and rapidly turned on and off at unique temporal rates (5/sec or 6/sec) against a Brownian noise background. Competition between the overlapping stimuli was quantified in the EEG frequency domain before and after training. ssVEP data were projected to a distributed source space using an L2 (minimum) norm estimation with Tikhonov-philips regularization (lambda = 0.01), and competition between faces and objects compared (before vs after training) using permutation-controlled mass univariate t-tests. Results showed that after a short expertise training period, trained objects attained a competitive advantage over faces, selectively in left and right occipitotemporal cortex, and in prefrontal cortical areas.These findings show task-relevant modulation of visuo-cortical regions during learning and suggest that neural processing of faces and objects are not functionally independent and are flexibly modulated during learning.

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43.341 **Seeing, fast and slow: effects of processing time on perceptual bias** Ron Dekel[1](ron.dekel@weizmann.ac.il), Dov Sagi[1]; [1]Department of Neurobiology, Weizmann Institute of Science, Israel

According to the diffusion-to-bound decision model (DDM), decisions are made by a gradual process of noisy evidence accumulation until a bound is reached, resulting in variability of decision times. The "starting point" of evidence accumulation is the prior, so processing is faster when prior is consistent with evidence. A less intuitive model prediction is that prior-derived decision bias gradually decrease with processing time, which, for difficult decisions and moderate prior, leads to close to zero bias in slow (>median) trials. Here, we tested the interaction of bias and processing time by manipulations of prior probability (exp. i-ii) and of visual context (exp. iii-iv). Specifically, we tested the following tasks. (i) Detection biased by target probability (25%, 50%, or 75%; using low-contrast Gabor patches, d'=~1.5, duration=50ms, σ=0.42°, λ=0.3°). (ii) Orientation discrimination biased by orientation probability (25%, 50%, or 75%; using near-vertical Gabor patches, d'=~1, duration=50ms, σ=0.42°, λ=0.3°). (iii) Orientation discrimination biased by a previously seen oriented adaptor (tilt aftereffect; using Gabor patches for both adaptation and test, ISI=600ms, duration=50ms, σ=0.42°, λ=0.3°). (iv) Orientation discrimination biased by the orientation of a surrounding ring (tilt illusion; using circular sine-wave gratings). Reaction time (RT) was used as the standard proxy for decision time. Results showed interaction of bias and time: trials with faster (median>) RT measured response bias in accordance with the experimental manipulation (prior-derived beta of ~2, induced tilt of ~2.5°), while trials with slower RT (>median) measured either zero bias (prior manipulations, beta=~1, p< 0.001) or a reduced bias (~35% reduction of induced tilt, p< 0.001). We observed a minor reduction in task accuracy for slower RT, which could not trivially explain the effect of bias. In conclusion, reduced bias with longer processing time is predicted by a standard decision model assuming temporal integration of noisy evidence, suggesting the interaction is ubiquitous in brain systems.

Acknowledgement: Supported by the Israel Science Foundation (ISF)

43.342 **Extensive training with feedback reduces attentional demand in visual feature binding** Yoko Higuchi[1,2](yokohiguchi0114@gmail.com), Naotsugu Tsuchiya[3], Ryota Kanai[4], Kazuhisa Shibata[1,2]; [1]Department of Functional Brain Imaging Research, National Institute of Radiological Sciences, [2]Graduate School of Informatics, Nagoya University, [3]School of Psychological Sciences, Monash University, [4]Araya, Inc.

Successful recognition of an object often requires binding of features of the object by attention. Withdrawing attention to a very demanding visual task at fixation can impair discrimination performance of even very simple stimuli such as colored bisection disks presented in the periphery (Fei-Fei, VanRullen, Koch, Perona, 2002). A number of studies reported that the impaired performance under dual-task conditions cannot be compensated even after training for more than 10 hours across multiple days (e.g., Fei-Fei, VanRullen, Koch, Perona, 2005; Reddy, Reddy, Koch, 2006). These results suggest that the underlying processes of feature binding is rigid and cannot be trained. Contrary to this view, we report significant training effects on discrimination performance under a dual-task condition. In a single central task, participants were asked to report whether all the letters shown on the fovea are identical or not. In a single peripheral task, they discriminated a red/green disk from a green/red disk in the periphery. Performances for the single-task condition were kept at 80% accuracy by QUEST during the entire experiment (Matthews et al., 2017). In the dual-task, participants were asked to conduct both tasks simultaneously, with emphasis on the central task. Consistent with the previous studies, this dual-task condition resulted in chance performance in the peripheral task presumably due to exhaustion of attention by the central task. However, after 10 days of training on the dual-task with trial-by-trial feedback, performance on the peripheral task significantly improved. The training effect was not specific to the trained location, suggesting improvements in readout of sensory representations by the training. We also found the training effects are long-lasting and can be observed even after a month. These results suggest that feature binding process becomes less attention-dependent as a result of extensive training.

Acknowledgement: This work is supported by JSPS Kakenhi Grant Number 17H04789 to KS, ARC Discovery Projects (DP180104128, DP180100396) and Templeton World Charity Foundation "Intelligence and consciousness in flies" to NT.

43.343 **Different types of response feedback in perceptual training are necessary to improve the detection of different types of breast cancer** Sebastian M Frank[1,2](sebastian_frank@brown.edu), Andrea Qi[1], Daniela Ravasio[1], Yuka Sasaki[1], Eric Rosen[3], Takeo Watanabe[1]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University, [2]Institute for Experimental Psychology, University of Regensburg, [3]School of Medicine, University of Colorado Denver

Perceptual learning (PL) is not only a strong tool for understanding visual plasticity (Sasaki, Nanez and Watanabe, 2011; Watanabe & Sasaki, 2015) but also for reducing symptoms of eye diseases. Here, we show that PL can also be a strong tool to increase the detectability of breast cancers in mammography scans only if an appropriate response feedback during training is given for different types of breast cancer. Response feedback is known to facilitate PL (Herzog and Fahle, 1998; Shibata et al., 2011), although a detailed role of feedback remains unclear. We examined the role of response feedback for two types of breast cancer: calcification cancer and architectural distortion cancer. The former is easier to detect than the latter. Thus, we examined how different contents of feedback are effective on PL for different breast cancers. Three 30-min long training sessions were conducted on separate days. Detection performance was measured in pre-training and post-training tests. Three different groups of participants (N = 48 subjects in total) without medical training background were trained with different contents of feedback. In the detailed feedback condition, participants were given feedback regarding the location of cancer as well as the correctness of detection. In the partial feedback condition, participants were provided with feedback only about the correctness of detection. In the no feedback condition, participants received no feedback. In the detailed condition detectability improved for architectural distortion and calcification cancers, whereas in the partial feedback condition detectability improved only for calcification. No learning for either cancer was observed in the no feedback condition. These results suggest that PL significantly improves the detectability of breast cancers in mammograms. More importantly, the content of feedback leads to different learning outcomes for different breast cancers, indicating the importance of future studies on the effect of content of feedback on PL.

Acknowledgement: NIH R01EY019466, NIH R21EY028329, NIH R01EY027841, BSF2016058

43.344 **The influence of self-construal priming on visual perceptual learning** Stephanie Yoke Ping Chua[1](stephanie.chua@mail.bcu.ac.uk), Panagiotis Rentzelas[1], Zoe Kourtzi[2], Maxine Lintern[1], Eirini Mavritsaki[1, 3]; [1]Department of Psychology, Faculty of Business, Law and Social Sciences, Birmingham City University, [2]Department of Psychology, University of Cambridge, [3]School of Psychology, University of Birmingham

Culture is a dynamic construct composed of a network of diversified, but sometimes paradoxical knowledge structures which can be activated or suppressed according to situational demands (Briley, Wyer, & Li, 2014). The emphasis of independence and personal achievements within individualistic societies have been linked to an increased tendency for analytic thinking, whereas collectivistic societies which emphasize interdependence and group goals have been associated with more holistic thinking styles (Han & Humphreys, 2016). Clearly, adherence to these independent or interdependent values could influence cognitive styles; priming independent self-construal has been found to increase local processing tendencies, while priming interdependence increases global processing (Lin, Lin & Han, 2008). Priming procedures can temporarily shift independent or interdependent self-concepts to reveal the cognitive processes that are modulated by culture. The present study thus aims to identify if there are differences in perceptual learning abilities when specific cultural values are situationally activated. Forty-one British and European students were primed with either independent or interdependent self-construal using Brewer and Gardner's (1996) pronoun circling task. Participants primed with interdependent self-construal were expected to be better at extracting global forms in the Glass pattern discrimination task than those primed with independence. As predicted, a difference in reaction times was found between both groups during training. Those primed with interdependence made significantly slower responses, and this could be attributed to the additional time needed for perceptual decision-making in accurately identifying feature differences in the stimuli. Those primed with interdependence also had higher performance than those who were independently-primed despite perceptual uncertainties in the stimuli – revealing the increased tendency for global processing when interdependent self-concepts are activated, although the differences were not significant. These findings provide evidence that self-construals can be causally linked to differences in processing styles during visual learning.

43.345 **Effects of Daily Training Amount on Visual Perceptual Learning** Yongqian Song[1,2,3,4](pkusyq@gmail.com), Nihong Chen[5,6], Fang Fang[1,2,3,4]; [1]School of Psychological and Cognitive Sciences and Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing 100871, People's Republic of China, [2]Peking-Tsinghua Center for Life Sciences, Peking University, Beijing 100871, People's Republic of China, [3]Key Laboratory of Machine Perception (Ministry of Education), Peking University, Beijing 100871, People's Republic of China, [4]IDG/McGovern Institute for Brain Research, Peking University, Beijing 100871, People's Republic of China, [5]Department of Psychology, Tsinghua University, Beijing, 100084, People's Republic of China, [6]Department of Psychology, University of Southern California, Los Angeles, California 90089-1061

Perceptual learning has been widely used to study the plasticity of the visual system in adults. However, the learning protocol is usually time-consuming, which requires subjects to practice a task for thousands of times over weeks. To understand the relationship between the training amount and the behavioral improvement, four groups of subjects underwent motion discrimination training over 8 successive days for 40, 120, 360, or 1080 trials per day. Subjects were trained around one motion direction, and were tested at 0°, 30°, 60°, and 90° away from the trained direction before, one day after, and two weeks after training. In both the tests after training, we observed a significant reduction in the threshold at the trained direction. Surprisingly, the magnitudes in the threshold reduction were similar across groups with different daily training amounts, ranging from 40 trials (2 minutes) to 1080 trials (54 minutes) per day. We further quantified the specificity of learning as the difference between the threshold change at the trained direction and the average threshold change at the untrained directions. We found that, immediately after training, the group with the smallest training amount showed a weaker specificity compared to the other groups. However, the difference in the specificity among the groups disappeared two weeks after training. These findings demonstrated that the behavioral improvement from training was independent of the daily training amount. Also, the development of learning specificity in the time course indicated that the neural mechanisms underlying perceptual learning could be dependent on the training amount and evolve with time.

43.346 **Individual differences in learning: Relations between cognition, personality, and responsiveness to perceptual training** Aaron K Cochrane[1](akcochrane@wisc.edu), C. Shawn Green[1]; [1]University of Wisconsin -- Madison

There is considerable interest in understanding whether individual-level factors exist that predict either the ability to acquire new skills or the ability to generalize skills acquired in one context to new contexts. Understanding such factors would not only contribute to mechanistic theories of learning, but could also identify potential foci of interventions designed to enhance the utility of behavioral training. Here we report an experiment designed to address three core questions: (1) To what extent is learning on two distinct perceptual tasks correlated across individuals? (2) to what extent is the ability to transfer perceptual learning gains correlated across individuals and (3) do other measures of cognition and personality relate to learning and/or generalization? Participants were trained for four days on two different visual perception tasks (motion orientation discrimination and oddball texture detection). The training was followed by tests of generalization on each task (same task, but new directions/orientations). Participants also completed a battery of individual-difference level measures including tasks designed to assess reasoning, attention, working memory, various life experiences (e.g., media use), and personality factors. We estimated participant-level learning trajectories in a nonlinear hierarchical regression framework. We observed robust correlations between participants' asymptotic performance levels on each learning task, with weaker evidence for correlations between parameters directly linked to changes in performance. Measures of generalization also correlated across learning tasks. Finally, while we identified several individual difference level predictors of learning (e.g., measures that load on speed of processing and/or executive function were related to both learning rate and initial performance), we found minimal evidence for variations in transfer that were explained by measures apart from performance on the trained tasks themselves. While clearly preliminary, these results suggest that the ability to transfer learning is inherently linked to the overall ability to learn.

43.347 **Ultra-high field imaging of perceptual learning in the human visual cortex** Ke Jia[1](kj350@cam.ac.uk), Elisa Zamboni[1], Nuno Reis Goncalves[1], Catarina Rua[2], Valentin Kemper[3], Guy Williams[2], Chris Rodgers[2], Zoe Kourtzi[1]; [1]Department of Psychology, University of Cambridge, [2]Wolfson Brain Imaging Centre, Department of Clinical Neurosciences, University of Cambridge, [3]Department of Cognitive Neurosciences, Faculty of Psychology and Neuroscience, Maastricht University

Training is known to improve perceptual judgments; yet the neural underpinnings of learning-dependent plasticity remain controversial. Previous physiological studies found little evidence of learning-dependent plasticity in the visual cortex, whereas fMRI studies have reported more pronounced changes in functional brain activity due to training. Recent advances in brain imaging technology (i.e. ultra-high field 7T imaging) afford us with higher resolution to examine learning-dependent brain plasticity at the finer scale of laminar layers in the human visual cortex. Here, we tested whether training results in brain activity changes in input compared to deeper layers, consistent with learning-dependent changes in local vs. feedback processing, respectively. We trained participants on an orientation discrimination task over five consecutive days. Both before and after the training phase, we measured participants' behavioral performance along three different orientations (55°, 125°, or 0°) at two different locations (left or right to the fixation) and their functional brain activity across visual cortex layers. The trained orientation and location remained the same across training sessions and were counterbalanced across participants. Participants' behavioral performance improved significantly over the course of training. Analysis of the fMRI data did not show significant differences in overall BOLD response before vs. after training. However, multivoxel pattern analysis (MVPA) showed enhanced decoding accuracy for the trained orientation after than before training. These learning-dependent changes were specific to middle rather than deeper or superficial layers in primary visual cortex. Further, using forward encoding modeling (FEM), we found enhanced channel response selective to the trained orientation after training. These learning-dependent changes in both behavioral improvement and multivoxel activity patterns (MVPA and FEM) were specific to the trained orientation and location. These results suggest that training to discriminate fine orientation differences relates to enhanced local information processing in the primary visual cortex.

Acknowledgement: Wellcome Trust, BBSRC, Alan Turing Institute

43.348 **Using Closed-Loop Real-Time fMRI Neurofeedback to Induce Neural Plasticity and Influence Perceptual Similarity** Marius Cătălin Iordan[1](mci@princeton.edu), Victoria J. H. Ritvo[1], Kenneth A. Norman[1], Nicholas B. Turk-Browne[2], Jonathan D. Cohen[1]; [1]Princeton Neuroscience Institute & Psychology Department, Princeton University, [2]Psychology Department, Yale University

Learning to group diverse visual stimuli into categories is correlated neurally with increased within-category pattern similarity and increased between-category pattern separation in high-level visual cortex (Folstein et al. 2015; Clarke et al. 2016; Hammer & Sloutsky 2016). However, the causal link between the neural representation of categories and their perception remains unclear. To address this question, we use closed-loop real-time fMRI neurofeedback to induce neural plasticity (Jackson-Hanen et al. 2014; deBettencourt et al. 2015), similar to what we would observe during category learning, but underneath the threshold of awareness and without any explicit learning taking place from the participants. More specifically, we constructed a stimulus space of complex artificial shapes that varied along multiple dimensions independently and confirmed (n=750) that each stimulus dimension is perceived in an equivalently graded manner, as are manipulations of the space along these dimensions. Moreover, multiple brain regions represented this space as a putative cognitive map, mirroring perception (EVC, LOC, PFC, temporal pole). Within this space, we hypothesized that using neurofeedback to strengthen unique features and suppress shared features of visual categories should also differentiate the categories perceptually. To compute the neurofeedback provided to differentiate categories, we developed a novel computational approach (KL-Evidence) based on mutual information between the distributions of neural responses they elicit. We will present preliminary evidence that this procedure influences perceptual similarity of the items after training, that is, that we induced the presence of stronger implicit perceptual categories along the trained dimension, compared to the untrained dimensions. This suggests a potential causal link between neural representations in these brain regions and perception.

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More broadly, this technique shows promise for becoming a novel conduit to access and manipulate the contents of complex subjective visual experience, as well as learning in a non-invasive way via fMRI.

Acknowledgement: John Templeton Foundation, Intel Corporation, NIH R01 MH069456

43.349 **Statistical learning enables implicit subadditive predictions** Yu Luo[1](yuluo@psych.ubc.ca), Jiaying Zhao[1,2]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

The visual system readily detects statistical relationships where multiple cues jointly predict a specific outcome (e.g., two co-authors publishing a paper, or two co-founders starting a company). What is less known is how the visual system generates predictions when only a single cue is present, after learning that the two cues were previously jointly associated with an outcome. Here we examine three hypotheses: (1) complete inheritance hypothesis where the single cue predicts 100% of the outcome previously associated with the two cues, (2) proportional inheritance hypothesis where the single cue predicts 50% of the outcome, and (3) subadditive hypothesis where the single cue predicts more than 50% but less than 100% of the outcome, consistent with support theory (Tversky & Koehler, 1994). To test these hypotheses, we used a statistical learning paradigm where participants were exposed to two objects (e.g., red and blue squares) that were followed by a circle with a specific size. After exposure, participants viewed a single object (e.g., a red square) at a time and were asked to estimate the circle size that was associated with the object. Afterwards, participants recalled the size of the circle that followed the two objects during exposure. We found that the estimated size associated with the single object was significantly smaller than the recalled size associated with the two objects, but significantly larger than 50% of the recalled size (Experiment 1), or larger than 33% of the recalled size in case of three objects (Experiment 2). This confirms the subadditive hypothesis. Importantly, no participants were consciously aware of the association between the objects and the circle size. The results reveal a new consequence of statistical learning on visual inferences: when multiple objects predict a specific outcome, the single object is implicitly expected to predict an outcome in a subadditive fashion.

43.350 **Visuo-motor adaptation during interaction with a user-adaptive system** Priscilla Balestrucci[1](priscilla.balestrucci@uni-ulm.de), Marc O. Ernst[1]; [1]Applied Cognitive Psychology, Faculty for Computer Science, Engineering, and Psychology, Ulm University, Ulm, Germany

User-adaptive systems are a current trend in technological development. Such systems are designed to sense the user's status based on ongoing interaction and automatically change certain features (e.g. content, interface, or interaction capabilities) in order to provide a targeted, personalized experience. In this scenario, users are likely to adapt to the evolving characteristics of the interaction (Burge et al., 2008), changing their own behavior to correctly interact with such systems and thereby leading to dynamics of mutual adaptation between human and machine. We investigated such mutual adaptation dynamics within a visuo-motor adaptation paradigm. Participants were instructed to perform fast pointing movements on a graphic tablet as accurately as possible, while also seeking to minimize the error between target and feedback location on a screen in front of them. The feedback location reflected the pointing performance of the user according to the underlying tablet-to-screen mapping, which changed systematically over time due to the introduction of a step offset. Concurrently, an adaptive algorithm corrected the feedback location according to an estimation of the participant's error, thus contributing to the reduction of the displayed error over trials. In different experimental conditions, the extent of such contributions varied systematically, and we measured the adaptive performance of the human-machine system as a whole, as well as the underlying motor performance of participants. The greater the correction introduced by the adaptive algorithm, the more effective was the joint system in reducing visual error after the introduction of the step offset. On the other hand, when considering human's motor behavior alone, the pointing error did not decrease, but tended to increase over time with higher contributions from the algorithm. Our findings indicate that, in order to obtain desired outcomes from interactions with user-adaptive technology, the sensorimotor mechanisms underlying such interactions must be considered.

Acknowledgement: The current study was funded by the German Research Foundation (DFG) within SFB/Transregio 161

43.351 **Decrease of the tilt illusion effect through perceptual learning** Nari Jeong[1](xjsjfrhleka1@naver.com), Soojin Lee[1], Kyou Dong Lee[1], Hoon Choi[1]; [1]Department of Psychology, Hallym University, South Korea

Perceptual learning shows that our perceptual ability can improve, and numerous previous studies have focused on increasing sensitivity to trained stimuli. However, another way of improving perceptual ability is to see stimuli more accurately, especially when one misperceives a given stimulus through optical illusion. The current study investigated whether the illusion can be reduced through perceptual learning, employing the tilt illusion in which the orientation of the center grating is misperceived because of the surrounding grating's orientation. The study consisted of seven sessions: a pretest, five sessions of training, and a posttest. In pretest and posttest trials, participants were given a training stimulus, consisting of a center grating with (tilt-illusion condition) or without the surrounding grating (center-grating-only condition). The orientation of the center grating was one out of 357°, 0°, 3°, 87°, 90°, and 93°, and the orientation of the surrounding grating was 72° or 162°. Participants were asked to rotate the center grating by pressing arrow keys on a keyboard until they perceived it vertically or horizontally, and the amount of illusion was defined as the difference between the actual and the perceived orientation. Each training session comprised 450 trials. Participants were randomly assigned to the control training group, which were given only a center grating as a training stimulus, or the illusion training group, which were given both a center and a surrounding grating. During training sessions, response feedback was provided. Consequently, a smaller amount of tilt illusion was found after training sessions. In particular, the learning effect was larger in the illusion training group than in the control training group. These results suggest that learning occurs in such a way as to suppress the effects of surrounding stimuli.

Acknowledgement: 2017S1A5A8021943(National Research Foundation of Korea)

43.352 **Direction selective habituation of motion adaptation** Xue Dong[1](dongx@psych.ac.cn), Min Bao[1]; [1]CAS Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing 100101, China

Both adaptation and perceptual learning can change how we perceive the visual environment, reflecting the plasticity of the visual system. Our previous work has attempted to investigate the interaction between the two aspects of visual plasticity. One of the main findings is that multiple days of repeated motion adaptation attenuates motion aftereffect (MAE), which is explained by habituation to the motion adapter. Interestingly, there is little transfer of habituation effect to the untrained adapter which differed from the trained one in the features including retinotopic location, spatiotopic location and motion direction. Research on visual perceptual learning has suggested that the transfer of learning effect can vary according to the features tested. Since features are processed in different neural loci along the visual pathways, probing the key features that determine the transfer of habituation in repeated motion adaptation may help disclose the underlying neural mechanisms for this phenomenon. Participants were trained to adapt to a motion adapter for 8 days. Before and after training, the MAE of the trained and an untrained adapter were tested. In three experiments, we examined the role of retinotopic location, spatiotopic location, and motion direction on the transfer of habituation, respectively. In each experiment, only one of the features was kept the same for the trained and untrained conditions. Suppose we can observe a significant transfer of habituation effect when one feature is rendered the same for the two conditions, but no transfer when it differs across the conditions. Then that feature would be the key determinant for the transfer. We found that the habituation effect transferred across both the retinotopic and spatiotopic locations as long as the adapting direction remained the same, suggesting that the habituation of motion adaptation is likely related to the plasticity of direction-selective neurons with large receptive fields.

43.353 **Visual representations outside of conscious awareness can support sensory preconditioning** Cody A Cushing[1](codycushing@live.com), Mouslim Cherkaoui[1], Mitsuo Kawato[2,3], Jesse Rissman[1,4,5,6], Hakwan Lau[1,4,7,8]; [1]Department of Psychology, University of California Los Angeles, [2]Department of Decoded Neurofeedback, Computational Neuroscience Laboratories, Advanced Telecommunications Research Institute International, [3]Faculty of Information Science, Nara Institute of Science and Technology, [4]Brain Research Institute, University of California Los Angeles, [5]Department of Psychiatry & Biobehavioral Sciences, University of California Los Angeles, [6]Integrative Center for Learning and Memory, University of California Los Angeles, [7]Department of Psychology, University of Hong Kong, [8]State Key Laboratory of Brain and Cognitive Sciences, University of Hong Kong

When one of two previously-paired neutral visual stimuli starts to subsequently predict reward, subjects treat the other neutral item as if it similarly predicts reward despite the lack of direct reinforcement for that particular visual stimulus. Termed sensory preconditioning, this phenomenon is often used to explore model-based learning. However, it has been suggested that sensory preconditioning may happen even for stimuli that are not consciously perceived. We tested this hypothesis in a decoded neurofeedback (DecNef) experiment. To form an association between a viewed stimulus and an unrelated non-conscious visual representation, online fMRI data was analyzed through a MVPA classifier while participants (N=5) viewed a fullscreen dot-motion display at 100% motion coherence. Visual feedback was given based on the likelihood that BOLD activity while participants viewed the dot-motion display represented an unrelated target image category (DecNef target), which was never consciously seen. After 3 days of neurofeedback, participants completed a betting task with feedback which reinforced participants to value the previously presented dot-motion display as a significant financial loss. Following this, participants completed another round without feedback in which a critical decision was made between two previously unseen objects: the DecNef target and a neutral control. Participants bet on the neutral control significantly more often than the DecNef target (individual $\alpha 2$'s, all p's< 0.05 with 3 subjects showing the maximum possible effect at $\alpha 2(1, N=30) = 30$, $p< 0.001$), indicating successful preconditioning of a visual stimulus outside of conscious awareness. These results suggest associations can indeed be formed and conditioned between visual stimuli outside of conscious awareness, questioning whether consciousness is necessary for model-based learning. This opens a discussion on how these neurofeedback-driven subliminal visual presentations may complement traditional methods of rendering visual stimuli unconscious, such as: masking, continuous flash suppression, crowding, and other methods.

43.354 **Unitization of audio-visual conjunctions is reflected by shifts in processing architecture** Jackson C Liang[1](jacksoncliang@gmail.com), Layan A Elfaki[1], Morgan D Barense[1]; [1]Department of Psychology, University of Toronto

Unitization is thought to integrate multiple features into a single unit across repeated learning instances; thus, the combination of features unique to your pet dog becomes elevated above a sea of overlapping canine features at the park. There is ample evidence consistent with unitization across many domains, yet how unitization is implemented within the human brain is largely unconfirmed. Here we test two central hypotheses: first, unitizing audio-visual object conjunctions should promote parallel processing during perceptual judgments involving the component features. Second, processing architecture should vary according to the representational hierarchical view, which proposes that the neural representations of feature conjunctions are organized hierarchically relative to the individual features themselves. Thus, unitization benefits highly familiar conjunctions, while other conjunctions benefit little even when they comprise the same underlying features. Participants learned to identify conjunctions of birdcalls (A through D) and bird images (1 through 4) as belonging to a Lake or River (e.g., A1 and B2 were Lake birds, while C3 and D4 were River birds). We constructed an Intact set of birds that matched directly trained conjunctions (e.g., A1 and B2), and a Recombined set of birds that were never directly trained (e.g., A2 and B1). We tested participants' ability to identify Lake features while manipulating the saliency of the audio and visual features via rainfall-like audio and visual noise. The resulting reaction time distributions were analyzed using the Systems Factorial Technology framework to determine whether the audio-visual processing architecture was more parallel, serial, or coactive. Consistent with unitization theory, we observed survivor interaction contrasts (SICs) indicating parallel processing for Intact birds. Futhermore, we observed SICs consistent with serial processing for Recombined birds, despite sharing features with the Intact birds. These data show how unitization sharpens perceptual processing for familiar conjunctions and is robust to confusion from overlapping features.

Acknowledgement: NSERC (for M.D.B.) and James S McDonnell Foundation Grant (for M.D.B.)

43.355 **Learning to calibrate age estimates** Jordan W Suchow[1](suchow@berkeley.edu), Thomas L Griffiths[2]; [1]Department of Psychology, University of California, Berkeley, [2]Department of Psychology, Princeton University

Age is a primary social category and, with little effort, we can quickly approximate it from photographs. Here, we analyze 1.5 million age judgments derived from a popular online website where participants estimate the age of a person depicted in a photograph, with feedback. We find that median age judgments across participants are linear in the actual age, with little bias. However, the slope is considerably less than one, such that the aggregate overestimates the age of younger people and underestimates the age of older people. Age estimates are found to be unbiased at 37.5 years, which coincides with the median age across all the depicted persons. These results are consistent with an account in which, over time, participants learn to calibrate an analogue magnitude to the learned distribution of encountered ages, combining photographic evidence with distributional information to arrive at an estimate that balances the two.

Scene Perception: Cortical coding, neural mechanisms, neural networks

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43.356 **Adaptation to the Amplitude Spectrum Slope of Natural Scenes in Modified Reality** Bruno Richard[1](bruno.richard@rutgers.edu), Patrick Shafto[1]; [1]Department of Mathematics and Computer Science, Rutgers University - Newark

The amplitude spectrum of natural scenes falls inversely with spatial frequency (f) according to 1/fa, where a dictates the rate of descent in amplitude, ranging between 0.6 and 1.6 in natural environments. Human observers are sensitive to the value of a: discrimination thresholds peak when reference a ranges between 1.0 and 1.3. This peak in sensitivity is thought to be related to the prevalence of as values encountered in the natural world: most scenes have as of approximately 1.0 (Hansen & Essock, 2005, Vis. Cog.). Indeed, an adaptation study (Elliott et al., 2011, JoV) has shown that adapting to shallower as makes shallow a images appear steeper, while the opposite holds true when adapting to steeper as. These effects are indicative of a renormalization to some pre-adapted state of the human visual system. If this is true, then placing observers in a natural environment with a values that deviate from the 1.0 average should shift the peak in a sensitivity towards the new environment average. We investigate this using modified reality: we immersed 3 observers in an environment where the a of images in either steepened (a + 0.4) or shallowed (a - 0.4). Observers were placed in modified reality for a total of 60 minutes and a discrimination thresholds were measured for 5 reference a values (0.4, 0.7, 1.0, 1.3, 1.6) at 20 minute intervals. Steepening a resulted in flat tuning to a for the first 20 minutes of adaptation while shallowing a had little effect. In the steeper environment, thresholds for all reference a returned to baseline values, except for a reference a of 0.7 following adaptation (60 min). We explain these effects with a model of contrast adaptation that pools the responses of multiple, differently tuned spatial frequency channels, according to the 1/f property of natural scenes.

Acknowledgement: NSF CHS-1524888

43.357 **Assessing the similarity of cortical object and scene representations through cross-validated voxel encoding models** Nicholas M. Blauch[1](blauch@cmu.edu), Filipe De Avila Belbute Peres[2], Juhi Farooqui[1], Alireza Chaman Zar[3], David Plaut[1,4], Marlene Behrmann[1,4]; [1]Center for the Neural Basis of Cognition, Carnegie Mellon University, [2]Computer Science Department, Carnegie Mellon University, [3]Department of Electrical and Computer Engineering, Carnegie Mellon University, [4]Department of Psychology, Carnegie Mellon University

Object and scene perception are instantiated in overlapping networks of cortical regions, including three scene-selective areas in parahippocampal, occipital, and medial parietal cortex (PPA, OPA, and MPA), and a lateral occipital cortical area (LOC) selective for intact objects. The exact contributions of these regions to object and scene perception remain unknown. Here, we leverage BOLD5000 (Chang et. al, 2018), a public fMRI dataset containing responses to ~5000 images in ImageNet, COCO, and Scenes databases,

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to better understand the roles of these regions in visual perception. These databases vary in the degree to which images focus on single objects, a few objects, or whole scenes, respectively. We build voxel encoding models based on features from a deep convolutional neural network (DCNN) and assess the generalization of our encoding models trained and tested on all combinations of ImageNet, COCO, and Scenes databases. As predicted, we find good generalization between models trained and tested on ImageNet and COCO and poor generalization between ImageNet/COCO trained models and Scenes for most DCNN layer/ROI encoding models. Surprisingly, we find generalization from ImageNet/COCO to Scenes only in early visual cortex with encoding models of intermediate DCNN layers. Additionally, LOC and PPA exhibit similarly good generalization between ImageNet and COCO and poor generalization to Scenes. Excluding MPA responses to Scenes, all scene-selective areas generalize well to held-out data in the trained image database, but PPA exhibits the most robust generalization out-of-database between ImageNet and COCO, reflecting a more general perceptual role. Our work reflects a novel application of encoding models in neuroscience in which distinct stimulus sets are used for training and testing in order to test the similarity of representations underlying these stimuli. We plan to further test the effect of pretraining the DCNN on Places365 rather than ImageNet, and to look at image-level predictors of generalization.

43.358 **Organization of population receptive fields in the parahippocampal place area** Charlotte A Leferink[1](charlotte.leferink@mail.utoronto.ca), Claudia Damiano[1], Dirk B Walther[1]; [1]University of Toronto

Decades of research have confirmed that all stages of processing within the visual system show retinotopic organization, from retinal ganglion cells to high-level visual areas, such as the parahippocampal place area (PPA). The parahippocampal cortex in particular has been shown to exhibit a peripheral field bias, which is commonly interpreted as leading to a lack of sensitivity to high spatial frequencies (Arcaro et al., 2009). However, neuroimaging studies have shown that the PPA is activated more strongly by high than low spatial frequencies (Rajimehr et al., 2011). How can this be the case if the PPA is not sensitive to high spatial frequencies? Using a stimulus that is known to activate high-level visual cortex, we sought to thoroughly map the population receptive fields (pRFs) in order to verify previous findings and explore the apparent contradiction regarding the representation of high spatial frequencies in the PPA. Here, we used the pRF scans from a subset of the participants in the Human Connectome Project database, obtained with high field strength (7T) fMRI. We estimated the eccentricity, angle, and pRF size using a nonlinear optimization model fitting procedure (Kay et al., 2013). Within the PPA, we find that pRFs range from small and foveal representations, to larger pRFs, which are located in the peripheral visual field regions. The anatomical location of voxels fitted for pRF eccentricity are significantly correlated along the anterior-posterior axis, with more foveal pRFs located closer to the anterior regions of the brain. In line with previous studies (Silson et al., 2015), there was a significant contralateral hemifield bias, and a bias for the top-half of the viewing plane in the PPA. In their combination, these results suggest that both high and low frequency visual information is processed in specialized areas of the PPA.

Acknowledgement: NSERC, SSHRC

43.359 **The neural basis of local contour symmetry in scene perception** John D Wilder[1](jdwilder@cs.toronto.edu), Morteza Rezanejad[2], Kaleem Siddiqi[2], Allan Jepson[3], Sven Dickinson[3], Dirk B Walther[1]; [1]Department of Psychology, University of Toronto, [2]School of Computer Science, Centre for Intelligent Machines, McGill University, [3]Department of Computer Science, University of Toronto

The visual system is tasked with turning light impinging onto our retinas into meaningful percepts. Providing a strong cue to the presence of objects and surfaces, symmetry is one of the Gestalt principles underlying the grouping of visual information in mid-level vision. In fact, it has recently been demonstrated that there is a perceptual advantage for symmetry for the perception of complex real-world scenes. Here we uncover the neural basis of the perceptual advantage of symmetry. Specifically, we show how local contour symmetry modulates neural activity patterns elicited by complex scenes throughout visual cortex. Participants were shown full, intact line drawings of scenes as well as line drawings containing the most symmetric/asymmetric half of the contour pixels. We decoded scene categories from the voxel activity in early visual cortex as well as high-level, scene-selective brain regions. Decoding of scene categories was more accurate in the symmetric than the asymmetric condition in PPA, OPA, and LOC. In areas V1-4, on the other hand, scene categories were more accurately decoded in the asymmetric than the symmetric condition. A searchlight analysis yielded consistent results, showing that mid- and high-level areas show higher decoding accuracy in the symmetric condition, while the opposite is true for early visual cortex. Our results indicate a crucial role for symmetry in grouping visual information into meaningful units for high-level processing. In fact, our findings in high-level regions mirror the perceptual advantage of symmetry in behavioral categorization performance. Early visual cortex, on the other hand, does not appear to benefit from local symmetry as a grouping cue. On the contrary, the information redundancy inherent to symmetry leads to lower fidelity of the category-specific signal in V1-4. In summary, we here demonstrate the emergence of symmetry as a mid-level grouping cue for real-world scenes along the visual processing hierarchy.

Acknowledgement: Sony, Samsung, SSHIRC, NSERC

43.360 **Neural coding of non-visual properties inferred from images of natural scene** Yaelan Jung[1](jung.yaelan@gmail.com), Dirk B Walther[1]; [1]Department of Psychology, University of Toronto

When people see an image of a natural scene, they can extract non-visual properties from the visual stimulus: Is the depicted environment likely to be hot or cold? Is it noisy or quiet? How are these properties represented in the brain, and how do their representations compared to those elicited by actual sensations of the same non-visual properties? In the present study, we address these questions using fMRI. Twenty participants saw images of natural scene while their brain activity was recorded. The scene images were selected so that their thermal (hot versus cold) and auditory (noisy versus quiet) features were orthogonal to their basic-level categories. To examine how thermal and auditory information is represented in the brain, we performed a leave-one-run-out classification analysis using neural activity patterns. We found that non-visual properties inferred from images could be decoded from the sensory cortices that are dedicated to their direct senses (auditory or thermal) and also from regions in prefrontal cortex (PFC). Thermal features inferred from images could be decoded from the post-central gyrus, which is known to process thermal sensations, and from the inferior prefrontal gyrus (IFG) opercularis. We were able to decode auditory features from the superior temporal gyrus, which processes auditory information, and also from IFG opercularis and IFG orbitalis. Furthermore, neural representations of inferred non-visual cues in prefrontal regions are similar to those elicited by direct stimulation with sounds and thermal stimuli, respectively. These findings indicate that non-visual properties inferred from images evoke similar neural activation patterns as direct sensations in PFC. Together, the current study demonstrates that non-visual aspects of visual stimuli are represented in the brain areas that are not exclusively dedicated to vision.

Acknowledgement: NSERC

43.361 **Task demands flexibly change the dynamics of feature use during scene processing** Bruce C Hansen[1](bchansen@colgate.edu), Michelle R Greene[2]; [1]Department of Psychological & Brain Sciences, Neuroscience Program, Colgate University, [2]Neuroscience Program, Bates College

Our visual environments contain multiple sources of data relevant to categorization. These information sources are usually operationalized as component "features" within a comprehensive conceptual space, and scene categories can be differentiated according to many perceptual and conceptual features. However, the task that is being performed informs which features may be preferentially processed (Schyns, 1998). The goal of the current study was to assess how changing task demands influences feature usage over time as indexed by event related potentials (ERPs). Participants viewed repeated presentations of 28 different scene images while making cued judgments about 1) relative orientation biases, 2) presence of various objects, or 3) the functions afforded by the scenes. The images were selected to create maximally different representational dissimilarity matrices (RDMs) based on those three features. The stimuli (subtending 18.5 degrees of visual angle) were presented for 500 ms each, and brain activity was recorded via 128-channel EEG. Our analysis followed an encoding approach. For each task, we used the orientation, object, and function RDMs to predict the ERP activity of each electrode in a sliding 40 ms time window. The results revealed that each RDM predicted unique ERP variance at specific time intervals (orientation at ~95 ms; object and functions at 150-175 ms) and with different scalp topographies. The orientation RDM explained the same occipital scalp topography regardless of task, while the object and function RDMs predicted different central and parietal scalp topographies with different tasks. Together, these findings suggest that low-level visual features such as orientation are less subject to changing task demands, while high-level features such as functions and objects strongly influence the processing of those features

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over time and across the scalp. These results provide insight into the types of visual tasks that seem to be encapsulated from higher-level cognitive processes (Firestone & Scholl, 2016).

Acknowledgement: National Science Foundation (1736394) and James S. McDonnell Foundation (220020439) grants to BCH, National Science Foundation (1736274) grant to MRG.

43.362 **Early electrophysiological correlates of scene perception are sensitive to inversion** Assaf Harel[1](assaf.harel@wright.edu), Hamada Al Zoubi[2]; [1]Department of Psychology, Wright State University, [2]Department of Neuroscience, Cell Biology and Physiology, Wright State University

Recent work has reported that the first Event-Related Potential (ERP) component to carry scene-selective information is the posterior P2 component (peaking 220ms post-stimulus onset)(Harel et al., 2016). P2 amplitude was higher in response to scenes than to faces and objects and was also sensitive to the global properties of scenes (e.g. naturalness and openness), suggesting that global scene structure is encoded by 220ms of processing. The present study aimed to extend this finding by testing the impact of scene inversion on the P2 component. Inversion is assumed to disrupt global processing, and as such can be used to test the P2 sensitivity to global information, and more generally establish how early stages of scene perception are impacted by inversion. This is especially important as to this date only a handful of studies have examined scene inversion. We recorded ERPs from participants while they passively viewed upright and inverted color images of faces, objects, and scenes. We used 192 individual images in each category, spanning a wide range of category dimensions and properties to prevent the possibility of a salient image property affecting our results. First, we established that the P2 response was indeed scene-selective, with its amplitude higher in response to scenes than faces and objects, replicating Harel et al.'s original study. Second, we found a P2 inversion effect in the form of a reduced P2 amplitude to inverted compared to upright scenes. Earlier visually-evoked components P1 and N1 did not show significant scene inversion effects. Lastly, faces showed the expected N170 inversion effect as well as P1 and P2 inversion effects, while objects showed no inversion effects for any of the early components. Together, these results suggest that global scene processing can be observed at the P2 time window and support the idea that P2 indexes scene-selective neural processing.

43.363 **Seeing the world from above: Uncovering the neural basis of aerial scene recognition** Joseph D Borders[1](borders.9@wright.edu), Bethany M Dennis[1], Birken Noesen[1], Assaf Harel[1]; [1]Department of Psychology, College of Science & Mathematics, Wright State University

Recognizing aerial scene imagery is an essential skill in a variety of work domains, yet little is currently known about how this skill forms and develops with experience. The current study aimed to elucidate the neural mechanisms underlying expertise in aerial scene recognition in order to understand the acquisition of experience with aerial imagery. We conducted an intensive six-session behavioral training study combined with multiple fMRI scans using a large set of high-resolution color images of real-world scenes varying in their viewpoint (aerial/terrestrial) and naturalness (manmade/natural). Half of the participants were trained to categorize these visual scenes at a specific-subordinate level (e.g., truss bridge, suspension bridge) and half of the participants passively viewed the same images while performing an orthogonal task. Both groups saw the same scene stimuli for five of the six training sessions; the sixth session consisted of a novel set of scenes to assess learning transfer. We found group-specific improvements in behavioral performance across training sessions and scene dimensions, including learning transfer, with greatest behavioral improvements observed for aerial scenes. In contrast, the passive-viewing group showed no major improvements despite equal exposure to the stimuli. Complementing the behavioral effects, we found experience-related neural changes in the experimental group: response magnitudes in scene-selective cortex (PPA and OPA) were correlated with improvements in behavioral performance for aerial imagery, but not in control regions (e.g., EVC, FFA). Whole-brain analyses revealed that over the course of training with aerial scenes, additional regions were recruited beyond scene-selective cortex, primarily lateral ventral-occipitotemporal cortex and posterior parietal cortex. Together these findings suggest that acquiring experience in categorizing aerial scenes entails the engagement of multiple visual areas involved in object and scene recognition, as well as the potential involvement of top-down attention mechanisms, and visuospatial processing. This research is supported by ONR BAA N00014-16-R-BA01.

Acknowledgement: ONR BAA N00014-16-R-BA01

43.364 **Explaining Scene-selective Visual Area Using Task-specific and Category-specific DNN Units** Kshitij Dwivedi[1](kshitij_dwivedi@mymail.sutd.edu.sg), Michael F Bonner[2], Gemma Roig[1,3]; [1]Information Systems Technology and Design, Singapore University of Technology and Design, Singapore, [2]Department of Psychology, University of Pennsylvania, Philadelphia, PA, United States of America, [3]Massachusetts Institute of Technology

Deep neural networks (DNN) trained for classification are often used to explain responses of the visual cortex. Recently it was demonstrated that a DNN trained on a task related to the function of a brain region explains its responses better than a DNN trained on a task which is not explicitly related. Taking motivation from the previous results, in this work we investigate if we can infer the functionality of different areas in the scene-selective visual cortex by comparing the correlation of brain areas with DNNs trained on different tasks. We select 20 DNNs trained on diverse computer vision tasks including multiple 2D, 3D, and semantic tasks from the Taskonomy dataset. We select 2 areas in the scene-selective visual cortex, namely occipital place area (OPA) and parahippocampal place area (PPA). We perform representation similarity analysis (RSA) of OPA and PPA with 20 DNNs to investigate if the relative correlation of brain areas with different tasks can shed some light into the functions of these brain areas. The results reveal that OPA shows a higher correlation with 3D tasks as compared to semantic and 2D tasks, while PPA shows a higher correlation with semantic tasks. We further probe the functionality of these brain areas by category-specific units of a scene-parsing DNN. The results reveal that OPA shows high correlation with the categorical units crucial for navigational affordances while PPA shows high correlation with the categorical units crucial for scene-classification.Our results are consistent with previous neuroimaging studies investigating the function of PPA and OPA showing that PPA is involved in scene classification while OPA is involved in representing 3D scene structure and navigational affordances.Our results suggest that performing a searchlight analysis with RDMs of DNNs trained on different tasks may reveal the functional map of the visual cortex.

Acknowledgement: This work was funded by the MOE SUTD SRG grant (SRG ISTD 2017 131). Kshitij Dwivedi was also funded by SUTD President's Graduate Fellowship.

43.365 **Adversarial examples influence human visual perception** Gamaleldin F Elsayed[1](gamaleldin.elsayed@gmail.com), Shreya Shankar[2], Brian Cheung[3], Nicolas Papernot[4], Alexey Kurakin[1], Ian Goodfellow[1], Jascha Sohl-Dickstein[1]; [1]Google Brain, [2]Stanford University, [3]UC Berkeley, [4]Pennsylvania State University

Computer vision models are vulnerable to adversarial examples: small changes to images that cause models to make mistakes. Adversarial examples often transfer from one model to another, making it possible to attack models that an attacker has no access to. This raises the question of whether adversarial examples similarly transfer to humans. Clearly, humans are prone to many cognitive biases and optical illusions, but these generally do not resemble small perturbations, nor are they generated by optimization of a machine learning loss function. Thus, adversarial examples has been widely assumed – in the absence of experimental evidence – to not influence human perception. A rigorous investigation of the above question creates an opportunity both for machine learning and neuroscience. If we knew that the human brain could resist certain classes of adversarial examples, this would provide an existence proof for a similar mechanism in machine learning security. On the other hand, if we knew that the brain could be fooled by adversarial examples, this phenomenon could lead to a better understanding of brain function. Here, we investigate this question by leveraging three ideas from machine learning, neuroscience, and psychophysics[1]. First, we use black box adversarial example construction techniques to generate adversarial examples. Second, we adapt machine learning models to mimic the initial visual processing of humans. Third, we evaluate classification decisions of human observers in a time-limited setting to limit the brain's utilization of recurrent and top-down processing pathways[2]. We find that adversarial examples that strongly transfer across computer vision models influence the classifications made by time-limited human observers. [1] A version of this work is accepted, but not yet presented, as a conference paper at NIPS 2018. [2] M. Potter et al. Detecting meaning in rsvp at 13 ms per picture. Attention, Perception, Psychophysics, 76(2):270-279, 2014.

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Motion: Biological

Monday, May 20, 8:30 am - 12:30 pm, Banyan Breezeway

43.366 **Spatiotemporal characteristics of cortical responses to biological motion** Dorita H. F. Chang[1,2](changd@hku.hk), Nikolaus F. Troje[3,4], Hiroshi Ban[5,6]; [1]Department of Psychology, The University of Hong Kong, Hong Kong, [2]State Key Laboratory of Brain and Cognitive Sciences, The University of Hong Kong, Hong Kong, [3]Centre for Vision Research, York University, Canada, [4]Department of Psychology, Queen's University, Canada, [5]Center for Information and Neural Networks, NICT, Japan, [6]Graduate School of Frontier Biosciences, Osaka University, Japan

Previous fMRI work has indicated that both biological form and biological kinematics information have overlapping representations in the human brain; yet, it is unclear as to whether there is a temporal distinction in terms of their relative engagement that is stimulus-dependent.We presented observers (N=21) with upright and inverted biological motion walkers that contained solely biological form (global stimulus), solely biological kinematics (local natural stimulus), or neither natural form nor kinematics information (modified stimulus) and asked them to discriminate the facing direction of the stimuli while concurrently imaging neuromagnetic responses using magnetoencephalography (Elekta Neuromag 360). For all three stimulus classes, we found early (100 ms) responses in lateraloccipital regions that preceded responses in inferiortemporal and fusiform (150-200 ms), and superiortemporal regions (350-500 ms), with response amplitudes differing among the three stimulus classes in extrastriate regions only.Specifically, amplitudes were larger for the inverted global stimulus than for the upright counterpart in fusiform cortex, in addition to surrounding inferior- and superior-temporal regions.In these same regions, amplitudes were higher for the local natural stimulus than for the modified stimulus, but only when stimuli were presented upright. Moreover, amplitudes were higher for the global stimulus than the local natural and modified stimuli, but only when stimuli were presented upside-down. We then compared the representational dissimilarity of MEG sensor patterns with ROI-multivariate response patterns acquired in a second group of observers (N=19) using fMRI (3T) and identical stimuli.Interestingly, we found a marked distinction between the onset of MEG-fMRI representational correspondence, occurring much earlier in early visual cortex (V1-V3) than in higher-order extrastriate body areas.These data suggest that biological motion perception proceeds with temporal systematicity in cortex, engaging early visual cortex prior to inferior-temporal cortex, and finally the oft-implicated superior temporal regions, with stimulus-specificity emerging in later stages.

43.367 **How the Brain Learns to See Biological Motion After Recovering from Visual Deprivation** Shlomit Ben-Ami[1](shlomit@mit.edu), Nikolaus F. Troje[2], Pawan Sinha[3]; [1]Department of Brain and Cognitive Science, Massachusetts Institute of Technology, [2]Department of Biology, Centre for Vision Research, York University, [3]Department of Brain and Cognitive Science, Massachusetts Institute of Technology

The perception of biological motion is handled effortlessly by our visual system and found even in animals and human neonates. Prior studies testing patients years after recovering from congenital blindness have revealed that this skill is spared, with subjects showing preserved behavioral and electrophysiological responses to visual displays of human coordinated movement even after prolonged periods of congenital blindness. These evidences of an early developing and resilient sensitivity have led to questioning if visual experience is at all required for development of specialization for biological motion or if development of neural systems for processing of biological motion may be independent of visual input. We addressed this question by testing the longitudinal development of the ability to detect biological motion and to extract meaningful information from it in 18 individuals aged 7-21 years with profound congenital visual deprivation, immediately after treatment with sight-restoring surgery. Subjects were shown unmasked point light displays and asked to identify a person by choosing between displays of actions and their inverted, spatially-scrambled or phase-scrambled version in experiment 1, and to determine walking direction in experiment 2. We found that the ability to discriminate biological motion and to determine walking direction were both correlated with visual acuity. We did not find such a correlation in age-matched controls with comparable simulated acuity-reduction. Together, these results paint a picture attesting to the role of visual experience in the emergence of biological motion perception. We probed the use of local cues by sight-restored patients for assessing walking direction in an additional experiment, by manipulating each individual dot and inverting its trajectory's directionality. We found reduced reliance of the patient group on local motion information, in contrast to healthy sighted adults and controls observing displays with comparable blur. This difference remained evident over the course of six months following surgery.

Acknowledgement: NEI (NIH) grant R01 EY020517 to PS

43.368 **Social Threat Perception from Body Movements** Akila Kadambi[1](akadambi@ucla.edu), Hongjing Lu[1,2]; [1]Department of Psychology, University of California, Los Angeles, [2]Department of Statistics, University of California, Los Angeles

Efficient and accurate judgments about threat from dyadic interactions are important for survival in the social world. Systematically assessing the separate impact of body movements and context has proven difficult due to the graphic nature of threatening displays and level of emotion involved. Here, we employed advanced computer vision algorithms to alter the videos, and assess the contribution of kinematic information and contextual information to support recognition of threatening actions. Experiment 1 presented 30 YouTube videos depicting a range of threatening and non-threatening interactions. Participants were asked to perform threat classification and provide written descriptions. In Experiment 2, twenty-six of the videos from Experiment 1 were processed to present the same dyadic interactions with two different display types that varied in contextual information: (1) patch display showing blurred scenes composed of patches ("superpixels"); or (2) body display presenting human body figures on a black background. Participants were asked to rate the degree of threat for each interaction in a display type. Results showed consistency in threat recognition from human interactions regardless of the display type, as the threat ratings in Experiment 2 were strongly correlated with the classification proportion for the raw videos in Experiment 1 ($r = .98$ for patch display; $r =.93$ for body display). To examine the underlying psychological dimensions governing threat perception, we used threat rating similarity to conduct the multidimensional scaling (MDS) analysis. The body display MDS result revealed a key dimension that was related to the duration of physical touching. This finding suggests that when contextual information is eliminated, some characteristics of body kinematics serve as critical signals for threat detection.

Acknowledgement: NSF grant BCS-1655300

43.369 **Perception of continuous movements from causal actions** Yujia Peng[1](yjpeng@g.ucla.edu), Nicholas Ichien[1], Hongjing Lu[1,2]; [1]Department of Psychology, University of California, Los Angeles, [2]Department of Statistics, University of California, Los Angeles

We see the world as continuous: given stationary frames as inputs, we perceive smooth movements of objects. The perceptual construction of smooth movements depends not only on low-level spatiotemporal features, but also high-level knowledge. We examined the role of causality in guiding perceptual interpolation of motion in human actions. We recorded 6 videos of human-object interactions (a thrower directing a ball to a catcher). Stimulus onset asynchrony (SOA) was manipulated for the 200-ms period in which the catcher prepared to receive the ball. Short SOAs consisted of 6 frames (33.3 ms/frame); long SOAs consisted of 2 frames (100 ms/frame). Participants were asked to judge whether the catcher's action showed smooth body movements or sudden changes. In Experiment 1, only the ball movement and catcher's action were shown, with the thrower occluded.In the causal action condition the catcher was facing the ball (so the ball movement would be interpreted as causing the catcher to move his body in preparation). In the non-causal condition, the catcher was facing away from the ball. The movement of the ball was identical in the two conditions. Participants were more likely to judge the catcher's movements to be continuous in the causal condition.The illusory percept of smooth motion was strongest when the SOA was long. In Experiment 2 the displays showed body movements of both the thrower and catcher, but occluded the ball movement (thus removing the direct cause in a causal chain of thrower-ball-catcher). Facing direction of the catcher was varied in the same manner as in Experiment 1. Once again, the catcher's motion was judged to be continuous more often in the causal condition. The findings indicate that causality guides interpolation of body movements, thereby completing the history of the observed action despite gaps in the sensory information.

Acknowledgement: NSF grant BCS-1655300

43.370 **Connectivity in cortex sensitive to biological motion in those high and low in autistic tendency.** David P Crewther[1](d-crewther@swin.edu.au), Svjetlana Vukusic[1]; [1]Centre for Human Psychopharmacology, Swinburne University of Technology

The brain has specialized networks for processing of biological motion (BM) of socially relevant items. It is suggested that autism spectrum disorder (ASD) would reflect a dysfunctional parieto-frontal motion processing system, but previous perceptual studies on impaired BM sensitivity in children and adults with autism are inconclusive. Here, we explored brain signatures within the broader autism phenotype. Participants were selected into low (AQ < 11, mean=9.5) and high (AQ>21, mean =25.1) Autism Spectrum Quotient (AQ) groups. The participants observed a white fixation cross followed by 3s BM point-like movies (Giese lab)while MEG signals were recorded (Elektra TRIUX MEG system). Walkers were predominantly moving to the left or the right for each block of trials and participants gestured the number of stimuli for the minority direction at the end of each block. Brainstorm was used for analysis of evoked responses. During data pre-processing, several participants were removed because of extensive artefacts, with 11 in each of the High AQ and Low AQ groups analysed. The grand mean average MEFs for the Low AQ and High AQ groups were used for overall source localisation, using a minimum norm estimate (MNE). A pattern of posterior cortical activation was observed in primary cortex, in motion area (hMT+), in superior temporal sulcus (STS), and bilaterally in orbitofrontal cortex (OFC). "Scouts" were established at each location using a seed growing process across the tessellated cortical surface, allowing the evoked activity to be measured for each source for each participant. Connectivity was explored via Phase Transfer Entropy (PTE – available in Brainstorm) across the 8 scouts. It demonstrated greater occipital cortex to OFC connectivity of the Low AQ group cf the high AQ group, particularly for extended latencies in the range of 250-400 ms after stimulus appearance, supporting the behavioural findings.

Acknowledgement: NHMRC

43.371 **Can two-stream convolutional neural networks emulate human perception of biological movements?** Hannah Lee[1](leehannah@ucla.edu), Yujia Peng[1], Tianmin Shu[2], Hongjing Lu[1,2]; [1]Department of Psychology, University of California, Los Angeles, [2]Department of Statistics, University of California, Los Angeles

Visual recognition of biological motion recruits form and motion processing supported by both dorsal and ventral pathways. This neural architecture is resembled by the two-stream convolutional neural networks (CNNs) (Simonyan & Zisserman, 2014), which include a spatial CNN to process static image frames, a temporal CNN to process motion flow fields, and a fusion network with fully-connected layers to integrate recognition decisions. The two-stream CNNs showed human-like performance for recognizing actions from natural videos. We tested whether the two-stream CNNs could account for several classic findings in the literature of biological motion perception. In simulation 1, we trained the model with actions in skeletal displays and tested its generalization with actions in point-light (PL) displays. We found that only the temporal CNN can recognize PL actions with high performance. Simulation 2 examined whether the two-stream CNNs could discriminate the form-only PL walker in which local motion was eliminated by randomly sampling points along the limbs in each frame (Beintema & Lappe, 2002). The image stream and the fusion network, but not the motion pathway, showed similar activity pattern as for intact PL walkers, indicating that the model was able to utilize appearance information such as body structure to detect human motion. In simulation 3, we tested whether the two-stream CNNs showed inversion effects (better performance for upright actions than for upside-down actions) across a range of conditions (Troje & Westhoff, 2006). The model showed the inversion effect in most conditions, but not in the spatial-scramble condition. This failure suggests that the feed-forward connections in the two-stream CNN model limit its ability to serve as a "life detector." The model would require additional long-range connections in its architecture in order to pass special local movements (e.g., foot movements in walking) to later layers for efficient detection and recognition.

Acknowledgement: NSF grant BCS-1655300

Monday AM

Perceptual Organization: Ensemble coding, summary statistics

Monday, May 20, 8:30 am - 12:30 pm, Pavilion

43.401 **Independent and parallel visual processing of mean, variance, and numerosity: Evidence from dual tasks** Vladislav A Khvostov[1], Igor S Utochkin[1]; [1]National Research University Higher School of Economics

The visual system can represent multiple objects in a compressed form of ensemble summary statistics (such as object numerosity, mean, and variance of their features). Yet, the relationships between the different types of visual statistics remains relatively unclear. Here, we tested whether two summaries (mean and numerosity – Experiment 1, and mean and variance – Experiment 2) are calculated independently from each other and in parallel, that is, without cost of dividing attention. Our participants performed dual tasks requiring report about two summaries in each trial, and single tasks requiring report about only one of the summaries. Observers were briefly shown sample sets of circles of various sizes. At test, they had to report the number of circles, their mean size, or the variance of sizes using the adjustment method. The relative difference between an adjusted value and a correct answer was used as a measure of precision. We estimated trial-by-trial correlations between the precision of reports in dual task separately for each observer, as well as correlations between averaged errors in reporting summaries in different conditions across all observers. Both analyses showed (1) the absence of correlations between different types of ensemble statistics suggesting their independence, (2) strong auto-correlations of same-type statistics in different tasks (dual vs. single) suggesting good between-test consistency. We also found no decrement (except that related to the order of report explained by memory retrieval) in performance in dual compared to single tasks, which suggests that two statistics of one ensemble can be processed in parallel. In an additional experiment, we found that the precision of variance reports did not change even when mean size and spatial density changed substantially between sample and adjustment sets. This finding also says for independence between the ensemble statistics.

Acknowledgement: Program for Basic Research of NRU HSE (TZ-57) and RSCF #18-18-00334

43.402 **Adaptation to mean and variance: interrelationships between mean and variance representations in orientation perception** Jinhyeok Jeong[1](jjh00413@gmail.com), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

When there are many visual items, our visual system could extract summary statistics of the items (e.g., mean, variance), facilitating efficient processing (Whitney & Yamanashi Leib, 2018). Although many researches have been conducted on mean or variance representation itself, a relationship between these two representations has not been investigated much. Thus, we investigated this relationship focusing on how perceived variance affects the estimation of mean and vice versa in two experiments using perceptual adaptation. Participants watched a sequence of orientation arrays during adaptation. In order to produce an adaptation to variance or mean, one property of the adaptor arrays (variance or mean) had a fixed value while the other property was randomly varied. After the adaptation, participants were asked to estimate the property of the test array that was varied during the adaptation. In Experiment 1, participants were adapted to two levels of variance (high, low) and then estimated the mean orientation of the test array whose physical variance remained constant. We found that the adaptation to a high variance resulted in more sensitive estimation of the mean orientation than the adaptation to a low variance. These results suggest that a perceived variance affects the estimation of mean orientation. In Experiment 2, participants were adapted to two levels of mean orientation (15°, 90° relative to the vertical) and then estimated orientation variance of test arrays whose mean orientation was vertical. Results showed that compared to the no adaptation, the adaptation to 15° mean orientation led to overestimation of the variance, but the adaptation to 90° mean orientation did not show that change. These results suggest that a perceived mean orientation affects the estimation of orientation variance. Collectively, these two experiments suggest that mean and variance representations in orientation perception are closely interrelated to each other.

Acknowledgement: This work was supported by National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (NRF-2016R1A2B4016171).

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43.403 **Variance modulates temporal weighting during integration of sequentially presented visual ensembles** Omer Daglar Tanrikulu[1](daglar@hi.is), Andrey Chetverikov[2], Arni Kristjánsson[1]; [1]Department of Psychology, School of Health Sciences, University of Iceland, [2]Center for Cognitive Neuroimaging, Donders Institute for Brain, Cognition and Behavior, Radboud University

While most studies on visual ensembles focus on spatial integration of simultaneously presented groups of items, recent studies have shown that observers can also estimate summary statistics from sequentially presented items. Very little is known, however, about how these spatial and temporal summaries are combined and whether such combined information is used during perception. We examined how observers temporally integrate two different orientation distributions that were presented sequentially in a visual search task. We manipulated the variance of the two distributions to investigate the influence of variance on their temporal integration. Participants performed streaks of sequential odd-one-out visual search for an oddly oriented line among distractors. In a streak of sequential learning trials, the distractor orientations were sampled from two different Gaussian distributions on alternating trials. After a certain number of trials, observers were given a test trial where the orientations of target and distractors were switched which resulted in slowed search due to role reversal effects. The reaction times from test trials revealed observer's internal model of distractor distributions. The variance of distractor distributions and the number of learning trials were manipulated. Our results revealed that summaries of orientation ensembles were largely biased by the orientation distribution presented in the last trial of a streak. However, this bias interacted with the variance of the two alternating distributions. When the variances of the distributions were relatively large, observers took into account the mean of the distractors from the earlier trial, which, in turn, weakened the influence of the last trial. These results indicate that complex weighting of information takes place in temporally encoded ensembles, where the recency effect depends on the variance of the integrated distributions.

Acknowledgement: RANNIS, Icelandic Research Fund

43.404 **The Perceptual Experience of Orientation Variability** Jessica K Witt[1](jessica.witt@colostate.edu); [1]Department of Psychology, College of Natural Sciences, Colorado State University

What is the perceptual experience of variability?Unconscious perceptual processes are well-calibrated to variability, as are unconscious motor processes, whereas cognitive processes are not well-calibrated and tend to underestimate variability.Regarding the perceptual experience of variability, perceivers are sensitive to differences in the variability of ensembles of objects, but any potential biases have not yet been explored.In the current experiments, participants viewed a set of lines at various orientations that were presented one at a time in a random order.Participants judged whether the orientations within each set were more similar to each other or more disperse.Although participants were sensitive to differences in spread, participants overestimated the variability of the set by 50%.This overestimation was replicated several times.The results have implications for mechanisms underlying ensemble perception, which is the extraction of summary statistics from a set of objects.In particular, there are both shared and unique processes related to perceiving similarities across objects (such as the mean orientation) and perceiving differences (such as their spread). Both visual abilities were thorough and used the full set of lines, rather than efficient by using only a subset, but the perception of spread relied more heavily on differences presented at the beginning whereas perception of the mean relied more heavily on features of the lines at the end of the animation. The results also have implications for visualizations of uncertainty, such as hurricane forecasts.A perceptual bias to overestimate variability could help counteract cognitive biases to underestimate variability.

Acknowledgement: National Science Foundation

43.405 **Independent Processing of Statistical Summary Representations of Size and Orientation Features** Harun Yoruk[1,2](harunyoruk42@gmail.com), Aysecan Boduroglu[2]; [1]University of Houston, [2]Bogazici University

People can rapidly extract average information of the features of an object set by visual statistical summary processing. Previous studies demonstrated independent mechanisms for summarizing low (e.g. color, orientation) and high-level (facial identity, emotion) visual information. Furthermore, evidence suggests a shared capacity for simultaneously summarizing multiple sets along the same feature dimension, but independent capacities for summarizing distinct feature dimensions. Here, we investigated whether statistical summary processing of low-level visual features relies on a feature-specific or a feature-general mechanism and whether there are capacity limitations to simultaneous averaging of different visual features. We asked participants to average one of the features in a set of lines that varied in size and orientation. The relevant feature was either the same throughout a block or mixed within a block. In Experiment 1 we found that participant performance on one feature did not predict performance on the other feature, regardless of whether the task-relevant feature was varied within versus across blocks. Furthermore, errors were similar between single-feature and mixed blocks for both features. These results imply that size and orientation features are independently averaged with no cost of simultaneous processing. In Experiment 2 we reduced the encoding time of the displays from 200 milliseconds to 50 and 100 milliseconds to determine if orientation averaging has an advantage over size at early processing. Results were consistent with Experiment 1: size and orientation averaging errors were similar across encoding durations. In Experiment 3, we added a visual mask to terminate iconic processing after 50 milliseconds. Size summaries remained similarly accurate regardless of whether the task-relevant feature was mixed or blocked. However, orientation averaging errors were higher in mixed than single blocks. Overall, results suggest there are further independent, feature-specific statistical summary processing mechanisms for size and orientation features.

43.406 **Patterns in noise: identifying Markov processes generating events and using them to predict future events** Maria F Dal Martello[1](mdm5@nyu.edu), Dana Pietralla[1,2,3], Federico Bozzolan[1], Laurence T Maloney[4,5]; [1]Department of General Psychology, University of Padova, [2]Department of Psychology, University of Klagenfurt, [3]Department of Psychology, University of Cologne, [4]Department of Psychology, New York University, [5]Center for Neural Science, New York University

People look for patterns in sequences of events and model the processes in the environment that generate them. Knowing the generating process of a sequence could potentially improve prediction of upcoming events and the many reports of sequential effects in cognitive, motor and perceptual tasks are sometimes claimed to be the consequence of erroneous pattern identification. Observed patterns are often corrupted by extraneous "noise" and we can model prediction as a two-stage process, an identification of pattern in "noise" followed by prediction enhanced by knowledge of the generating process. We tested the claim that errors in prediction are primarily due to failures in pattern identification. Methods: The possible pattern processes were limited to two Markov processes, one tending to produce repeating binary sequences (blue and yellow squares), the other tending to produce sequences that alternate more often than the tosses of a fair coin. Before the main experiment, observers were extensively trained to discriminate sequences produced by the two Markov processes. We examined human performance in an identification-prediction experiment with binary sequences varying in length: 4, 9, 14, and 19. A fixed proportion (10%) of the events in each sequence were flipped at random from blue to yellow or v.v. ("noise").The observer first attempted to identify the generating process and then tried to predict the next event. Each observer saw 120 sequences: 30 sequences of each of four lengths that were equally likely to be "repeating" or "alternating". 26 participants (age ranged from 19 to 30) completed the experiment. We compared human performance to that of an ideal statistical observer. Results: Human performance was sub-optimal in identifying generators with a strong bias toward alternating. Crucially, human use of information about the likely generating process in predicting the next event was markedly suboptimal.

Acknowledgement: DP: Erasmus+ by the European Commission, LTM: Guggenheim Fellowship

43.407 **The Contents of Visual Working Memory Bias Ensemble Perception** Ryan S Williams[1](ryanscott.williams@mail.utoronto.ca), Jay Pratt[1], Susanne Ferber[1], Jonathan S Cant[2]; [1]Department of Psychology, University of Toronto, [2]Department of Psychology, University of Toronto Scarborough

Across three experiments we investigated the interplay of visual working memory (VWM) and ensemble perception. In Experiment 1, participants estimated the mean orientation of 12 simultaneously presented bars while concurrently maintaining the shape and color of an irregularly shaped item in VWM. Critically, the color of the VWM-item could match a subset of ensemble elements oriented clockwise from the overall mean, counterclockwise, or neither – constituting three unique conditions. As predicted, when the color of the VWM-item matched a subset of elements, global mean estimation errors were systematically biased towards the mean of that subset, while such errors were centered around the global mean when the VWM-item matched neither of the subsets. In Experiment 2, we tested

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whether this effect was due to an explicit attentional strategy to improve VWM performance. We used the same procedure as above but changed the duration of the ensemble displays from 250 ms to 150 ms or 500 ms, reasoning that strategic attentional allocation would be less viable at short durations. Again, estimation errors were biased by elements matching the VWM-item, but the magnitude of this bias was not moderated by display duration, suggesting that the effect is unlikely to be accounted for by strategic processes. Lastly, in Experiment 3 we examined whether this effect requires active maintenance of the biasing feature in VWM. We made the color of the VWM-item irrelevant to the task, allowing the shape, but not color, of the item to change from study to test. Here, we observed no difference in estimation errors across the three conditions, which suggests that the biasing feature needs to be actively maintained in VWM to influence ensemble perception. Overall, we provide evidence that individual elements are overvalued in ensemble perception when they share a common feature with information actively represented in VWM.

43.408 **Ensemble Perception of Holistic Faces During Failed Change Localization** Shuchen Liu[2,1](liushuchen62@163.com), Allison Yamanashi Leib[1], Azin Mirzaagha[1], Julie Liu[1], David Whitney[1,3,4]; [1]Department of Psychology, University of California, Berkeley, [2]Department of Psychology, Tsinghua University, [3]Vision Science Program, University of California, Berkeley, [4]Helen Wills Neuroscience Institute, University of California, Berkeley

Ensemble perception refers to the visual system's ability to rapidly evaluate "gist" information from groups of stimuli. For example, participants can easily determine the average emotional tenor of a crowd (e.g., an angry mob of protestors, or mourners at funeral), even when they fail to recall individual emotions presented in the crowd (Haberman & Whitney, 2007, 2009). To extend prior findings, we tested ensemble perception during a change localization task. We used Mooney faces as our experimental stimuli. Mooney faces are two-tone, low-feature images which require observers to perceive holistically. First, participants viewed a crowd of Mooney faces. Next, participants viewed the same crowd again, with some of the faces either replaced by new faces or simply shuffled in locations. In the response phase, participants were asked to localize any one of the replacement/shuffled faces by clicking on the corresponding screen location. Participants were also asked to report whether the average emotions of the two displays were the same or different. Although the task was challenging, participants performed slightly, but significantly, above chance in both the ensemble and change localization tasks. Most surprisingly, participants were sensitive to the emotional tenor of the crowd even when their change localization failed. To ensure that participants were not just relying on information from a single display to probabilistically guess the answer, we conducted a control experiment where one of the two displays was occluded. As expected, performance in this control condition was at chance, demonstrating that participants relied on ensemble information from both displays to successfully discriminate the average expression in the crowd. These results reinforce and extend prior findings (Haberman & Whitney, 2011) by showing that holistic ensemble perception can remain intact even when individual objects that drive the ensemble are outside the focus of attention.

43.409 **Extrapolation of concealed ensemble motion** Matthew S Cain[1,2](matthew.s.cain6.civ@mail.mil), Dawn M Wendell[3]; [1]U.S. Army Natick Soldier Research, Development, & Engineering Center, [2]Center for Applied Brain & Cognitive Sciences, Tufts University, [3]Department of Mechanical Engineering, Massachusetts Institute of Technology

When individual visual objects are moving independently, the performance of human observers is well characterized, even when objects disappear from sight. How ensembles comprised of independent objects moving with a shared goal—such as flocks of birds, schools of fish, or swarms of robots—are visually tracked is less well understood. Here we examined how ensembles of triangles were visually tracked as they moved across a display and how that motion was extrapolated as they passed behind an occluder. In separate experimental blocks, ensembles either moved in lockstep, with each unit translating and rotating identically to the others (cf. a marching band), or with one unit acting as a leader and the others seeking to maintain a given distance behind. Additionally, the overall pattern of motion could either be a parabola or a sinusoid, which varied randomly trial-by-trial. On each trial, the ensemble moved visibly across two thirds of the screen and passed behind an occluder for the remaining third. Participants indicated with mouse clicks the time and vertical location at which the center of the ensemble reached the goal line marked on the occluder. Eye positions was recorded throughout the trial. Participants were more accurate at judging the time of arrival and position when the items moved in lockstep than when the items followed the leader.The pattern of motion did not affect the time of arrival judgement, but the final position was judged more accurately in the sinusoidal motion condition than the parabolic motion condition. These results provide a first look at how ensemble motion is processed and predicted, and suggests that the more that an ensemble acts like a single object, the easier it is to predict.

43.410 **Holistic Ensemble Perception** Linfeng Han[1,2](linfenghan98@gmail.com), Allison Yamanashi Leib[1], Danielle Budish[1], David Whitney[1]; [1]Department of Psychology, University of California, Berkeley, [2]Department of Psychology, Tsinghua University

In a brief glance, observers are able to evaluate gist characteristics from crowds of faces, such as the average emotional tenor or the average family resemblance. Prior research suggests that such high-level ensemble percepts rely on configural and viewpoint-invariant information. However, it is also possible that feature-based analysis could be sufficient to yield successful ensemble percepts in many situations. To confirm that ensemble percepts can be extracted holistically, we asked observers to report the average emotional valence in crowds of Mooney faces. Mooney faces are two-tone shadow-defined images that cannot be recognized in a part- or feature-based manner. To recognize a part or feature of a Mooney face, one must first recognize the image as a face by processing it holistically. In Experiment 1, we asked participants to report the average emotional valence of 6-face crowds viewed for 1 second. Participants successfully extracted the average emotional tenor of the crowd by effectively integrating 5 out of the 6 faces presented. In Experiment 2, we asked participants to report the average emotional valence of Mooney face crowds presented in a rapid sequence (10 Hz, 50% duty cycle). Participants were able to successfully report the average emotional valence of the sequentially-presented crowds, integrating up to 6 faces. In Experiment 3, we confirmed holistic processing by interleaving upright and inverted displays of Mooney face crowds. As expected, participants' ensemble percepts of emotional valence were negatively impacted by inversion. Taken together, these experiments are strong evidence that ensemble perception can operate selectively on holistic representations of faces.

43.411 **Variability discrimination between heterogeneous luminance ensembles** Eiji Kimura[1](eiji.kimura@chiba-u.jp), Yusuke Takano[2]; [1]Department of Psychology, Graduate School of Humanities, Chiba University, [2]Graduate School of Humanities and Social Sciences, Chiba University

We previously showed that, when asked to compare mean brightness of heterogeneous luminance ensembles, observers use a flexible weighted-averaging strategy to rely more on a few items in the ensembles such as the highest or lowest luminance patches depending on task requirement (Kimura et al., ECVP2018). The present study extended this finding and investigated whether, when asked to discriminate variability of luminance ensembles, observers also use some smart strategy of relying on proxies such as the luminance range, the highest luminance, or the lowest luminance of the arrays. We used a method of constant stimuli to measure discrimination performance. The standard and comparison stimuli were heterogeneous luminance arrays composed of 24 patches (each disk subtended 1.5°). The two arrays were presented side by side simultaneously for 47 msec and followed by a dynamic pattern mask. Observers' task was to indicate the more variable array of the two. Mean luminance of the standard and comparison stimuli was fixed at 35 cd/m2. The standard deviation (SD) of luminance distribution of the standard stimulus was set to one of 4 levels (4.0, 8.0, 12.0, or 16.0) and that of the comparison stimulus was varied from 0 to 20.5. Results showed that observers could accurately and reliably discriminate luminance variability of the ensembles, even though the stimulus was very brief and composed of many patches. However, unlike in mean comparison, no clear evidence for smart subsampling strategy was found. The percentage of correct responses could be described fairly well as a function of the difference in SD between the standard and comparison stimuli regardless of the level of the standard SD. Thus, Weber's law did not hold for the discrimination of luminance variability. Taken together, these results suggested that the variability of luminance ensembles is coded in a qualitatively different fashion from the mean.

Acknowledgement: Supported by JSPS KAKENHI (26285162 & 25285197)

43.412 **Irrelevant ensemble information may successfully be ignored… sometimes** Delaney McDonagh[1](mcddc-19@rhodes.edu), Jason Haberman[1]; [1]Department of Psychology, Rhodes College

Ensemble perception allows us to rapidly derive summary statistical information from groups of similar objects. Ensembles are generated so quickly and efficiently that some researchers hypothesize that they can help guide

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visual search. If ensembles leak through the limits imposed by the attentional bottleneck, is it possible to filter irrelevant ensemble information? In the current study, we examined whether observers could selectively ignore similar but irrelevant ensemble information. In a series of experiments, observers viewed multiple sets of gabors, presented simultaneously, and had to report the average orientation of just one of the sets, post-cued, using method-of-adjustment. The sets of gabors were either two sets of four gabors (two ensembles), or a set of four gabors presented with an additional individual gabor. Arrangement of the gabor sets and cueing procedures varied across experiments. The average of the irrelevant set of gabors was oriented 45° away from the average of the cued set, and could feasibly be incorporated into an average representation. The results revealed that the number of trials in which observers' average orientation responses were drawn in the direction of the irrelevant set was not different from chance. However, the magnitude of the pull on trials in which they were pulled toward the irrelevant set was significantly greater when the irrelevant set contained an ensemble as opposed to an individual. Interestingly, even on trials in which the response went in the unpredicted direction, the magnitude of deviation was smaller when the irrelevant stimulus was an ensemble, suggesting its presence kept observers more anchored. The overall pattern of these results was still present, albeit mitigated, when observers were pre-cued. We conclude that an irrelevant ensemble can be successfully ignored, but when observers fail in doing so the ensemble wields a larger influence than an individual item.

43.413 **Spatial sampling in ensemble perception of hue** Lari Virtanen[1](lari.virtanen@helsinki.fi), Maria Olkkonen[1,2], Toni P Saarela[1]; [1]Department of Psychology and Logopedics, Faculty of Medicine, University of Helsinki, [2]Department of Psychology, Durham University

Human observers can estimate the mean hue of a hue ensemble. We studied the spatial sampling characteristics of ensemble perception of hue by systematically varying the external noise and the amount of information available in a discrimination task. Presented for 500 ms against a gray background, our stimuli consisted of 1, 4, 16, or 64 1-degree square elements, each with a uniform hue. The hues ranged from yellow to blue on a hue circle in CIELAB color space. In different conditions, the hues were drawn from a von Mises distribution with one of three levels of external noise (no-, low-, or high-noise). Observers responded whether they perceived the comparison stimulus as yellower or bluer than a standard in a 2IFC task. The average comparison hue varied around the average standard hue. Discrimination thresholds were estimated by fitting psychometric functions to the data. The number of elements utilized in averaging was estimated through equivalent noise modeling. The relative importance of edge and surface information was tested by two 16-element conditions with the elements either abutting or separated by a 1/3-degree gap. Discrimination thresholds increased with increasing external noise, but decreased as the number of elements increased, the improvement being greater with higher noise. A gap separating the stimulus elements had no effect on performance. Modeling the number of samples used by the observer as a fixed power of the samples available gave an excellent fit to the data. For the 64-element stimulus, estimated effective number of samples ranged from 16 to 41. Control experiments confirmed that performance improved with the number of elements, not stimulus area. Observers sample and average stimulus elements to estimate mean hue, similarly to ensemble perception in other domains. The observed sampling clearly surpasses earlier estimates, and performance is most affected by surface, not edge information.

Acknowledgement: This project was supported by the Academy of Finland (grant number 319404).

43.414 **Interference between summary representations of average and range in ensemble perception** Dilakshan Srikanthan[1](dilakshan.srikanthan@mail.utoronto.ca), Marco A Sama[1], Adrian Nestor[1], Jonathan S Cant[1]; [1]Department of Psychology, University of Toronto Scarborough

Ensemble perception refers to the visual system's ability to compress redundant information from multiple objects (e.g., multiple sizes, orientations) into a single summary representation (e.g., average size, orientation). These summary representations are often formed more accurately than any single-item representation, which tend to be biased towards the average of the set. Interestingly, we have recently demonstrated that single-item perception is also biased towards the range of the set (Srikanthan et al., VSS 2018). Here we investigate this sensitivity to ensemble range further, by asking whether implicit processing of set range can interfere with representations of average orientation. Participants were shown 8 triangles of varying orientations and were instructed to remember the location and orientation of each triangle. In a 2AFC task, a target and distractor were presented and participants either reported the average orientation (global condition), or the orientation of a single triangle (local condition). In order to investigate whether set range can interfere with average orientation, the distractor in the global condition could either be an item within the range but not in the set, or an item outside the range. Similarly, in the local condition the distractor could either be an item within the range but not in the set, or the average orientation. Reports of single-item orientation in the local condition were significantly below chance for both distractor types, again demonstrating that representations of ensemble average and range bias single-object perception. Critically, reports of average orientation in the global condition were significantly less accurate when the distractor was an item within the range (but not in the set), compared with an item outside the range. Together, these results demonstrate implicit sensitivity to the range of ensemble items, and further our understanding of ensemble processing by revealing the presence of interference in the formation of different summary representations.

Acknowledgement: NSERC Discovery Grant to JSC

43.415 **Size-distance rescaling in the ensemble representation of variance** Natalia A. Tiurina[1](natalyatyurina@gmail.com), Yuri A. Markov[1], Igor S. Utochkin[1]; [1]National Research University Higher School of Economics

Numerous studies report that observers are good at evaluating various ensemble statistics, such as mean or range. Recent studies have shown that, in the perception of mean size, the visual system relies on size information individually rescaled to distance for each item (Utochkin & Tiurina, 2018). Here, we directly tested this rescaling mechanism on the perception of variance. In our experiment, participants were stereoscopically shown a sample set of circles with different sizes and in different apparent depths. Then they had to adjust a test set so that the range of sizes to match the range of the sample. We manipulated the correlation between sizes and depth for both samples and tests. In positive size-depth correlation, bigger circles were presented farther and had to seem larger and small circles were presented closer and had to seem smaller; therefore, the apparent range had to increase. In negative size-depth correlation, the apparent range had to decrease, since bigger circles had to become smaller, and vice versa. We tested all possible couplings of correlation conditions between samples and tests. We found that in general, observers tended to overestimate the range of the sample (over-adjusted it on the test). Yet, the strongest underestimation was shown when the sample had a negative correlation and the test had a positive correlation. This pattern is consistent with the prediction following from the idea of rescaling. As the negative correlation reduced an apparent range, participants had to under-adjust the range of a positively correlated test to compensate for the difference in variance impressions. We conclude, therefore, that multiple sizes are automatically rescaled in accordance with their distances and this rescaling can be used to judge ensemble variance.

Acknowledgement: Funding: RFBR 18-313-00253.

43.416 **Investigating the contribution of shape and surface properties in ensemble face processing** Adile Nexha[1](ada.nexha@mail.utoronto.ca), Marco A. Sama[1], Adrian Nestor[1], Jonathan S. Cant[1]; [1]Department of Psychology, University of Toronto, Scarborough

The inability of the visual system to process detailed information from multiple, simultaneously-viewed faces (i.e., an ensemble) is circumvented by encoding the various identities into a single summary representation. The attributes important in forming representations of face ensembles have yet to be elucidated. In single-face perception, attributes of shape and surface properties are both used to process identity, with differing accounts of which attribute is more influential. In this study, we investigated the importance of shape and surface properties in ensemble face processing. In each trial, participants saw an ensemble of six faces, after which they were shown a single probe face and asked to report whether it was a member of the preceding ensemble. The probe could be a member of the set, the average identity of the set, a member of a different set, or the average identity of a different set. Importantly, performance was assessed on trials where only shape, only surface, or both attributes varied. Consistent with the dominance of global processing reported in the ensemble literature, we found that participants were biased to report the average identity as a member, despite it never being explicitly seen in any ensemble. Moreover, participants were above chance at correctly identifying single faces as set members and rejecting faces from different sets. Interestingly, when shape changed, participants were more likely to mistake faces from different ensembles as members of the target set, relative to when surface properties or both attributes changed. This suggests a dominant role of surface properties in ensemble face processing, which is consistent with the known link between

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texture and ensemble processing (Cant & Xu, 2012). These findings have important implications for bridging models of single-face and ensemble-face processing, potentially revealing how different facial attributes contribute to the representation of identity in both domains.

Acknowledgement: NSERC Discovery Grant to Jonathan S. Cant

43.417 **Ensemble Coding of Facial Attractiveness is Largely Driven by the High Spatial Frequency Information** Haojiang Ying[1](ying0017@e.ntu.edu.sg), Wenxuan Cheng[1], Hong Xu[1]; [1]Psychology, School of Social Sciences, Nanyang Technological University

Perception of facial attractiveness is shaped by our visual experience and by context. Researchers recently showed that our visual system is capable of perceiving the facial attractiveness of a group of faces via ensemble coding. However, the mechanism of ensemble coding of facial attractiveness remains largely unknown. Specifically, does our visual system summaries the high spatial frequency information from the face, or the low spatial frequency information? To answer this question we used adaptation paradigm to scrutinize the spatial frequency in ensemble representation of facial attractiveness. Participants were asked to judge the attractiveness of the test faces, after adapting to four unattractive faces. In each block, participants were exposed to different kind of faces:1) four unattractive faces (full bandwidth; FB), 2) the high spatial frequency version (HSF; > 32 cycles per face), and 3) the low spatial frequency version (LSF; < 8 cycles per face) of them. Results suggested that compared to the non-adaptation baseline, both FB condition ($M = 7.58\%$, $SEM = 1.77\%$; $t(29) = 4.28$, $p < .001$, Cohen's $d = 1.59$) and the HSF condition ($M = 6.05\%$, $SEM = 21.93\%$; $t(29) = 3.13$, $p = .004$, Cohen's $d = 1.16$) generated significant and similar adaptation aftereffects; while the LSF condition ($M = 1.87\%$, $SEM = 1.32\%$; $t(29) = 1.42$, $p = .166$, Cohen's $d = 0.53$) failed to yield a significant aftereffect. Our results suggest that the ensemble coding of facial attractiveness is largely driven by the high spatial frequency information from the faces. This finding opens the question for the neural and computational mechanisms of ensemble coding.

Acknowledgement: Ministry of Education (MOE) Academic Research Fund (AcRF) Tier 1 Undergraduate Research Experience on CAmpus (URECA) program College of Humanities, Arts, and Social Sciences (CoHASS) Incentive Scheme, Nanyang Technological University, Singapore.

43.418 **The Effect of the Ensemble Average of Facial Expressions on Subsequent Facial Expression Recognition** Kazusa Minemoto[1](k.minemoto@gmail.com), Yoshiyuki Ueda[1], Sakiko Yoshikawa[1]; [1]Kyoto University

Facial expression recognition is affected by previously viewed faces. For example, faces with happy expressions impair the recognition of weakly happy expressions viewed subsequently. In this study, we focused on multiple faces leading to an ensemble average of their properties (Haberman & Whitney, 2007) and examined whether the average intensity of facial expressions affected the recognition of expressions subsequently presented. Four prime conditions (ensemble, single 20%, single 40%, and single 60%) were compared to the base, or no-prime, condition. As prime stimuli, two happy facial expressions from the 20% intensity group and two from the 60% intensity group were presented simultaneously in the ensemble condition; their average was 40%. One happy expression from the 20%, 40%, and 60% intensity groups was presented in the single 20%, 40%, and 60% conditions, respectively. The test stimuli were six intensities of happy facial expressions (from 10 to 60%, with increments of 10), which were morphed using 35 Japanese females. Prime stimuli were presented for one second, followed by the mask for one second; test stimuli were presented for 400ms, followed by the mask for 400ms. Participants were asked whether the test stimulus looked happy or not. The results showed that the points of subjective equalities of the ensemble, single 40%, and single 60% conditions were higher than that of the base condition: the prime presentation of four facial expressions made recognition of subsequent facial expressions difficult, and this effect was the same as that of a 40% single face. Additionally, the standard deviation of the psychometric function of the ensemble condition was not significantly different from those of the single prime conditions, suggesting that the participants did not look at one prime stimulus randomly in the ensemble condition but looked at the whole face set and extracted an ensemble average.

43.419 **The Positional Effect in the Diffusion of Individual Attractiveness Within a Group** Hwagyeong Jeong[1](junghk921@gmail.com), Misong Kim[1], Sohee Jang[1], Hoon Choi[1]; [1]Department of Psychology, Hallym University, South Korea

The human visual system can automatically form ensemble representations for not only low-level visual features such as size or orientation but also relatively higher-level visual features such as facial attractiveness. Interestingly, a previous study showed that people perceived the ensemble representation for a group's facial attractiveness as more attractive than the statistical average of the individual member's attractiveness. This phenomenon is known as the group attractiveness effect (GA-effect), and selective attention is considered its underlying mechanism. The most attractive person in a group gets more attention, resulting in that person's attractiveness diffusing within the group. The current study explored whether the location of the attended face influences the GA-effect. If the GA-effect is based on a kind of attentional capture of the most attractive person, the attended person's location would not influence the GA-effect. However, if the GA-effect is related in such a way that the visual system pays attention to spatial location, the location would have an impact. In particular, we are interested in the tendency that people are more likely to pay more attention to objects in the left visual field (LVF bias) than the right. Participants were asked to evaluate a group's attractiveness after the presentation of three faces simultaneously for three seconds, which consisted of two faces with low attractiveness and one face with high attractiveness; the attractive face was presented on the left side, the middle, or the right side. When the attractive face was located in the middle, the group attractiveness was highest (middle > left > right). This result suggests that selective attention alone cannot explain the GA-effect, which is not consistent with previous results showing the importance of attention in ensemble representation.

Acknowledgement: 2017S1A5A8021943(National Research Foundation of Korea)

43.420 **Change blindness from serial dependence** Mauro Manassi[1](mauro.manassi@berkeley.edu), David Whitney[1]; [1]University of California, Berkeley, USA

Despite a noisy and ever-changing visual world, our visual experience appears remarkably stable over time. Serial dependencies, which bias our percepts toward past stimuli, were proposed as a mechanism to facilitate perceptual stability: by smoothing the appearance of changes in the environment, the world looks more stable than it would otherwise. Here, we introduce a new visual illusion, which shows direct evidence of the causal link between serial dependence, change blindness, and perceptual stability. In a single-trial, single-shot experiment, 300 observers attended to a 30 second video in which a face aged from young-to-old (or old-to-young). At the end of the video, after a gap, observers reported the age of a visible test face that was physically identical to the last face in the video. The rated age of the test face was strongly biased towards the earlier faces seen in the video. Because of serial dependence, the identity of the face is continuously merged over time and, as a result, observers perceive a slower age change. In a second experiment, observers viewed the same videos, followed by a test face that jumped forward or backward in age, physically older or younger than the last frame of the video. We measured discrimination accuracy as a function of the difference in age between the last frame of the video and the test face. Sensitivity to the age jump was lowest when the test face jumped backward, toward a previously seen age. Because of serial dependence, the face in the video was perceived to age at a slower rate, and this caused a change blindness selectively for the backward jumping faces. The illusion shows for the first time how serial dependence can make us blind to temporal changes in the environment by actively smoothing the appearance of objects, thus maximizing perceptual stability.

43.421 **Retinotopic serial dependency in visual perception** Therese Collins[1](collins.th@gmail.com); [1]Integrative Neuroscience and Cognition Center, Paris Descartes University & Centre National de la Recherche Sientifique (CNRS)

Previously seen stimuli can influence the current content of perception. Examples of such history effects abound (aftereffects, hysteresis, masking). Recently, renewed interest has been sparked by studies on serial dependencies: the percept reported on one trial is pulled towards the stimulus seen on the previous trial (e.g. orientation, Fisher & Whitney, 2014; facial expression, Liberman et al., 2018; position, Manassi et al., 2018). These serial dependencies are proposed to be the result of a domain-general mechanism ("continuity field") that describes how the visual system deals with variability in the input, be it due to changes in lighting, perspective, or retinal location across eye movements. If serial dependencies are related to object recognition, then

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they should occur in a spatiotopic reference frame, since mechanisms that support the recognition of objects (that make up our subjective experience) must be spatiotopic (like our visual experience). The current experiment tested in what reference frame serial dependencies occur by asking subjects to report the perceived orientation of a Gabor. Both fixation and Gabor position could change across trials, giving rise to four types of two-trial sequences: identity repetitions (Gabor and fixation at same locations), spatiotopic repetitions (Gabor at same location on the screen but different fixation locations), retinotopic repetitions (Gabor and fixation at different locations, Gabor at same retinal location) and control repetitions (none of the previous). Responses were pulled towards the previously-seen orientation in the identity condition, replicating previous reports. Serial dependencies were larger in the retinotopic relative to the spatiotopic condition. These results suggest that serial dependencies might occur at multiple levels of visual processing, both early (retinotopic) and late (spatiotopic).

3D Perception: Shape

Monday, May 20, 8:30 am - 12:30 pm, Pavilion

43.422 **Perception of 3D slant from textures with and without aligned spectral components** Jeffrey A Saunders[1](jsaun@hku.hk), Zhongting Chen[1,2]; [1]Department of Psychology, University of Hong Kong, [2]Key Laboratory of Brain Functional Genomics (STCSM & MOE), School of Psychology and Cognitive Science, East China Normal University

Texture gradients provide multiple potential cues to the 3D slant. A number of studies have demonstrated that texture scaling and compression contribute to slant perception. Textures with oriented structure provide an additional perspective convergence cue, which would be most informative when the oriented structure is aligned with the tilt direction. Some findings suggest that aligned spectral components are important for 3D perception from texture, but this has only been demonstrated in restricted situations where other texture cues are unreliable. In this study, we tested the contribution of oriented spectral components in conditions where texture and scaling are more informative. Observers viewed simulated planar patches of textured surfaces with varied slant (0°-80°) and field-of-view (16° and 6°) and performed an adjustment task to estimate slant. The simulated textures were octotropic plaids with a full range of orientations, or with either the aligned or perpendicular plaid components removed. Removing these plaid components would not degrade information from texture scaling and compression, so any differences could be attributed to the oriented components. We measured perceptual bias in monocular conditions and also the relative weighting of texture and stereo information in binocular conditions. For all textures, we observed more underestimation of slant and less weighting of texture information for surfaces with low slant, replicating previous findings. Comparing across textures, we found that aligned spectral components produced some improvement in slant estimates, but differences were small and only observed in some conditions, and there were no detectable effects on texture cue weights. These results demonstrate that aligned spectral components contribute to perception of slant from texture, but suggest that the contribution is limited when other texture cues are informative. Our findings are consistent with the notion that the visual system utilizes multiple texture cues for 3D perception.

Acknowledgement: Supported by the Hong Kong Research Grants Council, GRF 752412H

43.423 **Contextual influences on shape perception** Elise J. Garmon[1](ejgarmon@yahoo.com), Nicole A. Liaw[1], Alexander J. Bies[1], Kelly E. Robles[1], Margaret E. Sereno[1]; [1]Psychology, Arts and Sciences, University of Oregon

Visual context influences the ability to process object shape (shape constancy) but can also hinder performance on tasks that require judgments of apparent object shape where an individual must rely on the retinal image of a target. Participants completed a shape judgment task including judgments of projective (apparent) and objective (actual) shape for figures with varying amounts of context, defined as inclusion of 3-D information in the form of additional sides of a polyhedron. In the first study, participants completed judgments on figures with three levels of context: context-absent (only the target face present), context-partial (target face and a portion of additional top and side faces visible), and context-full (complete 3-D shape). In the second study, objective and projective judgments were completed on the same context-absent and context-full figures as well as two additional sets of images where one face of a complete polyhedral shape was missing. Shape judgments were less accurate when projective decisions were made in conditions including context (partial, single face missing, and full context) and when objective decisions were made in conditions lacking full context (absent, partial, single face missing). As the amount of context decreased, errors increased in objective judgments but decreased in projective judgments. Degree of rotation moderates the effects of context such that overall error increases with greater rotation of the target face and illustrates the important influence of level of context on shape judgment, where the most accurate judgments of actual shape require complete 3-D context while this same level of context distorts apparent judgments which benefit from an absence of context.

43.424 **Drawing ability predicts flexibility in the use of context to accurately perceive shape** Kelly E. Robles[1](kne@uoregon.edu), Rebecca Florentine[2], Audrey Sherman[3], Alexander J. Bies[4], Margaret E. Sereno[5]; [1]Psychology Department, Art and Sciences, University of Oregon

The artistic ability to create accurate drawings serves as a modulator of visual processing, biasing artists towards a projective representation of stimuli through the suppression of context to actuate a 2D representation of a 3D target. Visual context plays a role in the ability to process object shape (shape constancy) but can also hinder performance on tasks that require projective judgments of object shape such as when creating a realistic drawing of the world. Participants in this study completed a series of shape judgment tasks, a drawing task to measure the accuracy of artistic ability through replications of photographs, and the Autism Quotient (AQ) and Systemizing Quotient (SQ) questionnaires, in order to determine the relationship between the accuracy of various visual shape judgments and drawing accuracy. The shape tasks measured participants' ability to make objective or projective shape judgments with or without the presence of context. As predicted, those with greater drawing ability were able to overcome the influence of visual context to make more accurate projective shape judgments. Surprisingly, participants were also able to use context to make more accurate objective shape judgments as well. Neither the AQ or SQ, used as measures of local processing bias, predicted shape perception ability. These results support a model of perceptual flexibility as opposed to perceptual bias as the basis for changes in accuracy of shape perception. Greater artistic ability facilitates a more flexible approach to visual perception as a whole that allows for more accurate shape perception.

43.425 **The Effects of Bilateral Symmetry, Viewing Distance, and Scene Context on Apparent 3D Shape** Ying Yu[1](yu.1416@osu.edu), James T Todd[1], Alexander A Petrov[1]; [1]Department of Psychology, The Ohio State University

Pizlo et al. (2014) argue that symmetry plays a critical role in the perception of 3D shape, but there are surprisingly few direct empirical tests of this hypothesis. The present experiment compares the adjustment accuracy for symmetric and asymmetric objects in a shape-matching task. Method: Computer-generated stereoscopic images of 3D polyhedra were viewed binocularly through shutter glasses. On each trial, two objects – adjustable and reference – were presented side by side and the participant adjusted the Z-scaling of the former to match the apparent shape of the latter. The stimulus set included 10 mirror-symmetric polyhedra similar to the stimuli of Li et al. (2011), and 30 asymmetric distortions thereof. The distortions were obviously asymmetric and were produced by randomly displacing in 3D every vertex of the polyhedron. Whereas the quadrilateral faces of the symmetric objects were all planar, those of the asymmetric objects were not, and appeared curved. The stimuli were rendered either against a black background or inside a corridor with textured walls receding stereoscopically in depth. Symmetry and context were manipulated in a 2x2 factorial design in four 90-trial sessions, one per condition. The distance to the reference object was manipulated across trials (0.7m, 1.5m, or 2.3m); the adjustable object was always placed at 1.5m and was physically larger than the reference. Results: All seven observers produced similar qualitative patterns. Although statistical power was high, there were no significant differences between the symmetric and asymmetric conditions and no significant interactions. Viewing distance had a large significant effect – the apparent depths of the reference objects became systematically compressed with increased viewing distance for all stimulus types. Scene context had a significant effect too – the reference objects appeared to have more depth when viewed in the corridor than against a black background, relative to the adjustment object.

43.426 **Perceptual biases in the interpretation of non-rigid structure from motion**
Ryne Choi[1,2](ryne.choi@rutgers.edu), Jacob Feldman[1,2], Manish Singh[1,2]; [1]Department of Psychology, Rutgers University - New Brunswick, [2]Center for Cognitive Science, Rutgers University - New Brunswick

Structure-from-motion research has largely focused on the perception of rigidly moving 3D objects. However, many of the objects we see in the environment are animate and move non-rigidly. Models of SFM based on rigidity cannot interpret articulated non-rigid motion.Recently it has been shown that subjects are just as good at perceiving the 3D structure of objects undergoing certain forms of non-rigid transformations (Jain & Zaidi, 2011). Our overarching goal is to investigate the kinds of non-rigid object transformations that are perceivable through SFM. In this study, we focus on two types of non-rigid motion that we believe to be categorically different: length change and orientation change of a protruding part. Orientation change is a part articulation that is more biologically plausible than length change. Our stimuli consisted of an ellipsoid with a protruding narrower part. The object was shown solely by a random dot texture. The whole object rotated back and forth about its vertical axis. At the same time, the protruding part continuously changed its length or orientation with respect to the base part. We found that when the part changed in length, subjects often perceived the transformation as an orientation change in 3D. We manipulated the magnitude of length change and used the method of constant stimuli and adjustment to measure subjects' perception of the length transformation. We found that even when the length of the part changed dramatically, subjects perceived an orientation change rather than a length change. The results demonstrate that certain non-rigid transformations are easier to perceive correctly through SFM than others. The visual representation of shape may include certain "non-rigid" transformations that are more "natural," such as the articulation of limbs (part-wise rigidity) on biological shapes. The visual system may be biased towards these more biomechanically plausible interpretations of motion.

43.427 **The strong influence of contour geometry in Structure from Motion (SFM)**
Xiaoli He[1,2](hxl.daybreak@gmail.com), Jacob Feldman[1,2], Manish Singh[1,2]; [1]Rutgers University, Department of Psychology, [2]Rutgers University, Center for Cognitive Science

The SFM literature focuses almost entirely on the role of image motion, ignoring contributions of contour geometry. However, our previous work (He et al., VSS, 2017, 2018) has shown that contour geometry can play a dominant role in SFM, often even overriding inconsistencies with image motion. Here we investigate the role of contour geometry by manipulating inconsistencies with image motion. Specifically, we manipulate the shape of the aperture through which the same image motion is shown. We start with a "motion region" (such as rectangle, trapezoid, ellipse) containing dot motion consistent with 3D rotation, and transform the shape of this motion region to define a smaller aperture. In many conditions, rather than looking like dots moving behind an aperture, the contour captures and defines the perceived 3D shape. In Experiment 1, we generate smaller apertures by compressing the horizontal width of the motion region. In Experiments 2 & 3, we break coaxiality (the aperture and motion region no longer share the same axis) by either translating or rotating the aperture within the motion region. The question is how much the aperture can be transformed and still determine the 3D percept. We used Method of Constant Stimuli to find the thresholds for perceiving a rotating 3D object defined by the contour shape. In Experiment 1, even with average width ratios as low as 0.2 (ellipse) or 0.6 (rectangle), the SFM percept was still dominated by contour shape. In experiment 2, the average threshold was around 0.35 (hexagon, barrel) or 0.65 (rectangle), indicating the strong effect of contour geometry on SFM percepts. These experiments document the conditions where contour geometry overrides image motion in SFM, thereby highlighting its critical, but neglected role. They also emphasize the need for mathematical models combining contour geometry and image motion in predicting SFM percepts.

43.428 **Haptic-visual crossmodal shape matching**
Farley Norman[1](Farley.Norman@wku.edu), Sydney P Wheeler[2], Lauren E Pedersen[1]; [1]Department of Psychological Sciences, Ogden College of Science and Engineering, Western Kentucky University, [2]Carol Martin Gatton Academy of Mathematics and Science

A set of two experiments evaluated the crossmodal perception of solid shape. Sixty-six total participants (mean age = 21.2 years) haptically explored a single randomly-selected object on each trial and then indicated which of 12 visible objects possessed the same shape. Three different types of objects were used, two of which possessed natural shapes (bell peppers & sweet potatoes: Capsicum annuum and Ipomoea batatas, respectively), while the third object type was a set of sinusoidally-modulated spheres (SIMS, see Norman, Todd, & Phillips, 1995). Each object was haptically explored with both hands for 7 seconds. Even though the particular object shapes within each object type were mathematically distinct and unique, the participants' crossmodal matching accuracies varied substantially ($F(2, 63) = 128.6$, $p < .000001$, partial eta squared = .80) across the object types (78.7, 60.9, & 18.6 percent correct for sweet potatoes, bell peppers, and sinusoidally-modulated spheres, respectively). The naturally-shaped objects (bell peppers & sweet potatoes) were much more identifiable to vision and haptics, because their distributions of distinctly shaped surface regions (areas of differing Gaussian curvature; e.g., convex or concave hemispherical regions, saddle-shaped regions, cylindrical regions) were heterogeneous. In contrast, the randomly-shaped SIMS were substantially less identifiable, because their distributions of distinctly shaped surface regions were much more homogeneous. The results of the current study document what variations in surface shape produce objects that are highly recognizable to human vision and haptics.

43.429 **Using psiTurk to explore correlations between delusional ideation and perceiving depth-inversion illusions**
Attila Farkas[1](ajf215@ruccs.rutgers.edu), Thomas Papathomas[2], Steven Silverstein[3], Hristiyan Kourtev[4], John Papayanopoulos[5], Dylan Forenzo[6]; [1]Laboratory of Vision Research, Center for Cognitive Science, Rutgers University, [2]Department of Biomedical Engineering, Laboratory of Vision Research, Center for Cognitive Science, Rutgers University, [3]Division of Schizophrenia Research, Rutgers University Behavioral HealthCare and Robert Wood Johnson Medical School Department of Psychiatry, Rutgers Biomedical and Health Sciences, Center for Cognitive Science, Rutgers University, [4]Center for Cognitive Science, Rutgers University, [5]College of Engineering, Georgia Institute of Technology, [6]Department of Biomedical Engineering, Rutgers University

Background: Depth-inversion illusions (DII) involve stimuli for which physically distant points are perceived to be closer to observers than physically near points. Schizophrenia (SZ) patients are less likely to perceive DII as strongly as controls. In particular, there is a negative correlation between the tendency to obtain DII and positive SZ symptoms (Keane et al. 2013). Objectives: First, to test the hypothesis that the tendency to obtain DII correlates negatively with delusional ideation in healthy controls, since delusion is an important positive SZ symptom. Second, to ascertain the frequency with which individuals in the general population perceive DII. Methods: We developed a test in psiTurk to obtain data from hundreds of participants. We assess DII tendency by testing performance with DII stimuli, and we measure delusional ideation adapting Peters Delusions Inventory (PDI; Peters et al. 1999) into an online version. We used two classes of 3D objects: perceptually stable unambiguous objects that serve as "catches": banana, apple, toy, etc.; and bistable objects that can exhibit DII but can also be perceived without depth inversion: human hollow mask, monkey hollow mask and a reverse-perspective scene. To obtain depth from motion, each object was rotated clockwise or counterclockwise around a vertical axis. We used 3-D probes embedded in strategic locations of the objects to infer whether participants obtained the veridical or illusory depth percept. Results: We conducted a pilot study with 9 participants that validated our approach of using probes to assess the perceptual state of participants. Results from large-scale psiTurk sessions are forthcoming. Discussion: Using the depth-from-motion approach is justified in light of results from a study that obtained evidence for its validity in DII experiments with SZ patients and controls (Keane et al. 2013). Our crowd sourcing experiments can study useful unexplored correlations that require large numbers of participants.

43.430 **Perceived distortions of 3D shapes are based on misestimates of viewpoint applied to correct mental geometry**
Akihito Maruya[1](amaruya@sunyopt.edu), Qasim Zaidi[1]; [1]Graduate Center for Vision Research, State University of New York

A 3D object seen from different views forms quite different retinal images. Humans are very good at inferring 3D pose by using knowledge of projective geometry (Koch et al PNAS 2018). Everyday observations suggest that we also infer correct 3D shapes despite projective distortions, but is that true? We presented frontal views of 3 rectangular parallelepipeds lying on the ground in 16 poses each (equivalent to 16 views of one pose), and 6 observers adjusted the height of an orthogonally attached narrow cylinder to equate the physical lengths of the two limbs. The projected length of the parallelepiped changes with pose as a distorted sinusoid, but the projected length of the vertically oriented cylinder stays constant. Length estimates of the parallelepiped were close to veridical for fronto-parallel poses, 2but were seriously underestimated for poses pointing at or away from the viewer. The

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variation in estimated lengths correlated with projected length. The inverse of the function relating projected length to pose, gives the optimal correction factor for inferring correct physical lengths from retinal images. Observers' correction factors were close to optimal for poses close to fronto-parallel, but seriously low for poses close to line-of-sight. Interestingly the underestimation increased with physical length of the parallelepiped. Inspection of the stimuli revealed that objects in poses away from front-parallel were seen as inclined more toward the viewer, equivalent to increases in viewing height, even with a grid on the ground plane. Increased viewing height requires smaller correction factors, so an overestimate of viewing height can explain the underestimation of object length. Since changes in perceived length of one limb with respect to the other define one class of shape distortion, these results show that shape inconstancy results despite using the correct geometric back-transform, if retinal images invoke wrong estimates of viewing height.

Acknowledgement: NIH EY13312

43.431 **Bulging out of the picture - or not? Oblique viewing effects on the convex-concave ambiguity.** Sylvia C Pont[1](s.c.pont@tudelft.nl), Huib de Ridder[1]; [1]Perceptual Intelligence lab, Industrial Design Engineering, Delft University of Technology

The perception of convex-concave ambiguous pictures is known to depend on the orientation of those stimuli in the frontal plane, because it is subject to the light-from-above (and convexity) biases. In Koenderink et al. (Pointing out of the picture, Perception 2004:33) it was found that perception of an obliquely and frontally viewed picture of a globally convex relief was very similar in that the pictorial relief simply was indicated by the proximal stimulus. So, they found no evidence for any 'correction' mechanisms under oblique viewing. We tested whether this also holds for convex-concave ambiguous stimuli. We tested frontal and oblique viewing of a real example of a convex-concave-ambiguous 'stimulus', a picture of a sculpted memory stone, for vertically and horizontally placed photographs in fully diffuse lighting. We found idiosyncratic differences between frontal and oblique viewing. For frontal viewing the pictorial relief was mostly perceived to exist of convex elements and by one observer as just concave elements. For oblique viewing the perceived relief changed for all observers: between 1 and 5 elements flattened or reversed depth; two observers reported that all relief elements looked flatter in the oblique than in the upright condition. This suggest that in this specific case 'correction' mechanisms might play a role, but it is not yet clear which and whether those relate to the picture's spatial attitude or foreshortening. To address this issue we will extend this study testing more viewing, positioning and lighting conditions for photographs and for simple computer rendered stimuli.

43.432 **Size Estimation of Visual Stimuli on Computer Screens** Emily L Laitin[1](emily.laitin@colostate.edu), Jessica K Witt[1]; [1]Colorado State University

Does our visual system interpret the size of visual stimuli on computer screens the same way it interprets visual stimuli in the real world? In perceptual science, participants are often asked to make inferences based on visual stimuli on a two-dimensional computer screen. However, there is a lack of sufficient evidence that participants will interpret this the same way as they do real visual stimuli. Without depth cues available in the real world, the size of such stimuli could be over or under estimated. In the present study, participants performed a visual matching task between real objects and images on a screen. Participants were instructed to take items out of a basket to put on a table in front of them and then manipulate a computer image of that object to match the object's true size. Participants were allowed to adjust the image as many times as they pleased before continuing to the next trial. Participants manipulated each of the 10 objects 5 times for a total of 50 trials. Of the 10 objects used in the study, participants made the computerized image significantly smaller than the actual size for 5 of the objects ($p < .05$) and significantly larger than the actual size for 2 of the objects ($p < .01$). Participants made the images the appropriate size for the remaining 3 objects. Although histograms of the results suggest that there is no clear bias of over or under estimation overall, it still remains apparent that participants misjudge the size of objects in pictures compared to real objects. The results of the present study suggest that more research needs to be focused on size estimation of visual images on computer screen before using it as a substitute for real world stimuli.

43.433 **Basketball Hoop Illusion Verified both Empirically and through Comic Strip Caricatures** Michael K. McBeath[1](m.m@asu.edu), Ty Y Tang[1]; [1]Psychology, Arizona State University

Introduction: The Basketball Hoop Illusion is a perceptual distortion in which distant, typically elevated, real-world, 3-D objects appear smaller than actual. We examined perceived size of basketball hoops and traffic lights, both empirically and by ascertaining extent that shrinkage is exaggerated within comic strips, and we confirmed geometric and cognitive factors contribute to the illusion. Methods: Observers estimated the size of an actual basketball hoop relative to the ball, or vice versa, while either holding a basketball, or with the ball placed under the basket. Observers also estimated the size of the glass lens on a traffic light from distances ranging from 20-500 feet. Participants were tested for susceptibility to classic geometric illusions potentially related to basketball hoop-size judgments, and were asked demographic questions.Finally, we assayed the hoop-to-basketball ratio from an assortment of a dozen different comic strips that contained basketballs and hoops at approximately equal implied viewing distances. Results: Observers reliably experienced a hoop-to-basketball ratio of 1.5 diameters, significantly below the veridical ratio of 1.85.The direction of estimate had no effect, nor did other demographic variables like sex, or sports expertise.Similarly, traffic light lenses were judged significantly smaller than actual (8 inches for standard 12-inch diameter lenses), independent of viewing distance.Experienced hoop shrinkage was found to be related to Müller-Lyer phenomena, and narrower rim-ovals appeared smaller.Finally, we verified that caricatures of hoops had hoop-to-ball ratios significantly below 1.5. Discussion: Our findings confirm that robust spatial illusions occur in naturalistic real-world environments like basketball or roadside settings, and that these distortions are consistent with classic geometric illusions.We corroborated that cartoons caricaturize and exaggeratedly shrink the size of basketball hoops relative to the ball.This is consistent with cartoons emphasizing notable features of observed stimuli, providing amplified representations of salient deviations from norms.

Acknowledgement: Arizona State University Global Sports Institute

Visual Memory: Objects, features

Monday, May 20, 8:30 am - 12:30 pm, Pavilion

43.434 **Are task-irrelevant object features stored in working memory in a hidden state?** Andrea Bocincova[1](andrea.bocincova@ndsu.edu), Jeffrey S. Johnson[1]; [1]Department of Psychology, Center for Visual and Cognitive Neuroscience, North Dakota State University

Existing evidence suggests that a single, task-relevant feature of a multi-feature object can be selectively stored in working memory (WM). Specifically, studies have shown that task-irrelevant object properties receive less priority during encoding and are not decodable from neural activity recorded throughout the delay period. Prominent WM theories posit that items in WM can be stored in different states of activation depending on the allocation of attention such that unattended-but-stored information can be represented in sub-threshold neural activity that is not directly observable using methods such as multi-variate pattern analysis (MVPA). However, it is possible to momentarily "reawaken" these representations using single-pulse TMS (Rose et al., 2017) or by flashing a task-irrelevant stimulus during the delay (Wolfe et al., 2017). In the present study, we used similar methods to examine whether task-irrelevant features of a single object are stored in WM in a similar hidden state. Specifically, we used MVPA trained on EEG data to examine the temporal evolution of the task-relevant and irrelevant feature representations of a two-feature object. In different blocks, participants remembered the orientation or color of a colored, oriented grating, and, during the delay period, a task-irrelevant stimulus was flashed on the screen. A support vector machine classifier was then used to classify the identity of the stimulus features. Our results replicated previous findings showing that orientation was only decodable throughout the delay period when it was task-relevant. However, analysis of the signals evoked by the presentation of the flash stimulus revealed above-chance decoding for both task-relevant and irrelevant orientations, although decoding accuracy was generally higher and less variable across subjects for task-relevant versus irrelevant orientations. These results suggest that task-irrelevant features may be stored in WM in a hidden state and that participants may vary in their ability to selectively store only task-relevant features.

Acknowledgement: R15 MH105866-03, P30 GM103505-02

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43.435 **The Interaction of Time and Depth: Visual Working Memory in Depth Across Multiple Retention Intervals** Dawn M Sarno[1](dawn.sarno@Knights.ucf.edu), Mark B Neider[1]; [1]Psychology, College of Sciences, University of Central Florida

Recent work has suggested that the presence of depth information can extend working memory performance beyond typical limitations (Qian et al., 2017). This benefit appears to be reliant on a strategy that involves the segmentation of items in the display by depth. What remains unclear are the temporal characteristics of such a benefit. The present study investigated how manipulating the retention interval in a change detection task would affect the benefit of depth. Participants viewed arrays of colored cubes and determined whether a single cube changed colors after one of four retention periods (i.e., 500 ms, 1000 ms, 2000 ms, 4000 ms). All arrays were presented as anaglyphs and varied by the number of items (2,4,6, or 8 items) and by the number of depth planes (1 or 2) in which the items appeared. In the multiple depth plane condition items were evenly distributed across depths. Consistent with previous research, all four retention intervals demonstrated benefits for multiple depth planes at set size 6 with an ~8% increase in task accuracy. Despite consistent patterns of performance across all retention intervals, overall accuracy varied. Participants in the 500 ms and 1000 ms retention intervals had remarkably similar performance (77% & 76% accuracy, respectively); those in the 2000 ms and 4000 ms retention conditions were less accurate (both with 71% accuracy). The present study coincides with previous research indicating that depth benefits manifest at higher working memory loads (i.e., 6 items). Additionally, these results indicate that depth benefits can be observed when holding items in memory briefly (e.g., 500 ms), or for more extended periods of time (e.g., 4,000 ms). Taken together our results suggest that although depth benefits vary with the number of items in an array, they are robust across a range of retention intervals.

43.436 **Visual working memory for stimulus feature saturation**Weizhen Xie[1](weizhen.xie@email.ucr.edu), Weiwei Zhang[2], Kareem Zaghloul[1]; [1]National Institute of Neurological Disorders and Stroke, National Institutes of Health, [2]Department of Psychology, University of California, Riverside

Stimuli in natural vision differ in various physical attributes such as size, location, and surface feature, posing a unique challenge for visual cognition. However, previous research in visual working memory (VWM) mostly used simple and well-controlled laboratory stimuli (colors with different hues but matched saturation), making it difficult to assess how diverse stimulus features affect VWM. To examine this issue, this study developed a two-dimensional face space with continuous variations in the circular dimension for face identities and in the radial dimension for feature saturation. The center of this face space represents the average (norm) face. The radial distance of a face represents its strength/intensity, similar to color saturation defined as the eccentricity of a color in standard color space. In Experiment 1, participants remembered either 1 or 2 faces randomly sampled from the face space across different radial and circular locations and recalled the face on both dimensions after a short delay. Modeling of recall errors on the circular axis showed that VWM precision was reduced by set size and increased by face saturation. However, the number of retained VWM items was only significantly influenced by set size but not by face saturation. Furthermore, participants' recall on the radial axis showed more centripetal errors at a larger set size, suggesting a general bias toward the norm. To examine how face saturation affects neural activities underlying VWM maintenance, in Experiment 2, we recorded electrocorticography signals along the ventral processing pathway in epileptic patients during the face VWM task. Representational similarity analyses showed that face saturation strengthened the association between delay-period neural activities and retained VWM representations estimated by behavioral recall performance. Together, these preliminary findings reveal novel neurocognitive effects of feature saturation on VWM maintenance, suggesting that saturation may be a critical aspect of VWM representations beyond capacity and precision.

Acknowledgement: NINDS/NIH Visiting Fellows Program

43.437 **Contextual Relearning Following Target Relocation in Visual Search** Elizabeth G Esser-Adomako[1](eesser@gmu.edu), Patrick Mead[1,3], Shane Kelly[1], Matthew S Peterson[1,2]; [1]Department of Psychology, George Mason University, [2]Neuroscience Interdisciplinary Program, George Mason University, [3]Human Systems Integration Branch, Naval Surface Warfare Center Dahlgren Division

In contextual cueing, visual search is more efficient when viewing repeated visual contexts compared to randomly generated displays (e.g., Chun & Jiang, 1998). However, other research has indicated that no efficiency benefit occurs for displays in which there are unexpected changes to the target location in previously learned contexts (Conci and Müller, 2012; Conci, Sun, and Müller, 2011; Zellin, Conci, Mühlenen, and Müller, 2011; Zellin, Conci, Mühlenen, and Müller, 2013). This suggests that individuals do not "relearn" contextual cues following target relocation. In these studies, only the spatial location of distractors and targets were predictive of the target location, and targets were relocated to previously unoccupied locations, changing the displays' overall spatial configurations. One possible explanation for the lack of relearning in these studies is that targets were swapped to a previously unoccupied location, which in turn changed the context. In addition, previous studies used grayscale displays, and the lack of color information might have led to impoverished contexts that were harder to learn. Another possible explanation is the size of the displays allowed for quicker searches, which in turn masked any relearning benefits. Lastly, another possible explanation is that the studies were underpowered or did not provide enough opportunities for relearning to occur. The current study accounts for these potential explanations of the lack of relearning after target relocation. Across four experiments, relearning was demonstrated with large and small visual search displays, with monochromatic and colorful targets and distractors, and with targets that moved to an unoccupied location as well as a previously occupied location. In contrast to previous studies, these results show that relearning of a secondary target location within previously learned contexts does occur, with faster search times to repeated contexts with a target relocation than to random displays.

43.438 **Do we actively inhibit recently attended but no longer relevant information?** Yingtao Fu[1](1848429283@qq.com), Jiahan Yu[1], Rende Shui[1], Mowei Shen[1], Hui Chen[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University

The limited capacity of visual working memory (VWM) requires an efficient information selection mechanism. However, an uneconomical object-based encoding manner of VWM has been consistently found in previous studies. That is, not only the target feature, but also the task-irrelevant features from the same object are extracted into VWM. Besides the totally task-irrelevant feature which is never useful throughout the whole task, there is another kind of "irrelevant feature" that is necessary initially but no longer useful for the left task, termed as key feature in Chen & Wyble (2015)'s Attribute Amnesia studies. Previous studies showed that despite participants could not explicitly report the key feature in a surprise memory test, they had some memory traces for this unreportable information that could still produce an inter-trial priming effect. The current study sought to investigate the status of memory representation of a key feature by directly comparing it with the memory representation of a totally irrelevant feature from the same object (which serves as a baseline). In a series of experiments, participants were asked to memorize one feature of a single object, and then performed a visual search task in which there was either one of the distractors matching the task-irrelevant feature or key feature of the memory item, or there was no match between the memory and search display. Surprisingly, the results convergingly showed that despite a reliable WM-driven attentional bias effect (i.e., longer search time in the match condition than the no-match neutral condition) was generated by a task-irrelevant feature of an object, there was no such an effect triggered by the key feature. These findings suggested that participants might tend to actively inhibit just used information (i.e., key feature), resulting in even weaker memory representation of such information as compared to that of completely task-irrelevant features.

Acknowledgement: NSFC (No.31771201) and Humanities and Social Sciences Foundation of the Ministry of Education of China (No.17YJA190001)

43.439 **Free-Floating Features in Visual Working Memory** Conne A George[1](cag615@msstate.edu), Michael S Pratte[1]; [1]Mississippi State University

A fundamental question in visual working memory is whether memories are made of collections of features, or of bound object-based representation. Whereas most of the research on this question has focused on the bindings between features such as color and orientation, here we focus on an object's location, and explore whether location is a fundamental feature that any object representation must have, or if other features can be stored in memory even in the absence of memory for their location. In a series of experiments we utilized different test conditions to separately measure memory capacity for item colors, item locations, and the bound color and location conjunctions. We repeatedly found that participants remember about one more color representation than bound color & location representations. This result implies that a feature such as color can be stored in memory without jointly maintaining the location corresponding to that feature.We hypothesized that perhaps this location-less color information was being stored in verbal memory (e.g. "red"), rather than in visual working memory. However, articula-

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tory suppression did not negate the presence of this information, suggesting that color information can be stored in visual working memory in the absence of location. We conclude that location is therefore not a necessary feature of working memory storage, but rather, that features can be stored in a location-less, free-floating state.

Acknowledgement: NIH NIMH Grant R15MH113075

43.440 **Dissociating visual working memory for objects and scene layout** Anna Shafer-Skelton[1](ashafers@ucsd.edu), Timothy F Brady[1]; [1]Department of Psychology, University of California, San Diego

A fundamental question in cognition is how our memory stores are structured. While neuroimaging evidence suggests that objects and the layouts of major surfaces in a scene may be processed separately, previous behavioral work has encountered mixed results in relation to working memory, possibly because this work has largely not isolated scene layout, instead using scenes that contain objects. To investigate scene layout vs. object memory stores, we asked participants to remember items in four types of displays (1) three colors, (2) four colors, (3) three colors plus a full screen background scene with no objects, and (4) three colors plus a large peripheral gabor stimulus. If object and scene memory rely on separate resources, remembering a scene should have a smaller cost to participants' object memory than remembering an additional object. As expected, we found that memory for three colors was better than four (measured using TCC, Schurgin, Wixted & Brady, 2018). We found that remembering a scene in addition to three colors had a reliable cost to participants' color memory performance ($t(19)=4.48$, $p< 0.001$), but that remembering a scene caused less of a cost to color memory than remembering a gabor ($t(19)=3.38$, $p=0.003$), a task designed to incur similar costs at encoding. There was no evidence that this can be explained by different tradeoffs between the gabor and scene memory task vs. the color memory task, as performance at the scene task was numerically higher than at the gabor task. Together, our results (1) indicate that previous work suggesting that scenes can be represented with reduced attention does not translate into effortless memory or completely independent memory resources for scene layout vs. objects, and (2) suggest that memory for object-less scenes is more distinct from object memory than memory for other classes of objects.

Acknowledgement: NSF CAREER BCS-1653457 to TFB, NSF GRFP to AS

43.441 **Investigating visual free recall of highly similar and competing scene stimuli** Elizabeth H. Hall[1,2](ehhall@ucdavis.edu), Wilma A Bainbridge[2], Chris I Baker[2]; [1]Center for Mind and Brain, University of California, Davis, [2]Laboratory of Brain and Cognition, National Institute of Mental Health

Drawings of real-world scenes made from visual memory can be highly detailed and spatially accurate, and often contain little information not found in the observed stimuli (Bainbridge et al., 2018). However, little is known about the specific visual detail recalled when episodes are highly similar, and the nature of what object information is likely to intrude on the memory of a competing scene. The current study probes this question by asking participants (n=30) to study and recall 8 complex-real world scene images (4 from a repeated category, 4 from unique categories) using a drawing task. We recorded participants' eye movements during the study period (10s each) to assess what percentage of detail studied in the scene was later successfully recalled, and to compare the order in which objects were studied versus recalled. After a distractor task, participants completed two memory tasks. For the first, they drew as many scenes as they could remember on a digital tablet that recorded timing and stroke order. Second, they completed an old / new recognition task for the original images intermixed with 8 matched foils. Participants recalled 83.8% of the images across the study, and recognized category-unique images significantly better than repeated category items. Online scorers of the drawings (n=964) were better able to match category-unique drawings to their original images than repeated category drawings, showing that recalled visual memory content was more accurate when there weren't competing exemplars in memory. Indeed, when a separate group of online workers (n=3,010) were asked to label intrusions (or non-original objects) within the drawings, repeated category drawings were found to contain significantly more intrusions than category-unique drawings. Overall, these results reveal the nature and extent of intrusions that can occur in competing visual memories for complex real-world scenes.

43.442 **Incongruent Objects in Real-World Scenes Distort Visual Memory Recall** Wan Y Kwok[1](wan.kwok@nih.gov), Wilma A Bainbridge[1], Chris I Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health

Previous work by Greene et al. (2015) has found perceptual deficits in description and classification for highly incongruent scenes (where an object did not match its surrounding scene context) compared to congruent scenes. However it is still unclear how visual memory for complex scenes is affected by incongruent objects, particularly during free recall. Using a drawing task to analyze the visual contents of memories (as in Bainbridge et al., 2018), here we evaluate the differences in visual memory recall elicited by incongruent objects in real-world scenes. 30 participants were eye-tracked while viewing 12 real-world scene stimuli, displayed with a congruent or incongruent object in the foreground. For example, a construction scene contained either a congruent construction sign, or an incongruent blender. Participants viewed an equal number of congruent and incongruent scenes, which were counterbalanced across participants. After stimulus viewing, they performed a distractor task to disrupt verbal working memory strategies. Then, participants were asked to draw as many images as they could recall, in as much detail as possible. On average, participants drew 8.4 out of 12 images from memory, with an average of 4.2 correct object/scene pairings. Eyetracking analyses revealed that incongruent objects affected the overall viewing patterns of the scenes. No significant differences in memory performance at the scene-level were found between incongruent and congruent images. However, participants made different object/scene binding errors – either remembering objects in isolation, or transposing objects in wrong scenes entirely. Significantly more errors were made with objects originally shown in incongruent scenes than congruent scenes. Differences were also found in drawing stroke order for incongruent versus congruent scenes. Ultimately, incongruent objects within scenes do not so much affect the memory for the scene background or the incongruent object, but how these features are bound together.

Acknowledgement: NIH Intramural Research Program

43.443 **Neural Mechanisms Underlying Reviewing Feature Binding of Color and Letter in Visual Working Memory** Jun Saiki[1](saiki.jun.8e@kyoto-u.ac.jp), Bo-Cheng Kuo[2], Ya-Ping Chen[2], Tomoya Kawashima[3,4]; [1]Graduate School of Human and Environmental Studies, Kyoto University, [2]Department of Psychology, National Taiwan University, [3]Research Center for Promoting Intercultural Studies, Kobe University, [4]Center for Information and Neural Networks (CiNet), National Institute of Information and Communications Technology and Osaka University

Feature-bound object representations facilitate matching of a perceptual input with a representation in visual working memory (VWM), but its underlying neural mechanism remains unclear. Using the redundant feature reviewing task (Saiki, 2016), the current study investigated the process of feature matching between a single object probe and multiple objects in VWM using MEG and EEG. A set of features was presented in a two-object memory display, followed by a linking display in which only placeholders remained visible. Then a single object probe was presented, and participants judged if it contained any features of the memory display, regardless of object correspondence. Two groups of participants in Taiwan and Japan performed this task while measuring brain activity using MEG and EEG, respectively. Both groups showed the advantage of feature conjunction relative to single features in memory matching, and this advantage was larger when target features were grouped in the memory display (intact condition) than when they were separated (recombined condition). Also, they showed the advantage of shared location between memory and probe displays, either in conjunction match or shape-only match. EEG/MEG data revealed that the difference in advantage of feature conjunction between the intact and recombined conditions was reflected by the amplitude of left frontal electrodes around 400 ms after the probe onset. Furthermore, the N3rs component reflecting retroactive search in VWM representations, defined as the mean amplitude at the midline electrodes between 340 ms and 400 ms, showed significantly smaller search costs in the intact condition than in the recombined condition, and in the two feature condition than in the one feature condition. These findings indicate that the advantage of feature conjunction in memory matching mainly reflects memory search process, and that the N3rs component reflects search cost in terms of feature redundancy, in addition to the number of memory representations.

Acknowledgement: JSPS KAKENHI Grant #JP16H01727, JSPS Bilateral Open Partnership Joint Research Projects

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43.444 **Simultaneous recall procedure reveals integrated object representations in VWM** Hirotaka Sone[1](hirotaka.sone@mail.utoronto.ca), Aedan Li[2], Keisuke Fukuda[1,2]; [1]University of Toronto Mississauga, [2]University of Toronto

Visual working memory (VWM) allows us to actively represent a limited amount of visual information in mind. A classic study by Luck and Vogel (1997) demonstrated that visual features are represented as integrated objects in VWM. On the other hand, recent studies (e.g., Fougnie and Alvarez, 2011) had participants represent multi-feature objects (e.g., colored triangles) in their VWM and had them recall all the features of the same object sequentially. The result revealed that multiple features composing the same object (e.g., color and orientation) are prone to independent and probabilistic representational failures, thus questioning the integrated object account of VWM representations. To reconcile this discrepancy, we invented a novel VWM recall paradigm that enabled simultaneous recall of multiple features. More precisely, participants encoded one or two colored triangles in their VWM, and after a short retention interval, a test probe was presented at one of the stimulus locations to prompt participants' recall. Critically, this test probe was composed of 180 concentric color rings whose radius covaried as its color changed continuously on a circular CIELab color space. Thus, by clicking on a specific color ring at a specific angular direction, participants reported the color and the orientation of the tested item simultaneously. Using this novel approach, we found that 1) remembering two features of one object is less taxing to our VWM than remembering one feature each from two objects and 2) the representational quality of multiple features of the same object tended to covary. Furthermore in Experiment 2, we replicated these results for two objects presented at the same location, thus demonstrating that the shared location is not enough to explain the object benefit. Taken together, our results provide a strong support for the integrated object account of VWM representations.

Acknowledgement: NSERC

43.445 **Eye Movements Are Required to Process Spatial Configurations in Visual Working Memory** J. David Timm[1](dtimm@psycho.uni-tuebingen.de), Frank Papenmeier[1]; [1]University of Tübingen

[Introduction] Previous research showed that object locations are not memorized independently but in relation to the global spatial configuration formed by the objects. It is possible to subset a global configuration into a task relevant partial one while encoding. With the present experiments, we investigated the flexibility of the memory representation underlying this spatial configuration effect. Thus, we studied the following research question: Is it possible that spatial configurations can be reorganized to a subset of objects by shifting attention to these objects only during encoding or also in visual working memory (VWM)? [Methods] Participants encoded the locations of six objects (first experiment) or twelve objects (second experiment) and performed a location change detection task for one object probed during retrieval. This object was displaced in half of the trials. We cued the side (left/right) of the object probed either during encoding or afterwards (retro-cue), thus allowing for the reorganization of spatial configurations either during encoding or in VWM. During retrieval, either a complete (all objects), a congruent (cued objects), an incongruent (non-cued objects) or no (probed object only) configuration was shown. In a third experiment, we manipulated eye movements and presented a retro-cue only. One group had to fixate the center of screen during a trial while the other group could move their eyes. [Results] The successful reorganization of spatial configurations was indicated by a higher change detection performance for both the complete and the congruent configuration condition as compared with the no configuration condition. We observed a reliable reorganization both when cued during encoding and also under some retro-cue conditions. Importantly, configuration effects disappeared with enforced fixation. [Conclusion] Our findings provide evidence for the reorganization of spatial configurations and indicate the requirement of eye movements for processing spatial configurations in VWM, which is contradictory to previous snapshot hypotheses.

Acknowledgement: Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – Project number 357136437

43.446 **Systematic biases in the representation of visual space** Sami R Yousif[1](sami.yousif@yale.edu), Yi-Chia Chen[2], Brian Scholl[1]; [1]Department of Psychology, Yale University, [2]Department of Psychology, Harvard University

The ability to accurately perceive, represent, and remember spatial information is one of the most foundational abilities of all mobile organisms.Yet in the present work we find that even the simplest possible spatial tasks reveal surprising systematic deviations from the ground truth — such as biases wherein objects are perceived and remembered as being nearer to the centers of their surrounding quadrants.We employed both a relative-location placement task (in which observers see two differently sized shapes, one of which has a dot in it, and then must place a second dot in the other shape so that their relative locations are equated) and a matching task (in which observers see two dots, each inside a separate shape, and must simply report whether their relative locations are matched).Some of the resulting biases were shape-specific.For example, when dots appeared in a triangle during the placement task, the dots placed by observers were biased away from the axes that join the midpoints of each side to the triangle's center.But many of the systematic biases were not shape-specific, and seemed instead to reflect differences in the grain of resolution for different regions of space itself.For example, with both a circle and a shapeless configuration (with only a central landmark) in the matching task, the data revealed an unexpected dissociation in the acuity for angle vs. distance: in oblique sectors, observers were better at discriminating radial differences (i.e. when a dot moved inward or outward); but in cardinal sectors, observers were better at discriminating angular differences (i.e. when a dot moved around the circle).These data provide new insights about the format of visuospatial representations: the locations of objects may be represented in terms of polar rather than cartesian coordinates.

Acknowledgement: SRY was supported by an NSF graduate research fellowship. BJS was supported by ONR MURI #N00014-16-1-2007.

43.447 **Visual statistical regularities aid visual working memory of objects in a task-dependent manner** Gregory L Wade[1](gwade@psych.udel.edu), Timothy J Vickery[1]; [1]University of Delaware

People adeptly learn both spatial and visual statistical contingencies (visual statistical learning, or VSL). VSL supports explicit recognition judgments, and enhances performance in various contexts. For example, Brady, Konkle, and Alvarez (2009) demonstrated that spatial statistical contingencies between color features of memory items supports greater visual working memory (VWM) capacity (k), suggesting that VSL supports memory compression. In the present study, we first asked whether these findings generalize from simple features to complex shape characters. Secondly, we asked whether pre-exposure to temporal contingencies would support such compression. In the first experiment, subjects completed a VWM task in which they viewed 8 objects, maintained these in memory, and then were probed to identify the shape that had been presented at a cued location (8-alternative forced choice). In half of trials, 8 objects always appeared in paired configurations (e.g., shape A always appeared next to shape B), while in the other half, 8 different objects appeared in randomized configurations. Consistent with Brady, Konkle, and Alvarez (2009), participants learned paired configurations over time, resulting in a higher capacity for paired vs. randomized configurations ($p < .001$). In our second experiment, prior to performing the memory task, participants were given a VSL familiarization task where one set of objects co-occurred in pairs temporally within the image stream, and the other set was randomized. In the memory task both sets of images were presented in consistent pairs. If VSL supports VWM compression, we expected that scenes composed of previously paired shapes would support higher VWM capacity. However, no difference was observed, suggesting that VSL supports VWM compression, but may be task-dependent. Future studies will examine whether this finding was due to failure to generalize across tasks, and/or failure to generalize from a temporal to a spatial contingency.

Acknowledgement: NSF OIA 1632849 and NSF BCS 1558535

Visual Memory: Neural mechanisms 1

Monday, May 20, 8:30 am - 12:30 pm, Pavilion

43.448 **Synthesizing images with deep neural networks to manipulate representational similarity and induce representational change** Jeffrey D Wammes[1](j.wammes@yale.edu), Kenneth A Norman[2,3], Nicholas B Turk-Browne[1]; [1]Department of Psychology, Yale University, [2]Department of Psychology, Princeton University, [3]Princeton Neuroscience Institute, Princeton University

Humans have a seemingly limitless capacity for learning, despite having finite neural real estate. Consequently, different pieces of information must be represented in overlapping neural populations. Prior work has shown that statistical learning can affect this overlap, both increasing (i.e., integration) and decreasing (i.e., differentiation) representational overlap in hippocampus (Schapiro et al., 2012). Whether representations integrate or differentiate may depend on their initial degree of overlap, with high overlap leading

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to integration and moderate overlap leading to differentiation. Here we report an approach for controlling neural overlap in specific visual regions, in order to manipulate whether statistical learning causes integration or differentiation. Pairs of images were synthesized using a convolutional neural network (CNN), pre-trained for object recognition. Each pair was generated to achieve a specified similarity level, operationalized as the correlation between unit activities in later model layers coding for higher-order visual features. To validate the approach, human participants sorted images according to visual similarity. Model-defined visual similarity was correlated with the resulting pairwise distances. We then chose eight pairs of images, varying parametrically in model similarity, and embedded the pairs in a statistical learning paradigm during fMRI. Before and after learning, we extracted patterns of voxel activity for each of the 16 images. A searchlight analysis revealed clusters in lateral occipital cortex and parahippocampal gyrus where neural pattern similarity tracked our predefined model similarity parametrically, indicating that we were able to control neural overlap with model-based image synthesis. Following learning, we found that hippocampal representations of moderately similar image pairs differentiated from one another, whereas highly similar image pairs integrated with one another. We are now conducting follow-up studies using fMRI to test the efficacy of model-based image synthesis at various levels of the visual processing hierarchy and behavioral experiments to test consequences for perception and memory.

Acknowledgement: This work was supported by NIH R01 MH069456 and an NSERC postdoctoral fellowship (JDW).

43.449 **Multifaceted integration – memory for faces is subserved by widespread connections between visual, memory and social processing networks** Michal Ramot[1](michal.ramot@nih.gov), Catherine Walsh[1], Alex Martin[1]; [1]National Institute of Mental Health, National Institutes of Health

Face memory abilities are at the core of human social interaction, yet there is great degree of variance in the population in face memory capabilities, ranging from congenital prosopagnosia at one end, to "super-recognizers" on the other. Face processing is among the most studied subjects in cognitive neuroscience, but this effort has mostly focused on the well-described ventral visual face regions and on their relation to face perception. In the context of face memory, we found that although the nodes of the face system are tightly coupled at rest, the strength of these correlations was not predictive of performance on a face memory task (measured by the Cambridge Face Memory Test, CFMT). Given these results, the nature of the face memory task, and the social context in which it takes place, we were interested in exploring how the collaboration between different networks outside the face network (measured through resting state connectivity) might better predict performance on the CFMT. Our data revealed that face recognition memory was dependent on multiple connections between the face patches and regions of the medial temporal lobe memory system (including the hippocampus), and the social processing system. Moreover, this network was selective for memory for faces, and did not predict memory for other visual objects, such as cars. These findings suggest that in the general population, variability in face memory is dependent on how well the face processing system interacts with other processing networks, with interaction among the face patches themselves accounting for little of the variance in performance.

43.450 **Deep learning fMRI classification of temporal codes during naturalistic movie viewing and memory recall** Matthew R Johnson[1](matthew.r.johnson@unl.edu), Thomas P O'Connell[2], Marvin M Chun[2], Marcia K Johnson[2]; [1]Department of Psychology, University of Nebraska-Lincoln, [2]Department of Psychology, Yale University

In this fMRI study, participants watched the same short video several times in separate scan runs. We used a novel cognitive task design that afforded direct, time-locked comparisons between perception and imagery-based memory recall for the same information, in contrast to other studies of audiovisual episodic memory recall in which the memory probe took place after the movie, and at a different pace. In some runs of our paradigm, participants saw and heard the full movie (audio + video, A+V); in other runs, they saw only the video and were instructed to imagine the audio from memory (0+V); and in still other runs, they heard only the audio and were instructed to imagine the video from memory (A+0). Using the DeLINEATE toolbox (http://delineate.it), we trained subject-specific deep-learning models based on a sensory cortex (visual + auditory) region of interest to discriminate whether two fMRI volumes from different runs represented the same point in time, or two different points in time. The model performed easily above chance at this task. Although classification was, as expected, best when comparing one full-movie (A+V) run to another, and video-only runs (0+V) tended to classify better than audio-only (A+0) runs, performance was high between all run-type pairs. Critically, this included comparisons between 0+V and A+0 runs, which shared no common sensory information. In fact, classification was higher on data drawn from one 0+V and one A+0 run than on data drawn from two different A+0 runs. We believe this technique provides a powerful new way to assess reinstatement of brain activity patterns in sensory regions during recall of complex, naturalistic information.

Acknowledgement: Supported by NSF/EPSCoR grant #1632849 to MRJ and colleagues

43.451 **Theory of neural coding predicts an upper bound on estimates of memory variability** Paul Bays[1](pmb20@cam.ac.uk), Robert Taylor[1]; [1]Department of Psychology, University of Cambridge

A popular method for interpreting responses in memory tasks is to statistically decompose errors into a mixture of remembered (normally distributed) and guessing (uniformly distributed) components. While intuitive, models based on such discrete memory states have typically provided a worse fit to data than those based on a continuum of representational fidelity. In particular, a model based on storing information in a noisy population of idealized neurons provides a more parsimonious account of working memory errors while also having some correspondence with neurophysiological principles. Here we consider how best to interpret results obtained from the mixture method if the population coding account is correct. We show that for an idealized homogeneous neural population, the width of the fitted normal distribution cannot exceed the average tuning width of the component neurons, and that this holds to a good approximation for more realistic populations also. Examining eight published studies of orientation recall, we find a consistent pattern of results suggestive of an upper limit of approximately 20 degrees, which compares well with electrophysiological estimates of orientation tuning in visual cortex. We discuss the implications for previous studies that have interpreted a plateau in width of the normal component as evidence for limits on the precision of perception, working memory and long-term memory.

Acknowledgement: Wellcome Trust, UK

43.452 **Contralateral delay activity indexes the number of items stored in working memory, not the current focus of spatial attention** Tobias Feldmann-Wüstefeld[1](tobias.fw@gmail.com), Edward K Vogel[2], Edward Awh[2]; [1]University of Southampton, [2]University of Chicago

Contralateral delay activity (CDA) scales with the number of items stored in working memory (WM) and predicts WM capacity. Thus, the predominant view has been that CDA activity indexes the number of items held in memory. Recently, however, Berggren and Eimer (2016) challenged this interpretation with a study in which colour memoranda were sequentially presented in opposite hemifields during a change detection task. They found that CDA activity was primarily determined by the contents of the second array rather than the total storage load across both displays, in line with the hypothesis that the CDA tracks the current focus of attention rather than storage per se. We note, however, that in the Berggren and Eimer study, probe stimuli were not presented in the same positions as the initial memoranda. Thus matching the probe array with the combined memoranda required a challenging spatial transformation of the two arrays.. Our hypothesis is that this lack of perceptual correspondence between sample and probe displays may have encouraged subjects to offload the active representation of array 1 (and retrieving it at the time of probing) rather than storing both arrays concurrently. In support of this hypothesis, we show that when spatially compatible sample and probe arrays are used, CDA activity represents the total storage load across both arrays, in line with the view that CDA activity indexes the number of individuated representations in visual WM. By contrast, when precisely the same memory displays were paired with a spatially incompatible probe display, we replicated the findings of Berggren and Eimer. Thus, our findings reinforce the view that CDA activity track the total contents of WM. Moreover, these findings offer insight into the factors that encourage transitions between online and offline memory states, a collaboration between memory systems that is essential for virtually all complex tasks.

43.453 **Recall of people and places reveals regions showing distinct effects of category and familiarity in high-level cortex** Adam Steel[1,2](adam.steel@nih.gov), Edward H Silson[1], Alexis Kidder[1], Adrian W Gilmore[1], Chris I Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, National Institutes of Health, [2]Wellcome Centre for Integrated Neuroimaging, FMRIB Centre, University of Oxford

Contrasting functional connectivity of anterior face-selective (FFA) and scene-selective (PPA) regions reveals interdigitated PPA- and FFA- preferring regions within medial parietal cortex (MPC) that exhibit corresponding face- and scene-selectivity in independent functional localizer data.Based on the overlap between these regions and activation typically elicited during memory recall, we hypothesized these regions would be selectively engaged during memory recall for people and places. We tested this prediction using task-based fMRI. During fMRI scanning, 24 participants completed a memory task in which they were cued by word stimuli to recall famous people (e.g. Tom Hanks), famous places (e.g. Eiffel Tower), personally familiar people (e.g. participants' mother) or personally familiar places (e.g. participants' home). Consistent with our hypothesis, the PPA- and FFA- preferring regions of medial parietal cortex were selectively responsive during recall of places or people and responded more strongly during familiar than famous conditions. In a whole-brain analysis examining effects of category and familiarity revealed a larger network of regions including additional areas in medial parietal cortex, amygdala, hippocampus, lateral parietal cortex, and prefrontal cortex. For example, hippocampus showed a strong familiarity effect but no category effect, while amygdala showed a category effect but not familiarity effect. Cortical regions demonstrating a familiarity effect showed a distinct posterior-anterior gradient in preferential activation during recall of personally familiar places to personally familiar people. Intriguingly, contrasting functional connectivity within subdivisions of prefrontal cortex revealed preferential connectivity with category-selective regions on both the lateral and ventral surfaces.Collectively, these data suggest that category-selectivity, a hallmark of VTC organization, is recapitulated in MPC for memory, and may reflect a global organizing principle in the brain-regions that support high-level cognitive functions.

Acknowledgement: AS, EHS, and CIB are funded by the NIMH internal research program (ZIA-MH002893)

43.454 **Examining the effects of memory compression with the contralateral delay activity** William X Ngiam[1,2](wngi5916@uni.sydney.edu.au), Edward Awh[2], Alex O Holcombe[1]; [1]School of Psychology, University of Sydney, [2]Department of Psychology, University of Chicago

While visual working memory (VWM) is limited in the amount of information that it can maintain, it has been found that observers can overcome the usual limit using associative learning. For example, Brady et al. (2009) found that observers showed improved recall of colors that were consistently paired together during the experiment. One interpretation of this finding is that statistical regularities enable subjects to store a larger number of individuated colors in VWM. Alternatively, it is also possible that performance in the VWM task was improved via the recruitment of LTM representations of well-learned color pairs. In the present work, we examine the impact of statistical regularities on contralateral delay activity (CDA) that past work has shown to index the number of individuated representations in VWM. Participants were given a bilateral color recall task with a set size of either two or four. Participants also completed blocks with a set size of four where they were informed that colors would be presented in pairs and shown which pairs would appear throughout, to encourage chunking of the pairs. We find this explicit encouragement of chunking improved memory recall but that the amplitude of the CDA was similar to the unpaired condition. Xie and Zhang (2017; 2018) previously found evidence that familiarity produces a faster rate of encoding as indexed by the CDA at an early time window, but no difference at a late time window. Using the same analyses on the present data, we instead find no differences in the early CDA, but differences in the late CDA. This result raises interesting questions about the interaction between the retrieval of LTM representations and what the CDA is indexing.

43.455 **Encoding of spatial working memory in virtual reality in the primate prefrontal cortex** Megan Roussy[1,2](mroussy2@uwo.ca), Rogelio Luna[1,2], Lena Palaniyappan[1,2], Julio C. Martinez-Trujillo[1,2]; [1]University of Western Ontario, [2]Robarts Research Institute

Spatial working memory (WM) allows us to briefly remember and manipulate spatial information. Traditionally, spatial WM is tested in non-human primates using an oculomotor delayed response (ODR) task that requires eye fixation away from the cue to be remembered. Using this task, a myriad of studies has shown that neurons in the primate lateral prefrontal cortex (LPFC) encode WM representations. One caveat of this highly controlled approach is that it departs from natural behavior – one would typically make eye movements when remembering locations. It currently remains unclear whether neurons in the LPFC encode spatial WM during natural behavior, that is, in the presence of distracting information and eye movements. To address this issue, we created a novel virtual reality (VR) spatial WM task which incorporates complex 3D stimuli and does not constrain eye movement. During a trial, a visual cue is presented to the animal in a circular arena in 1 of 9 locations for 3 seconds, it then disappears and the animal is required to remember its location during a 2 second delay period. Navigation in the environment is then enabled and animals navigate to the cued location using a joystick. We implanted two 10x10 Utah arrays in LPFC area 8A of 2 rhesus macaques (ventral and dorsal to the principal sulcus). Both animals correctly performed the task (average hit rate: MonkeyB=86%; MonkeyT=67%). Neurons were selective for target location during the delay period in both arrays (ventral=39%, N=1799; dorsal=47%, N=1725). We used a linear classifier with crossvalidation to decode remembered locations on a single trial basis from neural activity. Decoding was ~50% (chance=12%) and was not explained by neural activity influenced by target location specific patterns of eye movement. These findings show that LPFC neurons encode spatial WM during virtual reality tasks regardless of distracter information and eye movements.

Acknowledgement: CIHR NSERC

43.456 **The contralateral delay activity tracks the storage of sequentially presented colors and letters** Sisi Wang[1,2](wangsisi2017@gmail.com), Jason Rajsic[1], Geoffrey F. Woodman[1]; [1]Department of Psychology, Vanderbilt University, [2]School of Psychology and Cognitive Science, East China Normal University

The contralateral delay activity (CDA) is an event-related potential that is generally believed to be a neural index of visual working memory (VWM) storage, based on consistent electrophysiological findings that its amplitude during visual information retention period tracks the number of items stored in working memory. Despite the consistent and robust CDA findings for stimuli presented simultaneously in a visual array, there are still controversies about whether the amplitude of CDA reflects the storage of the summed number of sequentially presented stimuli, or attention to the most recently presented items. In the present experiment, event-related potentials were recorded while participants completed a lateralized visual change-detection task where each object was presented sequentially. Participants were shown bilateral pairs of one, three, or six sequentially presented colored squares or letters, such that they need to encode a single item in the attended hemifield with each stimulus onset. They then decided whether or not one of the objects in a test array were different from the stream of objects they had just seen. Behavioral accuracy of change detection decreased with increasing set size for colored squares and letters. The amplitude of CDA increased with the number of items stored in VWM for both colored squares and letters. These results suggest that the amplitude of CDA reflects the summed storage of sequentially presented stimuli and not only the most recently attended colored object or letter.

Acknowledgement: National Eye Institute (R01-EY019882, R01-EY025275, P30-EY08126, and T32-EY007135)

43.457 **Prioritization affects working memory precision and neural population gain** Aspen H Yoo[1, 2](aspen.yoo@nyu.edu), Alfredo Bolaños[1,2], Grace E Hallenbeck[1,2], Masih Rahmati[1,2], Thomas C Sprague[1,2], Clayton E Curtis[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Humans allocate visual working memory (VWM) resource according to behavioral relevance, resulting in more precise memories for more important items (Bays & Husain, 2008; Emrich et al., 2017; Klyszejko et al., 2014; Yoo et al., 2018). Theoretically, items may be maintained by feature-tuned neural populations, where the relative gain of the populations encoding each item represents precision (Bays, 2014; Ma et al, 2006). To test this hypothesis, we compared the amplitudes of neural activity in the different parts of retinotopic maps representing each of several VWM items. We predicted that the magnitude of delay period activity in areas topographically associated with different items would monotonically track the priority of those items. We scanned participants with fMRI while they performed a visuospatial WM task. Participants remembered the location of four items, one presented in each visual field quadrant, then generated a memory-guided saccade to a probed item after a 10 second delay. Before the four items appeared on each trial, a cue indicated the probability with which each item would be probed for response (0.6, 0.3, 0.1, 0.0). We measured fMRI activity in topographically

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organized dorsal stream areas known to be important for VWM. In a separate session, we defined visual field maps in occipital, parietal, and frontal cortex using a modified population receptive field mapping technique (Mackey, Winawer, & Curtis, 2017). Behaviorally, we found that the precision of VWM scaled monotonically with the priority of the item, replicating our previous work. Neurally, the amplitude of BOLD activation within voxels corresponding to the retinotopic location of VWM items scaled monotonically with the priority of the item. These results suggest that the distribution of WM resource according to priority sculpts the relative gains of neural populations that encode items with varying precision.

43.458 **Top-down control of spatial memory visualization in early visual cortex** Lora T Likova[1](lora@ski.org), Spero Nicolas[1], Christopher W Tyler[1], Kris Mineff[1]; [1]Smith-Kettlewell Eye Research Institute

Introduction. To analyze mechanisms of visual working memory and learning, we compared the brain networks involved in the processes of direct visual study, and (open-eyes) visualization from immediate memory, using previously unfamiliar material in a novel procedure to enhance memory representations. Methods. Functional MRI was run while complex spatial structures in the form of line-drawings were alternately i) visually explored to be learned, and ii) mentally visualized on a blank screen in a repeated sequence to maximize the accuracy of the memory trace. The viewing and visualization blocks were 30 s each, separated by 20 s rest periods, and repeated 3 times in each trial. The brain imaging session was followed by testing for comprehension and by direct readout of the memory trace through memory-guided drawing of the learned images. Results & Conclusions. The first response site of particular interest was the primary visual cortex (V1), which our previous studies in the blind have implicated as the neural implementation - in a supramodal form – of the 'spatial sketchpad' for working memory (Likova, 2012, 2013). V1 was subdivided into foveal, parafoveal, mid- and far-peripheral regions. Remarkably, direct viewing and memory visualization equally activated the mid- and far-periphery regions, whereas in the parafoveal representation the visualization signal dropped to about half of that for direct viewing, and even rapidly inverted into strong suppression throughout the extrastriate foveal confluence. Conversely, the classical visual hierarchy beyond V1 was not involved. Granger causal connectivity analysis was used to disentangle the interregional interactions within the activated networks and to provide deeper insights into cortical mechanisms of visualization from memory and its involvement in learning, including top-down causal influences to the V1-subdivisions and foveal confluence from hippocampal, parietal and frontal regions.

Acknowledgement: NSF/SL-CN & NIH/NEI ROI to LTL

43.459 **Neural networks supporting input gating and output gating in visual working memory** Emily J Levin[1](ejlevin3@gmail.com), David Badre[1]; [1]Cognitive, Linguistic, & Psychological Sciences, Brown University

Visual working memory is a capacity-limited system that requires processes to choose what information enters memory and to select what information guides a response. These processes are referred to as working memory gating mechanisms. Input gating regulates what information is allowed into working memory, and output gating regulates what information is used to guide behavior. Our previous work investigated which brain regions are recruited for input compared to output gating, finding that both processes recruit a frontostriatal network. (Chatham et al., 2014). However, this gating task did not require subjects to maintain a high-fidelity visual code. The purpose of the current study was to adapt this gating paradigm to include visual features, allowing us to test whether the same areas are recruited when subjects are required to maintain a visual code in working memory. We adapted the original task into a delayed estimation task, requiring subjects to remember one or two Gabor patches that they responded to by turning an orientation wheel. Additionally, subjects were presented with a higher-order context-cue that indicated which of the Gabor patches was relevant. This context-cue could either come first, putting task demands on input gating, or last, putting task demands on output gating. Subjects performed this modified gating task in the fMRI scanner across multiple sessions. We collected population receptive field mapping data from these subjects in order to identify regions of interest. We found that input gating conditions, where the context-cue was presented ahead of the items, and output gating conditions, where the context-cue was presented after the items, both activated a common set of frontoparietal areas, including anterior premotor cortex and inferior frontal sulcus. These results suggest that working memory gating engages a similar network of frontoparietal regions, regardless of whether the remembered stimuli require a visual or non-visual code.

43.460 **Manipulating attentional priority creates a trade-off between memory and sensory representations in human visual cortex** Rosanne L Rademaker[1,2](rosanne.rademaker@gmail.com), John T Serences[1,3,4]; [1]Psychology Department, University of California San Diego, La Jolla, California, USA, [2]Donders Institute for Brain, Cognition and Behavior, Radboud University, Nijmegen, the Netherlands, [3]3Neurosciences Graduate Program, University of California San Diego, La Jolla, California, USA, [4]Kavli Institute for Brain and Mind, University of California, San Diego, La Jolla, CA 92093

People often remember visual information over brief delays while actively engaging with ongoing inputs from the surrounding visual environment. Depending on the situation, one might prioritize mnemonic contents (i.e. remembering details of a past event), or preferentially attend sensory inputs (i.e. watching traffic while crossing a street). Previous fMRI work has shown that early sensory regions can simultaneously represent both mnemonic and passively viewed sensory information. Here we test the limits of such simultaneity by manipulating attention towards sensory distractors during working memory. Participants (N=6) remembered the orientation of a briefly presented (500ms) target grating while a distractor grating (11s) was shown during the middle portion of a 15s delay. Subjects reported the target by rotating a dial (3s). Target and distractor orientations were selected randomly and independent of one another. Critically, the distractor grating was continuously contrast-reversing at 4Hz, and on every trial, there were 2–4 brief (250ms) and subtle changes in its contrast (decrease or increase) and its orientation (counter-clockwise or clockwise). In three randomly interleaved conditions, participants were cued to either ignore the distractor, detect distractor-contrast changes, or detect distractor-orientation changes. Behavioral performance on the distractor-contrast and distractor-orientation tasks was equated via a staircase. Despite sensory stimulation being matched in all three conditions, memory representations differed strongly throughout the visual hierarchy: Fidelity was highest when the distractor was ignored, intermediate when participants attended distractor-contrast, and virtually absent when participants attended distractor-orientation during the delay. This is juxtaposed with representations of the sensed distractor during the delay: Fidelity was highest when attending distractor-orientation, intermediate when attending distractor-contrast, and lowest when ignoring the distractor (even absent in parietal regions). These data imply that any trade-offs between memory and sensory representations are due to changes in attentional priority as opposed to just the presence or absence of concurrent input.

Acknowledgement: Marie Sklodowska-Curie Grant Agreement No 743941 to RLR

43.461 **The spatiotemporal profile of diffusion MRI based measures of microstructural changes in white matter evoked by learning novel visual scenes** Cibu P Thomas[1](cibu.thomas@nih.gov), Mitchell Moyer[1], Brian Coleman[1], Philip Browning[1], Frank Ye[1], David Yu[1], Alexander Avram[2], Chris I Baker[1], Elisabeth A Murray[1]; [1]National Institute of Mental Health, [2]National Institute of Biomedical Imaging and Bioengineering

The ability to learn throughout our lifetime is known to be mediated by structural changes in the brain. However, the spatiotemporal dynamics of such changes during learning are unclear. Here, we trained 10 naïve, adult rhesus monkeys (Macaca mulatta) in two tasks sequentially. The monkeys were first trained to criterion (90%) in the "one-place" task, a visuomotor task which required the monkey to reach and touch an object on a computer screen.Next, the monkeys were trained to touch a target foreground object placed in an artificial visual "scene" composed of multiple geometric elements. The monkeys learned several unique scenes concurrently; the identity and location of the target object differed across scenes, but was fixed within scenes. We acquired multishell advanced Diffusion MRI (dMRI) images from the monkeys across two timepoints (before training and after reaching criterion in one or both tasks) using a Bruker 4.7T MRI system. Behaviorally, the monkeys showed wide individual variability in their ability to learn the different tasks. Whole brain analyses of white matter revealed significant changes in measures of water diffusivity (Radial (RD), Axial (AD), Parenchymal (PD)) but not measures of anisotropy (Fractional, Linear, Planar), between the timepoints. Interestingly, the decrease in PD, a measure of tissue density without freewater contamination, was correlated with faster learning of the visual scenes task. Analysis comparing monkeys that mastered the scenes task and those that did not, indicated a focal change in RD along the crus of the fornix. Further examination revealed that a decrease in diffusivity measures in the crus, possibly due to an increase in restricted/

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hindered water diffusion, tends to be correlated with faster scene learning. Overall, the pattern of changes in the dMRI measures suggest that prolonged learning of complex visual scenes evokes global as well as local changes in white matter microstructure.

43.462 **Reference Frames for Spatial Working Memory in the Lateral Prefrontal Cortex of primates** Rogelio Luna[1](rluna@uwo.ca), Megan Roussy[1], Stefan Treue[2], Julio C. Martinez-Trujillo[1]; [1]Department of Physiology and Pharmacology, Western University, [2]Department of Cognitive Neurosciences, German Primate Center

Studies in the macaque Lateral Prefrontal Cortex (LPFC) have shown that single neurons encoded spatial working memory (WM) signals. The majority of these studies have used oculomotor delay response (ODR) tasks that do not dissociate remembered locations in different frames of reference (e.g., retina-centered vs space-centered). Here we used a variation of the ODR task that allowed us to dissociate these two frames of reference, while recording the activity of neurons in the LPFC with two microelectrode arrays (10x10 Utah arrays) implanted dorsally (dLPFC) and ventrally (vLPFC) from the principal sulcus (areas 8A and 9/46), respectively. During task trials, animals fixated a dot that appeared at one of 16 different positions on the screen, then a target transiently appeared for 1000ms. The animal was required to maintain fixation for another 1000ms and upon extinction of the fixation point to make a saccade to the remembered target location to obtain a reward. The systematic variations in the initial fixation position allowed us to analyze the data for remembered locations relative to the fixation point (retinal frame), and relative to the screen (screen or space-centered frame). We found that 20% of all recorded dLPFC neurons and 12% of the vLPFC neurons were tuned for the remembered location in a retinotopic frame. Notably, 15% of dLPFC neurons as well as 9% of vLPFC neurons were tuned for the remembered location in a spatiotopic frame of reference. Our results show that the LPFC encodes working memory in both retinotopic and spatiotopic reference frames, with a bias for the former. Moreover, they show that dLPFC contains a larger proportion of neurons tuned for both retinotopic and spatiotopic frames than the vLPFC.

Acknowledgement: Canadian Institutes of Health Research, National Science and Research Council of Canada, German Primate Center

43.463 **Accurate Classification in Frontoparietal Network for Visually Identical Tasks at Varying Levels of Relational Abstraction** Kevin C Hartstein[1](kevin.c.hartstein.gr@dartmouth.edu), David M Kraemer[1], Peter U Tse[1]; [1]Psychological & Brain Sciences, Dartmouth College

The Prefrontal Cortex (PFC) is thought to be hierarchically organized and to perform executive control functions such as planning and goal-directed behavior. Past experiments have found that representations that are abstract in temporal span (Desrochers et al., 2016) or degree of relation (Badre and D'Esposito, 2007) are processed in anterior regions of the PFC, which influence more posterior regions in order to implement proximal aspects of goal-oriented behavior, such as motor acts. Several researchers have even reported accurate classification of task set (Bode and Dylan-Haynes, 2009) or working memory content (Zhang et al., 2013) in various regions of PFC and also in parietal areas involved in the frontoparietal network. Notably, many of these tasks used visual stimuli that were at least partially confounded with the high-level representation that served as the target of classification. In the current experiment, participants performed a task that involved comparing visual stimuli at three levels of relational abstraction. Critically, the stimuli were the same across all three tasks. Each trial consisted of 4 configurations of stimuli that varied on 4 dimensions (number, shape, orientation, and luminance). Two comparison criteria for the stimuli ("is there exactly one match/mismatch") were tested at each level of abstraction. After training to criterion on all levels of the task, participants performed the task during an MRI session. Whole-brain searchlight classification was performed to determine which areas contained task information encoding the difference in comparison criteria at each level of relational abstraction. Accurate classification was observed in frontoparietal areas for all levels, but most strongly for the most abstract level. While evidence for hierarchical organization of PFC was not observed in our experiment, our results replicate the finding that frontoparietal areas are critical for executive control, even when the stimuli are identical across tasks.

43.464 **The benefits of combined brain stimulation and cognitive training: a pilot study in the elderly** Sara Assecondi[1,2](s.assecondi@bham.ac.uk), Rong Hu[1,2,3], Gail Eskes[4], Jakob Kreoker[4], Kim Shapiro[1,2]; [1]School of Psychology, University of Birmingham, UK, [2]Centre for Human Brain Health (CHBH), University of Birmingham, UK, [3]Guangzhou First People's Hospital, the Second Affiliated Hospital of South China University of Technology, China, [4]Dalhousie University, Halifax, Nova Scotia, Canada

Average life expectancy has increased during the last century, resulting in an increasingly aging population. It is therefore of paramount importance to develop new strategies to address age-related cognitive decline. Recent advances in safe, non-invasive direct current stimulation (tDCS) combined with cognitive training show tremendous promise as means of slowing cognitive decline in the ageing population. In this pilot study we address the benefit of combined tDCS and cognitive training on working memory. Seven older participants receiving working memory training were randomly assigned to two groups: an active (rtDCS) group or a control (SHAM) group. Individuals included in the active group received 20 min of tDCS on the right dorsolateral prefrontal cortex while completing the cognitive training, whereas participants in the control group completed the cognitive training alone. The training task consisted of an adaptive spatial N-back task. Each participant completed 5 sessions of training, and pre- and post-training assessment sessions, to measure transfer of training to other cognitive domains. Our pilot data suggest that the concurrent use of cognitive training and tCS has a beneficial effect on the rate at which participants improve performance during the training. This agrees with recently published animal data. The data further suggest evidence of transfer to a non-spatial visual task, an important hallmark of successful training. Notwithstanding the limited sample size, we believe that our approach represents a viable path to reveal the potential of combined brain stimulation and cognitive training to improve cognitive performance in both normally and abnormally ageing adults.

Acknowledgement: This research is supported by an MRC Proximity to Discovery grant (DHAE RRAK 19115) awarded to S.A. and K.S. and by Guangzhou Planned Project of Science and Technology (2016201604030018) awarded to R.H. and K.S.

Temporal Processing: Timing

Monday, May 20, 8:30 am - 12:30 pm, Pavilion

43.465 **Temporal consequences of spatial acuity reduction** Pawan Sinha[1](psinha@mit.edu), Sidney P Diamond[1], Frank Thorn[1], Sharon Gilad-Gutnick[1], Shlomit Ben-Ami[1], Sruti Raja[1]; [1]Brain and Cognitive Sciences, MIT

The genesis of this work lies in the subjective experience of some of us with strong myopia. Unsurprisingly, without our glasses the world looks blurry. Less intuitively, though, the dynamics also seem to undergo a change; the world appears to move more 'smoothly.' Thus, a purely spatial optical transformation seemingly has temporal consequences. To formally test this anecdotal observation, we ask how convolution with a spatial Gaussian of individual images in a video-stack impacts the stack's temporal structure. Our approach involves computing spatial and temporal Fourier spectra of several short natural videos in their original form, as well as after subjecting them to multiple levels of spatial Gaussian blur. The spatial spectrum corresponds to the mean radial-average of the 2DFFT of all images in the stack. The temporal spectrum corresponds to the mean of the 1DFFT of several single pixel cores extending through the entire depth of the stack. Comparing the spatial and temporal spectra reveals a very consistent result: For every natural video tested, spatial blurring leads to a progressive reduction in power in high spatial-, as well as in high temporal-frequencies. This straightforward and unequivocal result has several interesting implications. First, it suggests that uncorrected refractive errors lead not only to the visual system being deprived of high spatial frequency content, but also high temporal frequencies. Such deprivation would lead to deficits in high-frequency spatial as well as temporal visual processing. Indeed, the few studies that have investigated temporal aspects of amblyopia have found precisely this result. Second, it provides an explanatory account for why severe spatial degradation leads to the development of nystagmus; the uncontrolled eye-movements may serve to endogenously enhance temporal stimulation. Finally, it makes the surprising prediction that exposure to rapid temporal flicker may enhance spatial acuity. Recent reports corroborate this prediction.

Acknowledgement: NEI R01 EY020517

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43.466 **Feeling the beat (and seeing it, too)** Robert Sekuler[1](vision@brandeis.edu), Mercedes B Villalonga[1], Rachel F Sussman[1]; [1]The Volen Center for Complex Systems, Brandeis University

Perceptual decision-making was studied with stimulus sequences of visual, vibrotactile, and concurrent visual-vibrotactile pulses.Subjects categorized the beat frequency of both stochastic and deterministic stimuli. Weevaluated the rate at which perceptual information accumulated over successive samples, and the robustness of signals from different modalities. METHODS. A handheld computer tablet delivered 30 msec visual orvibrotactile unimodal pulses, or both together in synch (bimodal).Visual stimuli were Gabor patches that turned on and off; vibrotactile stimuli were intermittent vibrations generated within the tablet and delivered to subjects' hands.Two beat rates, 3 and 6 Hz, were randomly intermixed; subjects had up to 1.6 seconds to sample and categorize stimulus rate. On 2/3 of trials, beat rates were stochastic: intervals between pulses were perturbed by samples from zero-mean Gaussian distributions with different variances. The random variation in beat rate was designed to influence the confusability of the two nominal rates. RESULTS. As the temporal randomness of beats increased, accuracy fell and judgment time lengthened. These changes were similar across modalities.Subjects behaved impulsively, rarely using all available information. Logistic regression showed that subjects' judgments were disproportionately influenced by the first one or two beats they experienced. With stochastic stimuli, subjects seemed to adjust their decision criteria in real time. Additionally, judgment times for bimodal stimuli suggested more rapid accumulation of information, a result confirmed by drift diffusion analysis. CONCLUSIONS. The robustness of temporal information conveyed by visual pulses is on par with that conveyed by vibrotactile pulses. The speeded responses produced by bimodal stimulation are consistent with theories in which timing information is processed by transmodal neural mechanisms. Finally, our results suggest that multimodal stimulation may have particular value for directing time-sensitive tasks.

43.467 **Depth from Motion Alters Radial & Rotational Motion-Defined Temporal Order Judgments** Nestor Matthews[1](matthewsn@denison.edu), Leslie Welch[2], Elena Festa[2], Anthony Bruno[1]; [1]Department of Psychology, Denison University, [2]Cognitive, Linguistic & Psychological Sciences, Brown University

Introduction: This study addressed a recently discovered dissociation between temporal order judgments (TOJs) of radial and rotational motion stimuli (Matthews, Welch & Festa, 2018). Specifically, radial TOJ thresholds exhibited 3-fold differences depending on whether stimuli initially radiated in the same versus opposite directions. By contrast, rotational TOJ thresholds exhibited no dependence on same versus opposite initial rotational directions. To understand this non-intuitive dissociation, we psychophysically tested diverging predictions from two hypotheses. (1) The Attentional Prior Entry (APE) hypothesis posits faster neural relays for radially looming stimuli than for radially receding stimuli because looming objects are potentially more threatening (Franconeri & Simons, 2003). APE predicts TOJ psychometric-function biases (PSE shifts) and reaction time advantages skewed toward initially looming stimuli. (2) The Depth Uncertainty (DU) hypothesis posits that our previous data showing poor performance for the opposite-radial condition was due to trial-by-trial uncertainty about the number of depth planes to monitor. Rotational and same-radial conditions depicted two plaids at the same depth while opposite-radial condition depicted two plaids moving apart in depth. DU predicts a reduction in opposite-radial TOJ thresholds after reducing depth-from-motion uncertainty by constraining all trials within a block to the opposite-radial condition. Method: We bilaterally presented plaids that either radiated or rotated before changing direction. College students reported whether the direction changed first on the left or right. In Exp 1 (n=26), one stimulus initially loomed while the other initially receded. In Exp 2 (n=22), one stimulus initially loomed then receded, the other stimulus rotated. In Exp 3 (n=28), one stimulus initially receded then loomed, the other stimulus rotated. Results & Conclusion. In total, across the three experiments 76 participants completed 21,280 TOJ trials for analysis. The data disconfirmed the APE predictions while supporting the DU predictions. Depth from motion can generate dissociations between radially and rotationally defined TOJs.

43.468 **The temporal profile of visual encoding in the recognition of familiar objects** Roxanne Ferrandez[1](Roxanne.Ferrandez@gmail.com), Martin Arguin[1]; [1]Centre de recherche en neuropsychologie et cognition, Département de psychologie, Université de Montréal

Processing effectiveness trough time in visual object recognition was investigated using random temporal stimulus sampling. Twelve young adults named photographs of familiar objects from the Bank of Standardized Stimuli. Stimuli were made by a linear combination of the target image and high density white visual noise. Signal-to-noise ratio varied throughout the 200 ms stimulus duration. A new temporal sampling function was generated on each trial by the integration of random amplitude and phase sinusoidal waves of frequency between 5 and 60 Hz. Individual temporal classification images were calculated by subtracting the weighted sum of the signal/noise ratio associated to errors from that associated to correct responses. Time-frequency classification images were obtained by applying the same procedure on the outcome of time-frequency analyses applied to the sampling functions of each trial. The mean temporal classification image indicates that processing effectiveness is lowest at target onset, then rises to a peak at 79-88 ms to then gradually decline to about its initial level until 200 ms. This temporal pattern was highly variable across participants. The highest effectiveness peak revealed by the mean time-frequency classification image occurred in the 0-67 ms time window for 25-35 Hz stimulus oscillations. The amplitude of this peak slowly declined from 67 to 167 ms while gradually shifting towards lower frequencies down to 10-15 Hz. Stimulus oscillation frequencies around 35-55 Hz in the 67-167 ms range were associated with the lowest processing effectiveness. However, a subset of these frequencies (40-50 Hz) led to high effectiveness between 133-200 ms. This time-frequency pattern was remarkably similar across participants, with a mean between-subjects correlation of .93. The present results indicate rapid variations of visual encoding effectiveness in the initial 200 ms of stimulus exposure and suggests that the time-frequency classification images tap a highly fundamental aspect of visual processing.

Acknowledgement: Centre de recherche en science naturelle et en génie du Canada

43.469 **Detecting time distortion in emotional context induced by visual stimuli: a new Subjective Time Adjustment paradigm** Tiziano A Agostini[1](agostini@units.it), Giulio Baldassi[1], Mauro Murgia[1]; [1]Department of Life Sciences, Psychology Unit "Gaetano Kanizsa", University of Trieste, Italy

Introduction. According to recent studies, cognition and emotions are strictly connected to timing behaviour and time perception, even though the underling psychological mechanisms are not completely understood. Only recently the topic of time distortions in emotional contexts has attracted the attention of researchers, who typically used the classical methods of time perception. In particular, the most employed paradigms consisted of Temporal Bisection Task (comparing temporal stimuli to two reference stimuli, "long" and "short") and Time Production. Here, for the first time, we propose a new paradigm based on the adjustment method, called Subjective Time Adjustment (STA), to evaluate time distortions in emotional contexts induced by visual stimuli. Methods. Thirty university students participated in this experiment and were divided in two groups (low vs. high arousal movies). All participants were tested individually in a quiet room. They were required to sit down and relax for about 10 minutes before starting the experiment. Then they were asked to adjust a flashing light in order to make its frequency equal to 60 flashes per minute: this measure was considered as individual baseline. After the baseline, participants were exposed to a five-minutes movie promoting either a low or a high arousal, depending on the assigned condition. After the movie, all participants were re-tested using the same method as the baseline. Results. The results showed that the adjustments made before and after the movie remained constant in the low arousal condition, but increased significantly in the high arousal condition. Conclusion. Our study shows that, similarly to previous studies, our STA paradigm can detect distortions in time perception due to the exposition to emotional movies.

43.470 **Both Low and High Contrast Flicker Fusion Sensitivity Differentiate Dyslexic and Typically Developing Children** Jessica L Peters[1](j.peters@latrobe.edu.au), Alyse Brown[1], Edith L Bavin[1,2], Sheila Crewther[1]; [1]Department of Psychology and Counselling, La Trobe University, [2]Murdoch Childrens Research Institute

Evidence over the last 30 years indicates that individuals with dyslexia may demonstrate reduced magnocellular-dorsal stream efficiency in regard to high temporal frequency and low contrast as compared to typically developing individuals. Although this area of research remains controversial, it could substantially alter the way that dyslexia is understood, diagnosed and treated. Hence, we aimed to investigate magnocellular processing sensitivity in dyslexic (n =40) and typically developing (n =40) children aged 7;06 - 12;11 years. Participants were individually matched on age (with 1 year) and nonverbal intelligence (Ravens Coloured Progressive Matrices; within 0.67 SD). Participant's processing thresholds were assessed using a four-option forced-choice flicker fusion task at 5% and 75% contrast. The high motion and low contrast components of the flicker fusion task are

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known to maximally activate magnocells, while higher levels of contrast increase parvocellular activity. Participants' phonological awareness (elision task) and text reading skills (York Analysis of Reading Comprehension) were also assessed. Results demonstrate that children with dyslexia show lower flicker sensitivity at both 5% and 75% contrast, and as expected, performed significantly worse on tests of text reading and phonological awareness as compared to typically developing children. Within group correlational analyses indicated that flicker fusion sensitivity at 5% contrast significantly and positively correlated with better reading comprehension in dyslexic children, while higher flicker fusion sensitivity at 75% contrast correlated with better nonverbal intelligence and phonological awareness in typically developing children. These findings suggest that primary school aged children with dyslexia show temporal processing impairments and low contrast deficits indicative of an attentional system that is slower to activate. Findings also suggest that contrast sensitivity thresholds of dyslexic and typical children show a different pattern of association with reading skills.

43.471 **Asymmetric time perception across visual depth planes and degrees of spatial certainty** Howard P Collins[1](hpcolli1@bradford.ac.uk), Neil W Roach[2], Andrew J Logan[1], Samantha L Strong[1], James Heron[1]; [1]School of Optometry and Vision Science, University of Bradford, UK, [2]Visual Neuroscience Group, School of Psychology, The University of Nottingham, UK

Typically, greater numbers of neurons encoding a stimulus characteristic provide greater perceptual sensitivity to changes in that characteristic (e.g., cardinal vs oblique orientation discrimination (Orban et al, 1984)). Within extrastriate cortex, neurons selective for crossed retinal disparity are more abundant than their uncrossed counterparts, which is associated with higher sensitivity to changes in the spatial characteristics of crossed disparity-defined stimuli (CDDS) (DeAngelis & Uka, 2003; Regan & Hamstra, 1994). Recent models of time perception (e.g. Eagleman & Pariyadath, 2009) propose that perceived duration scales with neural response magnitude, suggesting a metric for estimating duration may arise via the encoding of (potentially) non-temporal stimulus features. The current study used dynamic luminance noise to measure differences in perceived duration of stimuli defined solely by crossed or uncrossed disparity (±6 arcmins). Observers (n=9) made 2AFC judgements about the relative durations of a constant (333ms) 500Hz auditory tone and a variable (333ms ±Δms) disparity-defined disc-shaped stimulus. Duration discrimination thresholds were significantly higher for uncrossed disparity-defined stimuli (UDDS) than CDDS ($p< 0.05$), suggesting a possible link between the relative paucity of neurons selective for uncrossed disparity and the encoding of duration. However, UDDS are associated with greater spatial uncertainty which may also be contributing to reductions in reliability of temporal encoding. To test this, the relative spatial uncertainty of CDDS vs UDDS was measured using a disparity-defined shape discrimination task. Observers were significantly more sensitive to shape deformations (circle vs ellipse) within CDDS ($p< 0.05$). This suggests spatial uncertainty may be driving duration sensitivity; potentially implying that CDDS vs UDDS sensitivity may be equated by degrading the spatial reliability of the former. In a follow-up experiment, when CDDS diameter was jittered during stimulus presentation, duration discrimination thresholds elevated to match UDDS performance ($p=0.57$). Taken together, our findings reveal a hitherto unexplored link between spatial and temporal reliability.

Acknowledgement: The Wellcome Trust [WT097387]

43.472 **Saccades vs. Novelty: the joint influence of saccades and repetition on perceived stimulus duration.** Amirhossein Ghaderi[1,2](amirhoseinghaderi@gmail.com), George Tomou[1,2,3], John Douglas Crawford[1,2,3,4,5]; [1]Centre for Vision Research, York University, Toronto, ON, Canada, [2]Vision Science to Applications (VISTA) Program, York University, Toronto, ON, Canada, [3]Departments of Psychology, York University, Toronto, ON, Canada, [4]Departments of Biology, York University, Toronto, ON, Canada, [5]Departments of Kinesiology and Health Sciences, York University, Toronto, ON, Canada

The duration of visual stimuli that occur just before and during saccades may be perceived as half of those that occur during fixation (Morrone et al., Nature neuroscience 2005). On the other hand, novel stimuli are perceived as lasting longer than repeated stimuli (Pariyadath & Eagleman, PLoS One 2012). Since these temporal distortions do not follow a scalar association with durations, the Weber's law has failed to justify both effects. Here, we investigated how these time distortions interact. Seven participants were asked to judge the duration of a test stimulus (three parallel vertical lines) that appeared after a pre-test stimulus (three parallel horizontal lines), randomly presented between 1 and 3 times. Duration of the pre-test stimuli was fixed (200 ms), but duration of the test stimulus was varied (140, 170, 230 and 260 ms). The experiment was performed in three blocks (saccade with fixed spatial / different retinal pre/test retinal locations, fixation control with fixed stimulus locations, and fixation control with different saccade-matched retinal stimulus locations). In the saccade block, participants were cued to perform a saccade 100 ms before presentation of novel stimulus. Consistent with previous findings, we found a significant underestimation of test stimulus duration in saccade trials that followed a single pre-test stimulus (29.3% of longer trials perceived longer compared to 61.9% and 69.3% in the control fixation blocks). However, saccadic time compression was considerably reduced when repeated stimuli preceded a novel test stimulus (67.2% and 70.0% of longer trials perceived longer for 1 and 2 repetition of pre-test, respectively). These results indicate that saccadic time compression and the novelty / reptetion effect do not interact in a scalar accumulative manner. Instead, they can be explained by a nonlinear vector model based on the phase differences between time units (Ghaderi et al., PloS one 2018).

Acknowledgement: 1- NSERC Discovery Grant 2- VISTA Fellowship, supported by the Canada First Research Excellence 3- Fund Canada Research Chair Program

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Object Recognition: Convolutional neural networks

Tuesday, May 21, 8:15 - 9:45 am, Talk Room 1

Moderator: Gemma Roig

51.11, 8:15 am **Eccentricity Dependent Neural Network with Recurrent Attention for Scale, Translation and Clutter Invariance** Jiaxuan Zhang[1,3](jz2997@columbia.edu), Yena Han[2], Tomaso Poggio[2], Gemma Roig[1,2]; [1]Singapore University of Technology and Design, [2]Massachusetts Institute of Technology, [3]Columbia University

The human visual system perceives the environment by integrating multiple eye-fixations at different locations of the scene. For each eye-fixation, there is lower perceived resolution at the periphery and higher at the center of the visual field due to the receptive field size of the neurons of the retina and early visual cortex increasing with eccentricity from the fixation point to the periphery. The eccentricity dependence of the receptive field size has been argued to allow invariance to scale and background clutter in the vision system for object recognition, whereas the eye-fixation mechanism provides invariance to the object position. To further test this hypothesis, we propose a novel computational approach that integrates Eccentricity Dependent Neural Network (ENN) with Recurrent Attention Model (RAM). ENN, a recently introduced computational model of the visual cortex, processes the input at different scales, with receptive field sizes that change with eccentricity at multiple scale channels. This incorporates intrinsic scale invariance property into the model. RAM has an attention mechanism using Reinforcement Learning, which learns to fixate on different parts of the visual input at different time steps. When combined, RAM finds the best location to fixate on at each time step, then use the location as the center of the input in ENN. We conducted extensive experiments using MNIST dataset, where images of digits are trained and tested at different scales and positions to compare the proposed system, ENN-RAM, to the original RAM. Our experiment results reveal that with less training data used, ENN-RAM model is able to generalize to a different scale, i.e., it recognizes objects at scales different from the learned scales. We also observe that the new ENN-RAM is resistant to clutter when trained without such clutter, whereas vanilla RAM is not.

Acknowledgement: This work was funded by the MOE SUTD SRG grant (SRG ISTD 2017 131) and CBMM NSF STC award CCF-1231216.

51.12, 8:30 am **Zero-shot neural decoding from rhesus macaque inferior temporal cortex using deep convolutional neural networks** Thomas P O'Connell[1,2](thomas.oconnell@yale.edu), Marvin M Chun[1,3], Gabriel Kreiman[4,2]; [1]Department of Psychology, Yale University, [2]Center for Brains, Minds, and Machines, MIT, [3]Department of Neuroscience, Yale University, [4]Children's Hospital, Harvard Medical School

Deep convolutional neural networks (DCNN) constitute a promising initial approximation to the cascade of computations along the ventral visual stream that support visual recognition. DCNNs predict object-evoked neural activity in inferior temporal (IT) cortex (Yamins et al., 2014), and the mapping between neural and DCNN activity generalizes across object categories (Horikawa and Kamitani, 2017; Yamins et al., 2014). Generalization is critical to build models of the ventral visual stream that capture the generic neural code for shape and make accurate predictions about novel categories beyond the training sample (zero-shot decoding). However, the degree to which mappings between DCNN and IT activity generalize across object categories has not been explicitly tested. To address this, we built zero-shot neural decoders for object category from multi-electrode array recordings in rhesus macaque IT, obtained while viewing images of rendered objects on arbitrary natural scene backgrounds (Majaj et al., 2015). Our zero-shot decoders generalized to predict novel categories despite not being trained on neural activity from the test categories. DCNN activity was computed for each image using VGG-16 (Simonyan and Zisserman, 2015), and DCNN activity was reconstructed from IT activity using linear regression. Linear classifiers were trained to predict object category from DCNN activity, then these classifiers were used to predict object category from DCNN activity reconstructed from IT responses. We held out neural activity from two test categories when learning the IT to DCNN mappings and found robust zero-shot decoding accuracies, indicating that the mappings generalize across categories. Intriguingly, training on a single category alone was sufficient to permit zero-shot decoding of novel categories. We show the relationship between IT and DCNN activity is stable across object categories, demonstrating the feasibility of zero-shot neural decoding systems based on electrophysiological recordings.

51.13, 8:45 am **Enhancement of Representational Sparsity in Deep Neural Networks Can Improve Generalization** Hongjing Lu[1,2](hongjing@psych.ucla.edu), Gennady Erlikhman[1]; [1]Department of Psychology, UCLA, [2]Department of Statistics, UCLA

Sparse coding in the human visual system has been viewed as a fundamental mechanism to provide increased representational capacity and efficiency with discriminative features. For artificial networks, sparsity has been introduced in numerous ways, e.g., in the form of dropout during training, rectification of activation, or wholesale removal of network nodes or individual connections. However, the main goal of sparsifying artificial networks is to reduce overfitting and network size and the methods for enforcing sparsity are determined more by computational convenience than generalization improvement. We compared standard methods of introducing sparsity in deep learning models, such as dropout, with more human-like schemes like permanent, targeted removal of weights or nodes as might happen during synaptic pruning during normal human development. A series of simulations were systematically conducted using the handwritten digit dataset (MNIST) with a simple, fully-connected three-layer network. We show that introducing sparsity with human-like schemes can significantly improve generalizability in the form of far transfer to untrained datasets, such as digit images with added noise (either random Gaussian noise or extra digit parts in the background). These generalization tests are distinct from the typical ways of testing a network (i.e. with unseen exemplars that are similar to the training set). However, such far transfer tests more closely resemble the kind of generalization performed by the human visual system. Selective pruning for sparsity significantly increased recognition accuracy in the far transfer tasks by maximum 38%. A principal component analysis of the features encoded by the network showed that increased sparsity makes the digit representations more distinct. However, we also find that representational sparsity is bounded within a range: while insufficient sparsity reduces coding efficiency, over-sparsity could lead to reduction of generalization to untrained stimuli.

Acknowledgement: NSF grant BCS-1655300

51.14, 9:00 am **Inducing a human-like shape bias leads to emergent human-level distortion robustness in CNNs** Robert Geirhos[1,2](robert.geirhos@bethgelab.org), Patricia Rubisch[1,3], Jonas Rauber[1,2], Carlos R Medina Temme[1], Claudio Michaelis[1,2], Wieland Brendel[1], Matthias Bethge[1,4,5], Felix A Wichmann[1,4]; [1]University of Tübingen, [2]International Max Planck Research School for Intelligent Systems, [3]University of Edinburgh, [4]Bernstein Center for Computational Neuroscience Tübingen, [5]Max Planck Institute for Biological Cybernetics

Convolutional neural networks (CNNs) have been proposed as computational models for (rapid) human object recognition and the (feedforward-component) of the primate ventral stream. The usefulness of CNNs as such models obviously depends on the degree of similarity they share with human visual processing. Here we investigate two major differences between human vision and CNNs, first distortion robustness---CNNs fail to cope with novel, previously unseen distortions---and second texture bias---unlike humans, standard CNNs seem to primarily recognise objects by texture rather than shape. During our investigations we discovered an intriguing connection between the two: inducing a human-like shape bias in CNNs makes them inherently robust against many distortions. First we show that CNNs cope with novel distortions worse than humans even if many distortion-types are included in the training data. We hypothesised that the lack of generalisation in CNNs may lie in fundamentally different classification strategies: Humans primarily use object shape, whereas CNNs may rely more on (easily distorted) object texture. Thus in a second set of experiments we investigated the importance of texture vs. shape cues for human and CNN object recognition using a novel method to create texture-shape cue conflict stimuli. Our results, based on 49K human psychophysical trials and eight widely used CNNs, reveal that CNNs trained with typical "natural" images indeed depend much more on texture than on shape, a result in contrast to the recent literature claiming human-like object recognition in CNNs. However, both differences between humans and CNNs can be overcome: training CNNs on a suitable dataset induces a human-like shape bias.

This resulted in an emerging human-level distortion robustness in CNNs. Taken together, our experiments highlight how key differences between human and machine vision can be harnessed to improve CNN robustness---and thus make them more similar to the human visual system---by inducing a human-like bias.

51.15, 9:15 am **Generative adversarial networks can visualize information encoded by neurons** Katerina Malakhova[1](katerina.malahova@gmail.com); [1]Pavlov Institute of Physiology, Russian Academy of Sciences

Understanding the principles of information coding and transmission in the brain is a fundamental goal of neuroscience. This study introduces a novel approach for exploration of the functions of neurons in higher-level areas of the visual system. The approach allows visualizing the representation of information encoded by neurons with deep learning visualization techniques. First, a deep neural network is trained on the experimental data (Sato et al., 2013). The model mimics the behavior of neurons by predicting their firing rate to an arbitrary image. We show that given recordings of neural activity in the IT-cortex, the model can reach a correlation coefficient of 0.8 for specific cortical columns with basic fine-tuned ConvNet architecture. The performance can be further improved by minor changes in the architecture of fully-connected layers. The second stage implies the visualization of the trained model. The properties of its neurons are studied using Generative Adversarial Networks (GANs). The GAN aims to produce an image which causes a strong activation in a selected neuron. Here we use image generation technique introduced by (Nguyen et al., 2017), which in contrast to other visualization approaches, considers a constraint for natural-looking results. This additional regularizer allows for the avoidance of adversarial images (Szegedy et al., 2014). Qualitative evaluation of the results suggests the proposed method captures features seen in the experimental data (Fig. 1). Moreover, the space of generated images is not limited by an experimental dataset what helps to weaken biases in judgments on a neuron's function caused by a small number of presented stimuli. The latter is particularly valuable for the experiments with strictly limited recording time. Thus, the approach can be a useful addition to existing practices in visual neuroscience.

51.16, 9:30 am **Adaptation in models of visual object recognition** Kasper Vinken[1](kasper.vinken@kuleuven.be), Gabriel Kreiman[1]; [1]Children's Hospital, Harvard Medical School, Boston, MA 02115

Convolutional neural network (CNN) models of the ventral stream provide an unprecedented opportunity to relate neural mechanisms to sensory representations and even perception. Current CNNs lack the temporal dynamics of biological vision such as adaptation to previous stimulation. Perceptually, adaptation has been widely studied in the form of aftereffects (Webster, 2015), while in single neurons adaptation is often equated to repetition suppression (Vogels, 2016). Whereas the two are often thought to be associated, they remain to be integrated in a truly general framework. One proposed mechanism underlying repetition suppression is a reduced excitability depending on previous neural activity, called response fatigue. Here, we implemented fatigue in each unit of a CNN (Krizhevsky et al., 2012) and asked whether it could account for more complex phenomena of neural and visual adaptation. Specifically, we assigned a latent fatigue variable to each unit that increased after high, but decreased after lower activation. The activation of a unit was then obtained by subtracting its fatigue from its input activity (before the linear rectifier). The resulting CNN units showed repetition suppression matching neural adaptation on several hallmark properties: stimulus-specificity, increased adaptation in higher layers, adaptation degree proportional with the number of repetitions (Vinken et al., 2017), and decreased adaptation with longer interstimulus intervals (Sawamura et al., 2006). Furthermore, the response patterns could account for the perceptual effects we tested: from afterimages in the first layer to a face gender aftereffect in later layers (Webster et al., 2004). Thus, when considered in a CNN, a simple mechanism of response fatigue operating at the level of single neurons can account for complex adaptation effects. In addition to providing a general model for adaptation, these results demonstrate the strength of using deep neural networks to connect low-level canonical neural properties or computations to high-level neural and perceptual phenomena.

Acknowledgement: Research Foundation Flanders (FWO)

Temporal Processing

Tuesday, May 21, 8:15 - 9:45 am, Talk Room 2

Moderator: Tiziano Agostini

51.21, 8:15 am **Directional congruency effect in subjective time dilation induced by looming and receding images with implied motion** Euisun Kim[1](euisun.kim101@gmail.com), Joohee Seo[1], Sung-Ho Kim[1]; [1]Department of Psychology, Ewha Womans University

Because time cannot be directly perceived from sensory information, time perception of visual events depends on changes in visual attributes of the scene. Among these attributes, motion—change in space-time—is a fundamental cue for time duration estimation, and dynamic visual stimuli are, in fact, known to induce a time dilation effect—an illusion of lengthened time. Given recent findings that static images with implied motion can produce a time dilation effect and that looming visual stimuli are perceived as longer than receding ones, in this study we investigated the effect of directional congruency between two motion signals—looming/receding motion and implied motion in depth from an image—in subjective time dilation. In two experiments, observers were shown images of either front- or back-facing person in a running posture for one of seven probe durations (400-1000ms) and judged whether each presentation duration was more similar to the short (400ms) or to the long (1000ms) standard duration. The size of the running person image was either constant (Experiment 1), decreasing (receding, Experiment 2), or increasing (looming, Experiment 2) over the presentation time. In Experiment 1, we did not find any difference in perceived presentation duration between two running directions (front- vs. back-facing) depicted in images. In Experiment 2, however, we found a congruency effect between the directions of implied motion (front- vs. back-facing) and real motion in depth (looming vs. receding): the duration of the front-facing person image was perceived as longer when it was looming than receding, and the duration of the back-facing person image was perceived as longer when it was receding. These results suggest that higher-order motion processing which integrates signals of various types of motion is responsible for the perception of time duration.

51.22, 8:30 am **The duration aftereffect does not reflect adaptation to perceived duration** Chris Paffen[1](c.l.e.paffen@uu.nl), Jim Maarseveen[1], Frans AJ Verstraten[1,2], Hinze Hogendoorn[3]; [1]Experimental Psychology & Helmholtz Institute, Utrecht University, [2]Faculty of Science, the University of Sydney, [3]Melbourne School of Psychological Sciences, The University of Melbourne

Heron et al (2012) have argued that the perceived duration of visual events is the result of processing by duration-selective channels, akin to those for the spatial frequency domain. This was based on the duration aftereffect, where the perceived duration of an event is repulsed away from its physical duration following adaptation. However, the question is: what aspect of duration do observers adapt to: the (physical) time elapsed between the on- and offset of a stimulus, or its perceived duration?To dissociate between these options, observers were repeatedly presented with a radial pattern (adaptation stimulus, 2 deg in diameter). The adaptation stimulus could either be a rotating radial grating (2.1 cycles/s) with a physical duration of 0.3 s and an average perceived duration of 0.57 s (temporal-frequency-induced-time-dilation or TFITD condition), a static radial grating with the same duration (static-baseline or SB condition), or a static grating with a duration matched, for each observer, to the perceivedduration of the rotating stimulus (i.e. 0.57 s on average; static-dilation-match or SDM condition). After repeated exposure (100 repetitions for the first; four for consecutive trials), observers compared the perceived duration of a visual target stimulus to an auditory reference.The results show that the SB condition leads to a longer perceived duration of the visual target stimulus than the SDM condition. Moreover, Bayesian analysis showed that the perceived duration of the visual target stimulus in the TFITD condition did not differ from that in the SB condition, but was longer than that in the SDM condition. This shows that observers adapt to a duration defined by the onset and offset of a stimulus, and not to its perceived duration. Our results suggest that channel-based encoding of duration occurs at a processing stage preceding those of which the processing is related to perceived duration.

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51.23, 8:45 am **Sensitivity of confidence judgments for different duration estimations** Ljubica Jovanovic[1,2](lj.m.jovanovic@gmail.com), Pascal Mamassian[1,2]; [1]Laboratoire des systèmes perceptifs, Département d'études cognitives, École normale supérieure, CNRS, Paris, France

Humans can accurately estimate the likelihood of their perceptual decisions being correct. Here, we asked how well humans can estimate their performance in a duration discrimination task. We investigated whether metacognitive assessment is different for subsecond and suprasecond durations (Lewis & Miall, 2003). On each trial, we presented sequentially two white discs of size 4 dva. The duration of the first disc was constant across trials, and the duration of the second was varied in six different steps. Participants decided which of the two discs was presented for a longer duration. After two consecutive trials, participants indicated which of the two trials they thought their decision was more likely to be correct (confidence forced-choice judgement; Mamassian, 2016). In different blocks, we tested discrimination and confidence inference for three different durations: 200, 500 and 1400 ms. We calculated the sensitivity of the temporal discrimination as the slope of the psychometric function fitted to perceptual decisions. As expected, discrimination sensitivity was lower for longer durations (Gibbon, 1977). Metacognitive performance was estimated by comparing the sensitivity of perceptual decisions that were chosen as more likely to be correct, to the overall sensitivity irrespective of the confidence choices. Sensitivity was reliably better for trials chosen as more likely to be correct. When choosing between two physically identical trials, participants could reliably estimate in which of the two intervals their performance was better. Importantly, confidence gain did not scale with sensory uncertainty. Our results indicate that humans are able to reliably estimate their sensory noise when estimating durations. In addition, metacognitive judgements have different sensitivities for different levels of temporal uncertainty.

51.24, 9:00 am **Serial dependence in orientation perception alters perceptual templates: a classification image approach** Yuki Murai[1,2](ymurai@berkeley.edu), David Whitney[1]; [1]Department of Psychology, University of California, Berkeley, [2]Japan Society for the Promotion of Science

Our visual system must solve the difficult problem of stabilizing noisy and ever-changing visual input. Previous studies have demonstrated that serial dependence in visual perception is a potential mechanism to promote perceptual stability over time: the percepts of current stimuli are biased toward previously seen stimuli (Fischer & Whitney, 2014). Here, using a simple detection task and classification image technique, we show that such serial dependency alters the perceptual templates of orientation representations. In the experiment, a low-contrast near-vertical Gabor was embedded in a static white noise on half the trials, and subjects were asked to judge whether the target Gabor was present or absent in the noisy image. The target contrast was adjusted for each individual so that d' was around 1.5. Every 5 to 11 trials, a high-contrast Gabor was presented as an inducer with its orientation tilted 10 degrees clockwise or counter-clockwise relative to vertical. We drew classification images separately for trials following clockwise or counter-clockwise inducers and found that the classification images were significantly biased toward the most recent inducer orientation. Given the task was a simple detection task, subjects were not required to encode, maintain, or recall stimulus orientation from memory. Nevertheless our results indicate that the perceptual templates of orientation were biased toward stimuli presented up to 10 trials before the current trial, suggesting the presence of a long-lasting mechanism to stabilize orientation perception. Our results also pose a methodological question for the classification image technique itself. This widely used psychophysical method typically assumes that a subject's response is determined only based on the current stimulus input. However, this assumption may be violated since our perception is serially dependent. We will discuss the spatiotemporal continuity of serial dependence in classification images and the fruitfulness of investigating higher-order reverse correlation.

51.25, 9:15 am **How do temporal mechanisms influence numerosity perception?** Andromachi Tsouli[1](a.tsouli@uu.nl), Maarten J van der Smagt [1], Serge O Dumoulin[1,2,3], Susan F te Pas[1]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University, Utrecht, The Netherlands, [2]Spinoza Centre for Neuroimaging, Amsterdam, The Netherlands, [3]Experimental and Applied Psychology, VU University, Amsterdam, The Netherlands

We have previously shown that adaptation to visual duration affects numerosity perception, which supports the theory of a common magnitude system underlying numerical and temporal processing. We performed two follow-up experiments to elucidate the nature of the interaction between numerosity and duration. The first experiment tested the effect of adaptation to visual duration on numerosity discrimination, whereas the second experiment tested the combined effect of adaptation to visual duration and numerosity on numerosity discrimination. In both experiments, we manipulated the onset/offset duration of the adapter, the adapter's total presentation time and the total duration of the adaptation trial. We hypothesized that if the effect of duration on numerosity is driven by adapting duration 'channels' tuned to specific durations, then what matters is the onset-offset duration of the adapter, whereas if duration reflects the 'strength' of adaptation, then what matters is the total duration of the adaptation trial. We found that the effect of adaptation to duration on numerosity perception is driven by adapting specific duration channels. In contrast, the effect of adaptation to numerosity on numerosity perception is driven by the total duration of the adaptation trial, in accordance with the strength of adaptation hypothesis. We propose that different temporal mechanisms affect numerosity perception.

51.26, 9:30 am **Dramatic effect of duty-cycle on brain response and motion perception** Marlene Poncet[1](marlene.poncet@gmail.com), Justin Ales[1]; [1]University of St Andrews

Perceiving motion relies on the integration of a signal over time and space. These two components of motion have been examined in many behavioural experiments but rarely in relation with neural responses. On the other hand, neuroimaging studies have shown that neural responses are not enhanced for a moving stimulus but surprisingly, are instead inhibited. In this study, we investigated the role of the temporal component in motion perception, and specifically if it explains the inhibition of brain responses. For this, we recorded participants' electroencephalography while a stimulus was flashed periodically at slow (2.6 Hz), medium (5.2 Hz) or fast (10.4 Hz) frequencies. Such stimulation creates Steady-State Visual Evoked Potentials (SSVEPs) whose amplitudes have been shown to correlate with behaviour. The stimulus was presented either at the same location (flicker condition) or at two alternating locations (moving condition). We also manipulated the duty cycle, that is the proportion of time that the stimulus was presented during a cycle (five duty-cycles were used: 12.5%, 25%, 50%, 75%, 87.5%). Our results show that at 2.6 and 5.2 Hz, increasing duty-cycle decreases SSVEP amplitudes by a factor of up to 5. We also find that the perception of motion increases with longer duty-cycles for moving and, unexpectedly, for flickering stimuli as well. Importantly, we find that SSVEP amplitudes are inversely correlated with behaviourally reported motion perception irrespective of whether the stimulus is actually changing position (although motion ratings are always higher for moving than for flickering stimuli). However, at 10.4 Hz, both SSVEP amplitudes and motion perception are not affected by duty-cycle. Modelling of our data using the motion energy model reveals that stimulus energy cannot account for our findings. In conclusion, our study shows that the temporal component modulates motion perception and plays an important role in inhibiting neural responses.

Acknowledgement: BBSRC BB/N018516/1

Spatial Vision: Models, neural mechanisms

Tuesday, May 21, 10:45 am - 12:30 pm, Talk Room 1

Moderator: Tomas Knapen

52.11, 10:45 am **A model-based approach to link MEG responses to neuronal synchrony in visual cortex** Eline R Kupers[1](eline.kupers@nyu.edu), Noah C Benson[1], Jonathan Winawer[1,2]; [1]Department of Psychology, New York University, New York, NY, USA, [2]Center for Neural Science, New York University, New York, NY, USA

BACKGROUND: Under some conditions, neural responses are highly synchronized across large regions of visual cortex. This synchronized activity is thought to be important for many functions. However, inferring synchrony measured at the scalp (EEG or MEG) can be challenging. This is because measured response levels are not only affected by synchrony, but also by neuronal amplitude and geometry of cortical sources and these variables cannot easily be disentangled. METHODS: We simulated neural signals in V1-V3, with either the same phase (synchronous) or random phases (asynchronous) across cortex. We then combined these with a forward model of MEG sensor responses (axial gradiometers). We compared these model predictions to measured MEG data from individuals (N=11) viewing a full-field high contrast-reversing stimulus. MEG data were separated into two components: time-locked to the stimulus (steady-state visual evoked fields, 'SSVEFs') and asynchronous with the stimulus (broadband response). RESULTS: First, SSVEF and broadband responses from the same datasets showed distinct spatial topographies. SSVEF responses were lateralized into

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two groups of posterior sensors, whereas broadband responses were generally confined to one centralized group. Second, we found that these different spatial topographies could be explained by differences in synchrony rather than source locations according to our forward model. The model predicts that synchronous V1-V3 responses result in two lateralized sensor patches, similar to SSVEFs, due to signal cancellation of sources with opposite facing dipoles. Importantly, using identical V1-V3 sources, the model predicts that sources with random phases result in a spatial topography approximately matching broadband responses (a single, central group of sensors). CONCLUSION: Identical cortical sources can result in very different patterns of sensor activity, depending on the degree of synchrony. In turn, the topography of sensor responses, combined with a forward model, can be used to make inferences about the underlying synchrony of neural responses.

Acknowledgement: NIH Brain Initiative R01 MH111417-01

52.12, 11:00 am **The visual selectivity of the default mode network** Martin Szinte[1](martin.szinte@gmail.com), Daniel M van Es[1], Tomas Knapen[1,2]; [1]Department of Experimental and Applied Psychology, Vrije Universiteit, Amsterdam, Netherlands, [2]Spinoza Centre for Neuroimaging, Amsterdam, Netherlands

The default mode network (DMN) is a large scale brain network with correlated cortical activities in frontal, parietal and temporal nodes. These nodes deactivate when participants are actively engaged in perceptual tasks, and activate for high-level cognition tasks such as mind wandering and autobiographical memory. While recent findings indicate that activations and deactivations of the DMN carry visual information related to memory, the functional role of its deactivations remains a mystery. Using population receptive field methods (pRF) applied to the Human Connectome Project retinotopy dataset (181 participants, 7T), we show that voxels in the DMN selectively deactivate as a function of the position of a visual stimulus. Moreover, we demonstrate the DMN's functional representation of visual space by successfully decoding the location of a visual stimulus in a cross-validated analysis of another 7T fMRI dataset. Together, our results establish for the first time the DMN as a visually selective network and open up the possibility of using vision-science paradigms to understand the role of this network in high-level cognition.

Acknowledgement: This research was supported by a Marie Skłdowska-Curie Actions Individual Fellowship (704537) received by MS, a NWO-CAS (012.200.012) and a ABMP (2015-7) grants received by TK.

52.13, 11:15 am **Local variability causes adaptive spatial integration** Takahiro Doi[1](doi.takah@gmail.com), Johannes Burge[1,2,3]; [1]Department of Psychology, University of Pennsylvania, [2]Neuroscience Graduate Group, University of Pennsylvania, [3]Bioengineering Graduate Group, University of Pennsylvania

Visual systems integrate signals across space. Spatial integration operates at virtually all steps of visual information processing from retinae to higher cortical visual areas. Spatial integration is useful computationally because it can improve the precision of estimates by averaging out noise when local spatial variability is present. Classic studies model spatial integration with a fixed linear weighting of local inputs, the optimal strategy when variation is solely due to noise. In natural scenes, local variability can be caused by noise or signal variability, so a more subtle strategy may be required. Here, we report that human spatial integration deviates substantially from the predictions of the classic model. Human observers judged the average luminance or the average stereoscopic depth of spatially variable test stimuli relative to a surrounding surface. In both tasks, the test stimulus consisted of nine horizontal bars (60×6 arcmin each) vertically flanking the fovea. The luminance or disparity across bars was either uniform or independently sampled from normal distributions. For each sample variance (calculated across all nine bars), we varied the sample mean to measure a psychometric function. We separately analyzed human performance with stimuli having zero, small, medium, and large sample variance. The classic model linearly weights luminance or disparity across the stimulus; the sample mean is the optimal decision variable. Thus, identical performance is predicted for all sample variances. However, human thresholds increase markedly with sample variance (3 and 5 times in two tasks, respectively). This result indicates that spatial integration depends on the local variability across each stimulus. The classic linear model for spatial integration should be modified to account for these results. The modification likely involves variability-dependent changes to the gain (e.g. normalization) or pattern of the integration weights. These modifications may optimize performance in natural scenes.

Acknowledgement: NIH R01-EY028571

52.14, 11:30 am **A Natural Experiment in Aberrant Retino-Cortical Organization** Edgar A DeYoe[1](deyoe@mcw.edu), Ethan Duwell[1], Erica N Woertz[2], Joseph Carroll[2]; [1]Radiology, Medical College of Wisconsin, [2]Ophthalmology, Medical College of Wisconsin

Naturally occurring cases of extreme variation in visual system anatomy and neurophysiology, as in albinism, can aid identification of key factors responsible for brain-related vision deficits. To this end, we have quantitatively characterized retinal cone density, cortical magnification and population receptive field structure in 5 subjects with albinism, ultimately to develop a quantitative neurophysiological model predictive of visual dysfunction. In albinism, foveal cone density and Vernier acuity are reduced relative to healthy controls at all eccentricities from fovea to periphery (20o), yet acuity does not directly scale with cone density over this range. Accordingly, cortical magnification at/near the fovea is reduced relative to controls yet can be higher in the periphery than in controls (though this is markedly variable across subjects). fMRI-based cortical retinotopy and voxel receptive field structure are also markedly aberrant due to mis-routing of retinal afferents at the optic chiasm. This results in partially superimposed representations of the left and right visual fields within the same hemisphere and to a significant percentage (14%) of voxels with "dual" population receptive fields in V1-V3. The latter respond to visual stimuli at 2 separate locations, previously thought to be mirror symmetric across the vertical meridian. However, our pRF modeling of 2200 dual pRF voxels revealed that 32% were at least 45o off mirror symmetric, some with components in the same visual hemifield and/or straddling the horizontal meridian (incidence varying considerably across albinism subjects). This suggests that retino-cortical miswiring can be more complex than a simple decussation artifact at the chiasm. Together these results reveal that anatomy and neurophysiology are more variable and complex in albinism than previously appreciated. This may correlate with genetic variation within the albinism population and provides a rich source of "natural experiments" for exploring brain-related structure-function-deficit relationships.

Acknowledgement: NIH grants TL1TR001437, T32GM080202, T32EY014537, P30EY001931, and R01EY024969

52.15, 11:45 am **DC-balanced filtering in pRF maps of Human Primary Visual Cortex.** Daniel G Kristensen[1](dgramm@cfin.au.dk), Kristian Sandberg[1]; [1]Center of Functionally Integrative Neuroscience, Department of Clinical Medicine, Aarhus University Hospital

The functional organisation of neuronal receptive fields can give insight into how the visual system operates. In this regard, the center-surround organisation of the receptive field plays a crucial role in extracting spatial information from visual scenes, and requires constant adaptation as the visual scene is traversed. This adaptation is achieved through surround modulation which causes the classical receptive field to be influenced by stimulation of its surround. Surround modulation is considered an elementary computation of the visual system and its function is hypothesized to assist in object boundary segmentation, optimisation of neural coding as well as normalisation of visual scene contrast. A Difference of Gaussians with varying center-surround size- and/or gain ratio is often chosen to model receptive field surround modulation. By introducing the principle of DC-balanced filtering, we show that for any given size ratio there is a gain ratio that optimises the filters capabilities in terms of feature segmentation, neural coding and contrast normalisation. Examining these ratios by mapping population receptive fields in healthy human subjects using functional magnetic resonance imaging (fMRI), we find evidence that the human primary visual cortex adheres to the principle of DC-balanced filtering across all examined parts of the visual field and across all receptive field sizes. Since surround modulation is pervasive in all sensory modalities, we expect this result to be a corner stone in understanding how biological systems achieve their high information processing fidelity. Furthermore, research areas that finds inspiration in biological vision research, such as digital image processing with deep neural networks, could benefit from the insights gained here.

52.16, 12:00 pm **Two-photon imaging of V1 responses to complex stimulus patterns in awake macaque monkeys** Cong Yu[1](yucong@pku.edu.cn), Nian-Sheng Ju[1], Shu-Chen Guan[1], Shi-Ming Tang[1]; [1]Psychology, McGovern Brain Research, and Life Sciences, Peking University

V1 neurons respond to simple stimuli like bars and gratings, as well as to complex stimuli such as two-dimensional Hermite patterns (Victor et al., 2006). Here we used two-photon imaging (GCaMP5) to compare responses of V1 superficial layer neurons to simple gratings and complex Hermite patterns in two awake macaques. We recorded at two depths (150μm and

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300μm) from 850 x 850 μm2 windows at 4-5o eccentricity. The stimuli were either high-contrast (0.9) drafting (2 cycles/sec) Gabor gratings at 12 orientations, 6 SFs (0.25-8 cpd), and 3 sizes (>= 1 octave, for maximal responses and least surround suppression), or Hermite patterns including vignette, checkboard, and circular/dartboard-like types, at 3 sizes and 6 orientations if possible for maximal responses. V1 neurons were found to respond to either gratings only, Hermite patterns only, or both stimuli. There were more Hermite neurons and less grating neurons at more superficial depth at 150μm than at 300μm (Hermite neurons increased from 18% to 34%; Grating neurons reduced from 64% to 38%). Hermite neuronal responses were at least as strong as grating neuronal responses. More than half (55%) Hermite neurons were activated by circular/dartboard-like patterns, which increased sharply from 300μm to more superficial 150μm depth (from 42% to 63%). Hermite neurons preferred lower SFs than grating neurons (1.25 vs. 2.45 cpd), overlapped with neurons unturned to orientation, and showed some clustering. These results suggest that selectivity to complex stimulus patterns may be an emerging property within V1. The Hermite neurons, mostly clustered in low-SF domains and being orientation unselective, may form a specialized neuron subpopulation for feature integration in V1. The large number of neurons responding to circular/dartboard patterns may carry biological significance for monkey's survival (e.g., finding round-shaped fruits or faces).

52.17, 12:15 pm **Unsupervised Neural Networks Learn Idiosyncrasies of Human Gloss Perception** Katherine R Storrs[1](katherine.storrs@gmail.com)**,** Roland W. Fleming[1]; [1]Justus-Liebig University Giessen

We suggest that characteristic errors in gloss perception may result from the way we learn vision more generally, through unsupervised objectives such as efficiently encoding and predicting proximal image data. We tested this idea using unsupervised deep learning. We rendered 10,000 images of bumpy surfaces of random albedos, bump heights, and illuminations, half with high-gloss and half with low-gloss reflectance. We trained an unsupervised six-layer convolutional PixelVAE network to generate new images based on this dataset. This network learns to predict pixel values given the previous ones, via a highly compressed 20-dimensional latent representation, and receives no information about gloss, shape or lighting during training. After training, multidimensional scaling revealed that the latent space substantially disentangles high and low gloss images. Indeed, a linear classifier could classify novel images with 97% accuracy. Samples generated by the network look like realistic surfaces, and their apparent glossiness can be modulated by moving systematically through the latent space. We generated 30 such images, and asked 11 observers to rate glossiness. Ratings correlated moderately well with gloss predictions from the model (r = 0.64).To humans, perceived gloss can be modulated by lighting and surface shape. When the model was shown sequences varying only in bump height, it frequently exhibited non-constant gloss values, most commonly, like humans, seeing flatter surfaces as less glossy. We tested whether these failures of constancy in the model matched human perception for specific stimulus sequences. Nine observers viewed triads of images from five sequences in a Maximum Likelihood Difference Scaling experiment. Gloss values within the unsupervised model better predicted human perceptual gloss scales than did pixelwise differences between images (p = 0.042). Unsupervised machine learning may hold the key to fully explicit, image-computable models of how we learn meaningful perceptual dimensions from natural data.

Attention: Cues, context

Tuesday, May 21, 10:45 am - 12:30 pm, Talk Room 2

Moderator: Andrew Hollingworth

52.21, 10:45 am **Learned Distractor Rejection during Strong Target Guidance** Brad T Stilwell[1](brad-stilwell@uiowa.edu)**,** Shaun P Vecera[1]; [1]Department of Psychological and Brain Sciences, The University of Iowa

Most theories of visual attention posit a selective mechanism that allows relevant information to proceed through processing while filtering out irrelevant, distracting, stimuli. Visual search is more efficient when target-features are known in advance, through guidance with a target-template. Further, visual attention can learn to reject distractors through experience with statistical regularities, by establishing an experience-based template for rejection. The current study was aimed at determining whether visual attention could learn to reject distractors through feature-based experience in the presence of strong target guidance, and under which circumstances this learning occurred. In three experiments, we presented individuals with two-color, spatially unsegregated visual search displays. Prior to each search display, individuals were presented with a word cue either indicating the target color or the word "neutral". For each individual, the target never appeared in one color: the learned distractor color. In Experiment 1a, we presented neutral cues only, and observed learned distractor rejection, namely, faster mean RTs on trials with the learned distractor color present than absent. In Experiment 1b, to demonstrate learned distractor rejection with target guidance, we presented both types of cues, and observed a target cueing effect (faster mean RTs on trials following a target cue than a neutral cue), and critically, learned distractor rejection following both neutral cues and target cues. In Experiment 2, we asked whether learned distractor rejection required the neutral trials to establish learning, and found that it did not. Finally, in Experiment 3, we provided more direct target guidance, namely, the cue directed individuals to the only color-matching item in the display and we still observed learned distractor rejection during target guidance. Thus, we argue that visual attention can establish both target templates and templates for rejection and use both templates to guide visual search.

52.22, 11:00 am **Passive Suppression of Distractors in Visual Search** Bo-Yeong Won[1](bywon@ucdavis.edu)**,** Joy Geng[1,2]; [1]Center for Mind and Brain, University of California, Davis, [2]Department of Psychology, University of California, Davis

The ability to suppress distractors that appear repeatedly during visual search improves over time. For example, we previously asked participants to locate a gray square among three colored distractor squares (e.g., pink, orange, magenta) in a visual search task. After a "training" period, the three distractors sometimes changed to different sets of colors (e.g., blue, green, cyan). We found that the appearance of new (and very different) distractor colors slowed down search compared to "trained" distractors (Won & Geng, 2018). Although it was clear that experience with specific distractors improved suppression, it was unknown whether the enhanced suppression for "trained" colors was due to repeated active suppression of specific colors, or the passive viewing of those non-target colors during visual search (i.e., the habituation model; Turatto). Here, we address this question by adapting our previous paradigm to include a "habituation display" that was interleaved with visual search trials. The habituation display contained four colored circles and occurred briefly before each search display. Participants were instructed to ignore the circles but only focus on the search task. A control group experienced the same trial sequence, but was shown black circles during the "habituation display". Consistent with the habituation model, search RT in the control group was slowed when new dissimilar distractors appeared, but no cost was found for the color-habituation group. This suggests that passive color exposure from the habituation displays led to equivalent suppression for new dissimilar distractors and trained distractors. We also tested the specificity of habitation by manipulating the color range of circles in the habitation display. We found that distractor suppression only occurred for new distractor colors that were seen on habituation displays. These findings indicate that distractor suppression may improve over time as a consequence of passive mechanisms of perceptual habituation and not "active" attentional mechanisms.

Acknowledgement: NIH: 1R01MH113855-01A1 NSF: BCS-1230377-0

52.23, 11:15 am **The Architecture of Interaction between Visual Working Memory and Attention: Features from Multiple Remembered Objects Produce Parallel, Coactive Guidance** Andrew Hollingworth[1](andrew-hollingworth@uiowa.edu)**,** Brett Bahle[1]**,** Daniel Thayer[1]**,** J. Toby Mordkoff[1]; [1]Department of Psychological and Brain Sciences, University of Iowa

Visual search is guided by templates maintained in visual working memory (VWM). Currently, there is debate over the architecture of this guidance, with one theory claiming that only a single VWM item can guide attention at a time (single-item template hypothesis, SIT) and another claiming that multiple items can guide attention simultaneously (multiple-item template hypothesis, MIT). Thus far, relevant evidence has come primarily from costs when switching guidance between different VWM items and from capture when multiple items are maintained in VWM. However, switch costs do not necessarily distinguish between theories, and capture effects do not probe strategic processes. In the present study, we developed a redundancy gains paradigm to test this question for the core construct of interest: strategic attentional guidance by VWM. Participants searched for a target defined by either of two cued features (e.g., color, shape), which varied on a trial-by-trial basis. When present, the target matched the cue on either one feature value or both. Analysis of RT distributions tested for redundant trials that were faster than predicted by two independent guidance processes operating in parallel (i.e., violations of the race model inequality, Miller, 1982). Violations are consistent with a specific architecture in which both cue values guide attention in parallel and sum on the priority map (i.e., a coactive architecture, consistent with the MIT). With evidence in favor of a particular parallel model, all serial models can be eliminated (e.g., SIT). Robust violations were observed in four experiments. In particular, violations were observed when the two cue values came from the same dimension (two colors), were associated with different objects in the cue display, and could not have been easily combined into an integrated template. Together, the results provide strong evidence that features from multiple objects in VWM guide attention in a parallel, coactive manner.

52.24, 11:30 am **Eye Movement Patterns to Social and Non-social Cues in Early Deaf Adults** Claudia Bonmassar[1](claudia.bonmassar@unitn.it), Francesco Pavani[1,2], Cristina Caselli[3], Alessio Di Renzo[3], Wieske van Zoest[1,4]; [1]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy, [2]Department of Psychology and Cognitive Sciences, University of Trento, Italy, [3]Institute of Cognitive Sciences and Technologies-National Research Council (ISTC-CNR), Rome, Italy, [4]School of Psychology, University of Birmingham, United Kingdom

Centrally presented gaze and arrow cues cause covert shifts of attention even when they are uninformative. The validity effect of the cues is evident on manual reaction time (RT), as responses are faster for targets appearing at cued locations relative to those appearing at uncued locations. Interestingly, previous research on covert orienting to the periphery suggested that early profound deaf adults were less susceptible to uninformative gaze cues, though were equally if not more affected by non-social arrow cues (Heimler et al., 2015). The aim of the present work was to investigate whether spontaneous eye movement behaviour helps explain the absence of social cuing in the deaf observers. We tracked the gaze of age-matched deaf (n = 24) and hearing observers (n = 24) performing a peripheral discrimination task with uninformative central cues (gaze vs. arrow), SOA (250 vs. 750 ms) and cue validity (valid vs. invalid) as within-subject factors. In both groups, the cuing effect on RT was comparable for the gaze- and arrow-cue, although deaf observers responded significantly slower than hearing controls. While deaf and hearing observers responded equally to the cue presented in isolation, deaf observers relied significantly more on eye movements than hearing controls once the discrimination target was presented. Notably, in the deaf group, saccade latency was affected by cue type but not by cue validity, while for landing position the reverse was true. Saccade landing position was strongly related to the magnitude of the validity effect on RT, such that the greater the difference in saccade landing position between invalid and valid trials, the greater the difference in manual RT between invalid and valid trials. This work suggests that the contribution of overt selection in central cuing of attention is enhanced in deaf adults and determines the attentional performance, irrespective of cue type.

Acknowledgement: Autonomous Province of Trento (Italy), call "Grandi Progetti 2012", project "Characterizing and improving brain mechanisms of attention -ATTEND"

52.25, 11:45 am **Attentional (mis)guidance by a contextual memory template in early vision** Markus Conci[1](conci@psy.lmu.de), Artyom Zinchenko[1], Thomas Töllner[1], Hermann J. Müller[1], Thomas Geyer[1]; [1]Department of Psychology, Ludwig-Maximilians-University, Munich, Germany

Attentional orienting in our complex visual environment is supported by statistical learning of regularities in the ambient array. For instance, in visual search, detection of a target is faster when the spatial configuration of nontargets is repeatedly encountered, suggesting that learned contextual associations can guide attention (contextual cueing; Chun, 2000). However, scene layouts sometimes change, requiring observers to adapt previous memory representations. Recent work has demonstrated that contextual cueing is initially rather efficient to extract invariant statistical regularities. Yet, a subsequent change of the target location within an otherwise unchanged nontarget layout completely abolishes contextual cueing and the benefits deriving from the invariant context recover only slowly with extensive training (Zellin et al., 2014). This suggests that contextual learning is quite effective initially, but inflexible to incorporate changes. Here, we explored how memory-based attentional guidance is reflected in lateralized event-related EEG potentials. Our results revealed reliable contextual cueing (of 117 msec) during an initial learning phase, which was associated with an increased EEG amplitude for repeated, relative to random layouts in lateralized attention-related components, starting with an early posterior negativity, the N1pc (100-160 msec). In a subsequent test phase, the target location swapped hemifield within an otherwise unchanged context. This target location change led to a substantial reduction of contextual cueing (21 msec). Moreover, the N1pc component was now reversed in repeated layouts, showing a positive-going deflection after the target location change (and no reliable amplitude differences between repeated and random layouts in subsequent lateralized components). The N1pc may therefore be interpreted in terms of an automatic matching process that compares the incoming sensory information with a contextual memory template during early visual processing to guide attention effiently. However, after the change, template matching persists and still provides a bias to the initial target location, thus resulting in attentional misguidance.

Acknowledgement: German Research Foundation (DFG, grant: FOR 2293/1 and GE 1889/4-1)

52.26, 12:00 pm **Voluntary and involuntary attention elicit distinct biasing signals in visual cortex** Jonathan M Keefe[1](jmkeefe@ucsd.edu), Viola S. Störmer[1]; [1]University of California, San Diego

Voluntary and involuntary attention are traditionally studied as separate types of attention, although they often interact in everyday situations to jointly influence perceptual processing. Here, we developed a hybrid attention task that uses peripheral auditory cues that capture attention reflexively but also carry predictive information about the location of a subsequent visual target, and examined EEG activity elicited by these cues to tease apart neural effects of voluntary and involuntary attention. Participants discriminated the tilt of a visual target which was preceded by a peripheral auditory cue presented from the left or right side. In Experiment 1 (N=16), the peripheral cues were either informative of the target location (80% valid) or not (50% valid). In Experiment 2 (N=14), the informative peripheral cue was compared to an informative symbolic cue presented centrally (both 80% valid). Across all conditions, participants showed higher target discrimination accuracy for validly versus invalidly cued targets (all ps < .008). Peripheral cues elicited increased neural activity in visual cortex contralateral to the cued side regardless of cue informativity, observed as a slow positive deflection ~260-400ms after cue onset (all ps > .002). This early positive wave was absent for informative symbolic cues, indicating that it reflects a unique signature of the reflexive orienting of attention. Critically, only informative cues elicited a sustained decrease in contralateral alpha power (~10Hz) that emerged rapidly for peripheral cues but was delayed for symbolic cues, suggesting that alpha activity plays an important role in biasing visual cortex activity in preparation of an expected visual target. Together, these results demonstrate a dissociation between the neural effects of involuntary and voluntary attention that depends on cue format and informativity of the cue, and suggest that the deployment of involuntary attention can hasten the sustained visual excitability engaged in anticipation of an impending target.

52.27, 12:15 pm **Metacognitive estimates of time during spatial orienting of attention** Samuel Recht[1](samuel.recht@ens.fr), Vincent de Gardelle[2], Pascal Mamassian[1]; [1]Laboratoire des Systèmes Perceptifs, École Normale Supérieure — PSL University, Paris, France, [2]Centre d'Economie de la Sorbonne, CNRS UMR 8174, Paris, France, Paris School of Economics, Paris, France

How does orienting of attention in space affect one's ability to evaluate one's performance (i.e., metacognition)? Previous work has considered cases in which spatial attention is already fully deployed, but less is known about metacognition during attentional deployment. Here, we investigated how the timing of attention affected metacognitive ability. To probe exogenous and endogenous visuo-spatial attention, we adapted a "Wundt clocks" paradigm. This design builds on the fact that attention has been shown to alter the latency between objective and perceived events (i.e., "flash-lag" effect). Participants looked at 6 clocks at a fixed eccentricity that rotated at a fixed speed but different phases. At a random time, one of the clocks was either cued peripherally (exogenous) or centrally (endogenous), and when the clocks stopped, participants were requested to report the hand position at cue onset. The moment of attentional orienting was manipulated using a "pre-cue" condition, such that attention could have already been deployed at cued location or has yet to be deployed. After two trials, participants chose the one they felt more confident to be correct. The average reported times were delayed in accordance with exogenous/endogenous attention. Surprisingly, confidence was not correlated to these attention-induced delays. However, confidence judgments correlated with the relative error between each trial in the pair, suggesting that participants were able to estimate their internal deviation at the trial level. Importantly, exogenous/endogenous orienting of attention reduced this confidence-error relation compared to the pre-cue condition. To investigate this behavior, a second task required

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participants to make a speeded response followed by a confidence evaluation of their own reaction times. Metacognitive abilities in both tasks were correlated. These results suggest that orienting exogenous/endogenous attention in space alters metacognitive ability, possibly through domain-general impairment of internal time monitoring.

Faces: Gaze

Tuesday, May 21, 8:30 am - 12:30 pm, Banyan Breezeway

53.301 **Looking at the preferred point of fixation mediates the composite face effect** Puneeth N Chakravarthula[1](puneeth@ucsb.edu), Araks Ghazaryan[1], Miguel P Eckstein[1]; [1]Department of Psychological and Brain Science, UCSB

It is known that human observers have a preferred initial fixation location on the face which enables efficient integration of features and maximizes performance across a variety of face recognition tasks (Peterson & Eckstein, 2012). Less is known about the influence of fixating the preferred point of fixation on face part judgments. We hypothesize that fixating the preferred point is detrimental relative to other points of fixation in a task that requires making judgments on parts of faces. Fourteen observers completed a face identification task with 4 faces (faces A and B, and top-bottom composite faces AB and BA) embedded in luminance noise. We first used a free eye movements task to measure the preferred initial point of fixation on the face for each individual. Subsequently, in a parts task, observers judged the top or bottom half (based on the block) as matched or unmatched across two sequentially presented faces (Composite face effect, CFE, 50% matched, 50% unmatched, 200 msec. presentations). Within each block, observers were shown either aligned or misaligned faces, and they maintained their gaze either at their preferred point of fixation or 5.2° below it. When judging the top halves of faces while maintaining gaze at their preferred fixation point, observers performed worse in the aligned vs. the misaligned condition (PCaligned = 63.3%, PCmisaligned = 73%, pt-test = 0.005). This is the classic CFE (Young, 1987). This effect disappeared when observers were forced to fixate at a non-preferred location (PCaligned = 62.1%, PCmisaligned = 64.2%, pt-test = 0.34).A control condition judging bottom halves discounted an explanation in terms of spatial proximity of fixation to the judged part (bottom non-preferred PCaligned = 90.2%, PCmisaligned = 89.5%, pt-test = 0.39). The results suggest that face processing at the preferred point of fixation might be mediated by distinct computations that optimize integration of facial features but impair parts judgments.

53.302 **Link between initial fixation location and spatial frequency utilization in face recognition** Amanda Estéphan[1](aesthellophane@gmail.com), Carine Charbonneau[1], Virginie Leblanc[1], Daniel Fiset[1], Caroline Blais[1]; [1]Université du Québec en Outaouais

Recent face perception studies have explored individual differences with regard to visual processing strategies. Two main strategies, associated with distinct eye movement patterns, have been highlighted: global (or holistic) face processing involves fixations near the center of the face to facilitate simultaneous peripheral processing of key facial features (i.e. eyes and mouth); local (or analytic) face processing involves fixations directed to those facial features (Chuk et al, 2014; Miellet et al, 2011). Since it has been shown that peripheral processing entails lower spatial resolution (Goto et al, 2001), global face processing may theoretically be linked to lower spatial frequency (SF) sampling. By contrast, local face processing may allow the extraction of higher SFs. However, the link between eye movements and SF extraction has not yet been empirically verified for face recognition. Thus, the current study proposes to investigate this question. The eye movements of 21 Canadian participants were monitored while they completed an Old/New face recognition task. Subsequently, the SF Bubbles method (Willenbockel et al., 2010) was used to measure the same participants' SF utilization during a face identification task. Fixation duration maps were computed for each participant using the iMap4 toolbox (Lao et al., 2017), and participants' individual SF tuning peaks, obtained with SF Bubbles, were calculated. In line with previous studies, our participants' initial fixations generally landed near the center of the face, with varying degrees of proximity to this location (Euclidean distances: from 25.76 to 146.03 pixels; SD of 32.08 pixels). Crucially, SF peaks significantly correlated with the location of the first fixation ($r = -0.46$; $p = 0.037$): participants using higher SFs initially gazed closer to the left eye than participants using lower SFs. These results suggest that greater reliance on high SFs is associated with early fixations toward the left eye region.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

53.303 **Individuals with low other race effect employ a global eye movement strategy when recognizing other race faces.** Yavin Alwis[1](alwyv-20@rhodes.edu), Lisa Hsi[1], Jason Haberman[1]; [1]Department of Psychology, Rhodes College

The Other Race Effect (ORE) is a well-established phenomenon in which individuals better recognize and recall same-race faces over other-race faces. Both sociocognitive and perceptual theories have been proposed to explain the mechanisms of the ORE. One recent perceptual theory involves the face-space model, in which differences in featural processing strategies exist depending on the race of the face being viewed. Specific processing strategies may be revealed by monitoring an individual's eye movements while viewing a face. While different-race faces may be more effectively identified by employing race specific eye movement patterns, observers who demonstrate a strong ORE are non-optimal in their deployment strategies, and instead reveal similar eye movement patterns across different races. The current experiments used an individual differences approach to explore whether individuals who demonstrate a reduced ORE deploy race specific eye movements (what one might predict as optimal), or whether they use a more generalized, global strategy. To determine the extent of one's ORE, participants completed a face learning and recognition task using faces across three races. Eyetracking was used during the recognition task to measure eye deployment patterns and first fixation locations. Overall, eye movement patterns elicited by individuals with low ORE were highly consistent across the three races. This suggests that, although there are optimal recognition strategies specific to different-race faces, low ORE participants did not necessarily rely upon them. Despite this, their performance in recognizing other-race faces remained as good as it was for their own-race faces. These results suggest that low ORE participants employ a more global strategy when viewing other-race faces.

53.304 **Visual scanning of faces, race contact, and implicit racial bias** Elizabeth S Soethe[1](esoethe2017@fau.edu), Melissa Mildort[1], Eli Fennell[1], Arushi Sachdeva[1], Gizelle Anzures[1,2,3]; [1]Department of Psychology, Florida Atlantic University, [2]Brain Institute, Florida Atlantic University, [3] Center for Complex Systems and Brain Sciences, Florida Atlantic University

Past research indicates that adults generally show own-race recognition biases (Meissner & Brigham, 2001) and different scanning patterns for own- and other-race faces (Fu, Hu, Wang, Quinn, & Lee, 2012). In-group biases have also been shown to influence face recognition (Bernstein, Young, & Hugenberg, 2007). The present study examines how own- and other-race face scanning during a recognition task might be influenced by race contact and implicit racial bias. Caucasian young adults completed a face recognition task with Caucasian and East Asian faces blocked by race (order counterbalanced across participants) while their visual fixations and scanning behaviors were recorded. Prior to the face recognition task, participants completed an implicit association task measuring racial biases, as well as a questionnaire inquiring about contact with Caucasian and East Asian individuals. Preliminary analyses revealed that larger own-race recognition biases were associated with greater contact with own-race than other-race individuals ($p = .05$). Participants also showed a greater duration of looking at own-race than other-race eyes ($p < .05$), and greater visual scanning of the nose region and non-essential facial features of other-race compared to own-race faces (p values < .05). A greater number of Caucasian than Asian friends was also associated with greater visual scanning of the left eye of own-race than other-race faces, and with greater visual scanning between the eyes and mouth of other-race than own-race faces (p values < .05). There was a trend towards greater visual scanning between the nose and mouth of own-race than other-race faces with greater implicit own-race biases ($p = .08$). Thus, preliminary results suggest that own-race recognition biases are largely driven by lack of perceptual expertise with other-race individuals and relatively less influenced by implicit racial biases.

Acknowledgement: NICHD

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53.305 **A cross-cultural comparison of face scanning strategies in infancy: screen-based paradigms and live dyadic interactions**

Jen X Haensel[1](jhaens01@mail.bbk.ac.uk), Mitsuhiko Ishikawa[2], Shoji Itakura[2], Nadia Neesgaard[1], Raffaele Tucciarelli[1], Tim J Smith[1], Atsushi Senju[1]; [1]Department of Psychological Sciences, Birkbeck, University of London, [2]Department of Psychology, Kyoto University

The emergence of cultural differences in face scanning is shaped by postnatal social experience. However, previous studies mainly investigated eye movement patterns of adults and little is known about early development. The current study recorded eye movements of British and Japanese infants (aged 10 and 16 months) and adults, who were presented with static and dynamic faces on screen. The findings revealed cultural differences across all age groups, with British participants exhibiting more mouth scanning and Japanese individuals showing increased central face scanning. Against predictions, culture and age independently modulated face scanning, suggesting that cultural differences largely already manifested by 10 months of age. We also examined whether screen-based scanning strategies extend to more naturalistic settings. Specifically, British and Japanese 10-month-old infants engaged in face-to-face interaction with a local research assistant while their eye movements were recorded. To examine scanning strategies, we used traditional regions-of-interest analysis as well as a novel data-driven, spatially sensitive method (permutation test). In contrast to the screen-based paradigm, no cultural differences were found, with both groups predominantly scanning the mouth region which may indicate a role of low-level saliency or an adaptive mechanism for language learning. In combination, our findings suggest that various factors modulated face scanning, including culture, age, and stimulus characteristics, with their relative contribution changing across experimental conditions. Overall, this points to a highly adaptive face processing system that is shaped by early postnatal social experience and modulated by contextual factors.

53.306 **Smile and the world watches: Capture by happy gaze cues outside an attentional control set.**

Lindsay Plater[1](lplater@uoguelph.ca), Akshu Valecha[1], Rashmi Gupta[2], Jay Pratt[3], Naseem Al-Aidroos[1]; [1]Department of Psychology, University of Guelph, [2]Department of Psychology, Indian Institute of Technology, Bombay, [3]Department of Psychology, University of Toronto

Visual attention is biased towards stimuli portraying emotion. Recently, Gupta, Hur, and Lavie (2016; Emotion) demonstrated that positive valence stimuli have a unique effect on attention; whereas high perceptual loads can prevent negative task-irrelevant stimuli from interfering with task performance, they do not prevent interference from positive task-irrelevant stimuli. Across two experiments, we examined the generalizability of this finding by testing whether positive task-irrelevant stimuli capture attention even when inconsistent with an observer's attentional control set (ACS). Participants in Experiment 1 completed a colour-based go/no-go task, thereby inducing an ACS for the go colour. Go/no-go targets were presented to the left or right of fixation, and shortly before each target a schematic drawing of an emotionally neutral face appeared at fixation gazing to the left or right. As is typically found, although gaze direction was non-predictive of the peripheral target's location, participants responded more quickly to go targets appearing in the gazed-at location than the non-gazed-at location, suggesting these gaze cues captured and directed attention. Capture only occurred for faces drawn in the go colour, however, establishing that attentional capture by neutral gaze cues is contingent on ACSs. To examine the interaction between emotional valence and ACSs, Experiment 2 used the same design, but introduced an emotional manipulation: the expression on the face was either happy or sad. While sad faces replicated the results from Experiment 1, happy faces elicited a cueing effect regardless of the colour they were drawn in, indicating that happy faces are capable of capturing attention even when the face colour is inconsistent with the ACS. In addition to generalizing the conclusions of Gupta et al., the present results suggest that stimuli portraying positive emotions may be of sufficient behavioural relevance that "positivity" is a feature included in all ACSs by default.

Acknowledgement: This work was supported in part by NSERC grants to Naseem Al-Aidroos and Lindsay Plater.

53.307 **Positive and negative empathy exert different effects on the perception of neutral faces with direct and averted gaze**

Sarah D McCrackin[1](sdmccrac@uwaterloo.ca), Roxane J Itier[1]; [1]University of Waterloo

Empathy, the ability to share another's emotional state, is a hallmark of social cognition. Recent evidence suggests there are different neural correlates for sharing negative and positive emotion (so-called negative and positive empathy), but it is unknown how these two empathy types effect face perception. We tracked the time-course of when empathy impacted face perception using event-related potentials (ERPs). As perceiving direct gaze is associated with positive affect and increased emotional awareness, we also investigated the interaction between gaze direction and empathy. On each trial, a sentence eliciting positive, negative, or no empathy (e.g. "Her pet dog was saved/killed/fed yesterday afternoon.") was presented, followed by a direct or averted gaze neutral face picture of the individual described. Participants rated how much empathy they felt, and the valence of their emotional state. Eye-tracking ensured participants read the sentences and fixated on the face eye-region. Mean ERP amplitudes were analysed in 100ms windows post-face presentation (100-800ms) in a preliminary sample (n=31). The Early Posterior Negativity (EPN), an ERP component modulated by facial expressions, was enhanced for faces viewed within the two empathy conditions relative to the neutral condition, despite all faces bearing a neutral expression. Furthermore, relative to neutral trials, positive empathy trials elicited more positive amplitudes at frontal sites from 300-600ms, while negative empathy trials elicited more positive amplitudes at centroparietal sites from 500-800ms. Finally, during the positive empathy condition only, direct gaze elicited smaller EPN amplitudes than averted gaze, and more self-reported empathy (statistical trend). Participants also reported experiencing more positive emotion after viewing direct than averted gaze, and this effect was largest in the positive empathy and neutral conditions. Those results suggest that positive and negative empathy have a distinct spatiotemporal effect on face perception and that gaze direction uniquely interacts with positive empathy.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC Discovery Grant #418431)

53.308 **Gazing into Space: Systematic biases in determining another's fixation distance from eye vergence**

Alysha Nguyen[1](alysha.nguyen@unsw.edu.au), Colin Clifford[1]; [1]School of Psychology, UNSW Sydney, Australia

The eyes of others play a crucial role in social interactions, providing information such as the focus of another's attention, their current thoughts and emotions. Although much research has focussed on understanding how we perceive gaze direction, little has been done on gaze vergence, i.e. the angle between the two eyes. The vergence of the eyes yield potential information about the distance of another's fixation – the more converged someone's eyes are, the closer their object of fixation. We recently reported a systematic bias to perceive gaze as convergent, especially when gaze was directed downwards compared to upwards (Nguyen, Palmer, Otsuka and Clifford, 2018). In the present study, we aimed to determine the fixation distance at which participants perceive a face to be gazing in a stereoscopically simulated three-dimensional environment. Participants were presented with synthetic faces gazing at varying fixation distances and asked to indicate on which one of 10 small spheres the avatar was fixating. The data revealed a systematic underestimation of fixation distance for downwards-averted gaze as well as a limit in discrimination of gaze vergence beyond 35cm. When the faces were inverted, fixation distance was again underestimated for gaze vergence in the observer's lower visual field, this time corresponding to the avatar's upwards gaze. This pattern of results indicates that our bias to underestimate others' fixation distance relies more on our own internal sense of up and down than on that of the other person.

53.309 **Biases in perceived gaze direction using 3D avatars and immersive virtual reality environments.**

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Perceived gaze direction plays a significant role in successful communication between two people (Otsuka, S. et al., 2014). Specifically, eye contact provides information about the type of interaction taking place and regulates behavior accordingly (Tomonaga & Imura, 2010). Previous studies using two-dimensional face models displayed on flat monitors have shown two phenomena: a repulsive effect that causes gaze direction to be perceived shifted opposite to head orientation, and an attractive effect that causes a bias towards head orientation (Gibson & Pick, 1963). Here, using virtual reality, we determined whether or not the two effects persist when faces and their components (eyes) are perceived in three dimensions (3D). In an immersive 3D world, a model is presented with a combination of three head and seven pupil orientations, along with four eye types: Normal (white sclera, grey iris, black pupil), inverted (grey sclera, white iris, black pupil), pupil-only

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(white sclera, black pupil, absence of the iris) and no pupil (white sclera, grey iris, absence of the pupil). We observed a significant repulsive effect in each head rotation in almost all conditions (Wilcoxon Rank Test, p < .05), except for the inverted eyes (p > .156). Reaction times were not significantly different between the normal, no pupil and pupil-only conditions (Kruskal-Wallis, p > .043). However, they were significantly longer in the inverted eyes condition relative to the others (p ≤ .001). The slope of the psychometric function was not significantly different between conditions (Kruskal-Wallis, p = .247). This indicates that task difficulty across conditions was similar. Our results demonstrate that the repulsive effect of head orientation on perceived gaze direction is also present when using 3D virtual displays. Moreover, they suggest that the repulsive effect is caused by the high contrast between the white sclera and the tissue surrounding the eye aperture.

Acknowledgement: CIHR, Autism Research Chair Ontario, NSERC, CFI

53.310 **Unconscious pupillometry: Faces with dilated pupils gain preferential access to visual awareness.** Clara Colombatto[1](clara.colombatto@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

Of all the information we extract when viewing others' faces, one of the most telling is their attentional state: at a glance, we can readily determine both where others are attending, and whether they are attentive (vs. distracted) in the first place. Some of the specific cues to others' attention are relatively obvious (such as a turned head), but others are more visually subtle. For example, attentional engagement (e.g. in the form of heightened vigilance, increased cognitive load, or emotional arousal) can cause one's pupils to dilate. Of course, the difference between seeing someone with dilated vs. constricted pupils is visually subtle, since such stimuli differ by just a fraction of a degree of visual angle. But given that dilated pupils are meaningful signals of others' attentional states, we wondered whether such cues might be prioritized in visual processing — even outside of conscious awareness. To find out, we used continuous flash suppression (CFS) to render invisible faces with either dilated or constricted pupils, and then we measured the time that such stimuli took to break through interocular suppression. Faces with dilated pupils broke into conscious awareness faster than did faces with constricted pupils that were otherwise equated — and a monocular control experiment ruled out response-based interpretations that did not involve visual awareness. Another experiment demonstrated that such stimulus differences only drive visual awareness when represented as pupils, per se: when the identical stimuli were presented instead as (smaller vs. larger) buttons on the actors' shirts, there was no difference in breakthrough times (with a significant interaction). These results collectively demonstrate that pupil dilation facilitates the entry of faces into visual awareness — a case study of how visually subtle stimuli can be prioritized in visual processing when they signal socially powerful properties such as the attention of other agents.

Acknowledgement: BJS was funded by ONR MURI #N00014-16-1-2007.

Perception and Action: Arm movements

Tuesday, May 21, 8:30 am - 12:30 pm, Banyan Breezeway

53.311 **Oculomotor behavior during eye-hand coordination tasks** Tiffany Arango[1](tdarango@gmail.com), Peter J Bex[1]; [1]Psychology Department, College of Science, Northeastern University

Patients with central vision loss often adopt eccentric viewing strategies using a preferred retinal location (PRL) in the absence of functional foveae. Little is known about the oculomotor characteristics of the PRL under binocular eye-hand coordination. We examined PRL location, fixation stability and smooth pursuit under binocular viewing using simulated gaze-contingent scotomas in normally-sighted observers. Participants (N=7) completed two eye-hand coordination tasks in two conditions with gaze-contingent central scotomas. Scotomas were updated at 60Hz refresh rate based on a 500Hz eye tracker. In a fixation task, participants touched a target in the center of the screen with their hand. In a pursuit task, participants followed a horizontally oscillating target with their hand. In the second condition, participants viewed a picture of a hand that moved in same touch positions as previous trials in the fixation and smooth pursuit tasks. Participants completed two runs of each condition. Outcome measures were fixation stability (BCEA, 68%), PRL eccentricity and stability of smooth pursuit. PRL eccentricity increased with scotoma size (p < .001), but BCEA did not vary as function of scotoma size, task or condition (ps > 0.05). There was a significant interaction between run and condition (hand vs picture): PRLs were closer to the target in second run of the hand but not picture condition (p = 0.05). Smooth pursuit stability decreased with increasing scotoma size and was greater in the own hand than picture condition (p < .01). Smooth pursuit but not fixation stability varied as function of scotoma size and hand condition. There was a training effect for PRL location in the hand condition, suggesting that PRL use may adapt under eye-hand coordination. These differences offer insight into how the coupling of eye and hand movement may influence binocular visual function in patients with central vision loss.

Acknowledgement: 1 R01 EY029713

53.312 **Improved motor timing enhances time perception** Jianfei Guo[1](jianfei_guo@brown.edu), Zhaoran Zhang[2], Dagmar Sternad[3,4,5], Joo-Hyun Song[1,6]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University, [2]Department of Bioengineering, Northeastern University, [3]Department of Physics, Northeastern University, [4]Department of Electrical and Computer Engineering, Northeastern University, [5]Department of Biology, Northeastern University, [6]Carney Institute for Brain Science, Brown University

Previous studies demonstrated common timing mechanisms involved in perceptual judgments of time-intervals and performance of simple rhythmic movements (e.g., single-finger or foot tapping). For example, participants who showed larger timing variability in single-finger tapping also demonstrated lower acuity in time perception (Keele et al., 1985). Here, we examined whether motor training requiring complex movements without explicit periodicity affects perceptual judgments of time-intervals. We trained participants to throw a ball to hit a target as accurately as possible in a virtual environment across four-day sessions. We observed that as timing variability in motor performance decreased, the sensitivity of time-interval discrimination increased. Therefore, we demonstrated that improvement of motor timing enhances the sensitivity of time perception. Furthermore, our results suggest that a shared temporal mechanism exists between perception and movement regardless of rhythmicity or complexity of the motor tasks.

Acknowledgement: NSF CAREER Award 1555006

53.313 **Esports Arms Race: Latency and Refresh Rate for Competitive Gaming Tasks** Joohwan Kim[1](imjoohwankim@gmail.com), Josef Spjut[1], Morgan McGuire[1], Alexander Majercik[1], Ben Boudaoud[1], Rachel Albert[1], David Luebke[1]; [1]Nvidia Research

In the world of esports (competitive video games), hardware and software configurations are optimized for winning. In many games this means minimizing latency ('I see you before you see me') and maximizing refresh rate ('I see your move more accurately'). Most esports athletes and competitive players ensure this by using high-end hardware (computers, monitors, and GPUs) while turning off superfluous in-game graphics features. By doing so, one can achieve a latency of 15 ms and a refresh rate of 240 Hz. These figures are remarkable, but do they benefit competitive game players? Gamers have made anecdotal claims favoring 240 Hz, but no scientific studies have yet demonstrated the competitive benefit of modern display technologies. We conducted two studies that compare esports performance using common display settings. The task was to click on a moving target (visual size: 1 deg, speed: 5 deg/sec, direction changing at 1.5 times per sec). Two task versions were used: hitscan (eliminating the target with a single click) and tracking (requiring one sec of accumulated aiming to destroy the target). Experiment 1 compared the effect of refresh rates (60, 120, 240 Hz) using an LCD monitor. The result showed that performance improved monotonically with refresh rate. Experiment 2 further examined whether the effect in Experiment 1 originated from latency only. With the refresh rate fixed to 240 Hz, we added artificial latencies of 0, 4, 8 ms; this created average latencies similar to 240, 120, 60 Hz conditions in Experiment 1. Although performance was worse with longer latency, the effect was less pronounced than seen in Experiment 1. We conclude that 240 hz, today's highest-speed display technology, provides a competitive advantage. We also observed that latency, often considered the more important factor for competitive gaming, can matter less than refresh rate for some tasks.

53.314 **How spatial coding is affected by mid-level visual object properties within and outside of peripersonal space.** Harun Karimpur[1](harun.karimpur@psychol.uni-giessen.de), Filipp Schmidt[1], Katja Fiehler[1]; [1]Experimental Psychology, Justus Liebig University Giessen

We show enhanced behavioral responses to objects in our immediate surround compared to objects outside of reach space. Backed up by many neurophysiological studies this finding established the concept of peripersonal space. Within peripersonal space, we spatially encode objects-for-action based on a combination of egocentric (object-to-self) and allocentric (object-to-object) information. However, it is not clear how the interaction

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between these reference frames is modulated by the affordance of an object and the distance to the observer. This is in line with the recently proposed action-field theory of peripersonal space. Rather to think of an in-or-out zone, the theory defines peripersonal space as a graded field reflecting the context-dependent relevance of our actions which either aim to avoid or approach objects. Here we tested the role of object-affordance in spatial coding for different distances by using a pointing task in virtual reality. We presented a target object surrounded by task-irrelevant landmarks within and outside the participant's peripersonal space. After a brief mask and delay, the landmarks shortly reappeared without the target, either at the same position (baseline) or horizontally shifted. After their disappearance, participants were asked to point to the remembered target object within the empty scene. To manipulate the level of object-affordance, we varied mid-level visual object properties of shape and texture (spiky metallic versus soft rubber ball). We found that reaching endpoints deviated in the direction of landmark shifts suggesting the use of allocentric information. This effect was more strongly affected by mid-level visual object properties within compared to outside of peripersonal space. Our findings suggest that spatial coding in our immediate surround is modulated by object-affordance.

Acknowledgement: International Research Training Group IRTG 1901 "The Brain in Action" funded by the German Research Foundation (DFG), the Center for Mind, Brain and Behavior (CMBB), Collaborative Research Center SFB-TRR-135 "Cardinal Mechanisms of Perception" funded by the German Research Foundation (DFG)

53.315 Humans and Machine Learning Classifiers Can Predict the Goal of an Action Regardless of Social Motivations of the Actor

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How do people predict the actions of others? Does social context affect prediction? What information enables prediction? To answer these questions, two participants (an "initiator" and his/her partner the "responder") played a reaching game while video recorded. The social context was modified by asking the partners to either play competitively or cooperatively. Human subjects watched videos that were cut at different timepoints relative to when the initiator lifted his/her finger and predicted the direction of movement. Further, a support vector machine (SVM) classifier was trained to decode the direction of movement from optical flow of the videos. We found that humans and the SVM could predict the direction of movement well before the movement began. Both performed slightly better in cooperation than competition. An analysis of the speed of movement revealed that the advantage in the cooperative condition was due to slower movements. Finally, the performance of humans and the SVM was similar and correlated suggesting a simple algorithm based on instantaneous optical flow suffices to explain human levels of performance. Next, using a searchlight classification method on the videos, we investigated which pixels were most informative of the goal. The searchlight revealed that information is widely distributed throughout the body of the initiator. Further, the performance of the classifier generalized across social condition highlighting the similarity in the similarity of the distribution of information between cooperation and competition. In conclusion, our results show that subtle bodily adjustments prior to explicit execution of an action reveal action goals. Aside from the speed of movement, social context may not directly affect the availability of information. Thus, not only do we reveal our intentions in cooperation when communicating the goal is beneficial, but our movements may betray our action goals even when there is incentive to conceal the information.

Acknowledgement: NIH DIRP, NSF STC CCF-1231216

53.316 Weight and see: vicarious perception of physical properties in an object lifting task

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In order to engage with the objects we encounter in everyday life we must have accurate estimates of their physical properties (e.g. size, weight, slipperiness, and deformability). How do we discover this information? In some cases, an object's physical properties are readily observable or can be inferred based on previous experience with similar objects. In other cases, latent physical attributes are not accessible to visual inspection alone – for example, a box may be light or heavy depending on its contents. We can learn about latent physical variables by interacting with objects, but there are many more objects in our daily environments than we can interact with directly. Can we also learn about the physical properties of objects by observing others interacting with them? Here, we tested participants' ability to infer the weights of visually indistinguishable containers by watching actors lift them. Stimuli consisted of video clips of four actors lifting a set of metal canisters that were identical in appearance but varied in weight from 100-900 grams in increments of 100g. On each trial, participants were presented with a pair of lifting clips and asked to determine which canister was heavier. We found that participants were readily able to discriminate even small differences in the lifted weights, even without any training. Strikingly, participants were just as good at discriminating the weights of objects lifted by two different actors as they were when viewing two clips from the same actor, indicating that they can capitalize on visual cues to weight that are common across actors rather than idiosyncratic to the lifting behavior of particular individuals. These findings demonstrate that we can use our perception of others' behaviors to learn about the physical structure of the environment, and point toward a key role of action observation in physical scene understanding.

53.317 Influence of Gaze Direction on Hand Location and Orientation in a Memory-Guided Alignment Task

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Although eye-hand coordination and grasp have been studied extensively, the influence of gaze direction on the ability to align one's hand to a seen or remembered object is unclear. In this study, we investigated how gaze direction affects location and orientation errors in a memory-guided alignment task. Participants (N=16) were asked to reach and align an elongated rectangular object to a matching rectangular outline presented at the center of a computer screen in three possible orientations: 0o (horizontal), +45o (CCW) and -45o (CW). Gaze fixation was either central or 13o left/right. The target outline was either presented briefly in complete darkness (memory task) or remained illuminated along with visual feedback of the hand (visual task). Comparing the memory task to the visual control task, there was a significant main effect of gaze location: participants aimed further to the right of the target when fixating to the left (a 'gaze-dependent overshoot'). There was also an interaction between gaze location and orientation: when participants looked to the right, they over-rotated (too CCW for -45o and too CW for +45o), whereas when they looked to the left, they under-rotated (too CW for -45o and too CCW for +45o). In addition, there were significant interactions between task, orientation, and gaze position for variable errors. As expected, location was more precise in the visual task, and location was relatively more precise during central gaze fixation in both tasks. Likewise, orientation was more precise in the visual task, but for most target orientations central fixation only provided an advantage in the visual task. In other words, fixating a remembered target provided less advantage for orienting precision than location. Overall, our location results confirm the gaze-dependencies observed in previous pointing studies, and our orientation results reveal several additional interactions between vision, memory and gaze during manual alignment.

Acknowledgement: Canadian Institutes for Health Research

53.318 Effects of Observation on Visuomotor Generalization

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Our ability to learn and generalize new motor skills (e.g. driving) is a fundamental aspect of human behavior and is often critical for daily function. Prior work has demonstrated that in addition to physical practice, observation of others can facilitate acquisition of novel motor skills. Here, we examined if and how the benefits of observational learning extend to transferring acquired motor skills to novel contexts using a visuomotor adaptation task. In an initial observation phase, participants watched a short movie in which an actor demonstrated one of two visuomotor actions. The rotation group observed the actor adapting to a cursor rotated 45° from their hand movement, whereas the no-rotation group watched videos without any cursor rotation. In the subsequent training phase, each participant adapted to a 45° rotation of the cursor to the same target as the actor in the video. In the final generalization phase, participants attempted to transfer their motor adaptation to untrained target locations. The rotation group showed improved generalization of their visuomotor adaptation compared to the no-rotation group at both trained and untrained target locations. We further demonstrated that observation of rotation allowed participants to develop a stronger aiming strategy. Taken together, we suggest that observational learning facilitates explicit strategy formation, leading to an overall enhancement of visuomotor generalization.

Acknowledgement: NSF Career Award 1555006

53.319 **Compulsory social interpretation of giving but not of taking actions: Evidence from modulation of lower alpha oscillations** Jun Yin[1](yinjun1@nbu.edu.cn), Gergely Csibra[2]; [1]Department of Psychology, Ningbo University, [2]Cognitive Development Center, Department of Psychology, Central European University

Transferring resources among kin and non-kin is ubiquitous in all human societies. A common form of resource transfer is achieved by the act of giving, during which a resource is passed on between two agents: an actor who gives and a recipient. Both linguistic expressions and infant's studies implied that the giving act is represented as an instance of a social interaction, even in the absence of other cues of social engagement. It is not yet known whether adult observers would also interpret a skeletal act of giving as a social interaction. To assess how the participants interpreted the events, we exploited the fact that the mu rhythm (also known as the sensorimotor alpha rhythm, 8-13 Hz) of the electroencephalogram (EEG) can reflect action understanding. In two experiments we found that specific features of animated events modulated alpha-band neural activity over the right centro-parietal cortex of observers. In particular, contingent interaction among agents, which converted a following action into a chasing action, enhanced the attenuation of alpha band oscillations, and so did the reversal of the direction of a resource transfer action, which converted a taking action to a giving action. Importantly, such an effect was not observable when these action interpretations were disrupted by spatial separation of the agents, which disallowed perceiving their contingent interaction as chasing, or by replacing the target of a resource transfer with an inanimate recipient, which excluded the possibility of perceiving the transfer as an instance of giving. The comparison between chasing and following suggested that the attenuation of alpha oscillations can be used to assess the perceived level of social interaction. Hence, we demonstrated that observed giving actions are perceived as social interactions, irrespective of the contribution of the recipient.

Acknowledgement: National Natural Science Foundation of China (Grant no. 31600871) Advanced Investigator Grant of the European Research Council (#742231, PARTNERS)

Perception and Action: Affordances

Tuesday, May 21, 8:30 am - 12:30 pm, Banyan Breezeway

53.320 **Seeing what's possible: Disconnected visual 'parts' are confused for their potential 'wholes'** Chenxiao Guan[1](chenxiao@jhu.edu), Chaz Firestone[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

Perception research traditionally investigates how actual states of the world are seen — how we perceive the shapes, colors, and locations that objects actually have. By contrast, everyday life provokes us to consider possible states of the world that have not yet (and may not ever) actually obtain. For example, when assembling furniture or completing a jigsaw puzzle, we may appreciate not only the particular shapes of individual objects, but also their potential to combine into new objects with distinct shapes of their own. What is the nature of this experience? Here, we explore how visual processing extracts not only what objects are, but also what they could become. Our previous work showed that, for extremely simple displays, pairs of geometrically compatible objects prime their potential completions, such that (e.g.) two puzzle pieces activate representations of a completed puzzle. Here, we explore how the mind literally confuses potential objects for real ones. In 5 experiments inspired by the puzzle game Tetris, subjects had to respond to a particular target within a stream of distracting "tetrominoes"; surprisingly, subjects false-alarmed more often to pairs of tetrominoes that could create their target than to pairs of tetrominoes that couldn't — essentially representing possible objects as if they were physically present on the display. This pattern held for several types of objects and transformations, and could not be explained by previously known factors, such as spatial alignment, representational momentum due to imputed gravity, or various forms of response bias. We suggest that possible states of the world can not only be contemplated in moments of deliberate reflection, but also automatically represented by more basic mechanisms of perception and attention.

Acknowledgement: JHU Science of Learning Institute

53.321 **Processing Speed for Semantic Features and Affordances** Tyler A Surber[1](tyler.surber@usm.edu), Mark Huff[1], Mary Brown[1], Joseph D Clark[1], Catherine Dowell[1], Alen Hajnal[1]; [1]University of Southern Mississippi

Gibson (1979) conjectured that perception of affordances involves detecting meaningful possibilities for action. Is the meaning obtained when an affordance is perceived qualitatively different from other types of semantic knowledge? Pilot investigations in our lab have discovered that affordance primes are processed slower than semantic features and non-associates in a linguistic semantic-categorization task that presented words on a computer screen. The slower processing of affordance primes might be due to the fact that affordances are typically encountered through our senses, and not as linguistic information. Chainay and Humphreys (2002) found that action knowledge was processed faster when objects were presented as pictures rather than words. Sensory information (pictures over words) may therefore be more relevant to action. For the present study, we hypothesized that pictorial depictions of objects might be better suited for facilitating affordance-based priming than linguistic information such as reading words on a computer screen. We investigated the effects of affordance priming using a spatial categorization task. 81 object nouns were compiled from the McRae et al. (2005) norms. We used photographs of objects drawn from the database compiled by as visual stimuli (Brodeur, Dionne-Dostie, Montreuil,& Lepage, 2010). Affordances denoted possibilities for action in relation to objects (e.g. sit – chair), whereas semantic features indicated definitional characteristics (e.g. has legs – chair). Participants were presented with a prime and asked to respond by indicating whether the presented target object could fit inside of a shoebox (Bowers & Turner, 2003). We manipulated image quality at three levels of blur to assess differential effects of the fidelity of visual information. Results showed that blurry images were processed the slowest. Consistent with our hypothesis, affordances were processed faster than control stimuli across all levels of image quality, suggesting that the availability of affordance versus feature information may facilitate processing of visual objects.

53.322 **Near-hand effects are robust: Three OSF pre-registered replications of visual biases in perihand space** Morgan N Jacoby[1](morgan.jacoby@ndsu.edu), Stephen J Agauas[1], Laura E Thomas[1]; [1]Department of Psychology, College of Science and Mathematics, North Dakota State University

Previous work provides evidence that observers experience visual processing changes when they view stimuli in perihand space. For example, participants show facilitated target detection near the hands and enhanced visual working memory for orientation, but not color, information. However, recent investigations have questioned the reliability of these near-hand effects (Adringa et al., 2018; Dosso & Kingstone, 2018). We addressed this controversy by running three experiments pre-registered through the Open Science Framework. Experiment 1 was a direct replication of the seminal study on facilitated target detection near the hands (Reed et al., 2006, Experiment 1) in which participants performed the Posner attentional orienting paradigm while placing a single hand either near or far from the display. Experiment 2 was a direct replication of a recent experiment that failed to find near-hand facilitation in the same paradigm (Dosso & Kingstone, 2018, Experiment 4). Finally, Experiment 3 was a direct replication of a study in which hand proximity influenced working memory performance in a change detection paradigm (Kelly & Brockmole, 2014). Although the pattern of results we found across experiments differed from the original studies, critically, across all three experiments we found significant interactions that imply the hands' presence altered visual processing. More specifically, in Experiment 1 target detection times changed depending upon whether participants did or did not place a single hand near the display. Interestingly, we found a similar pattern of results in Experiment 2, failing to replicate Dosso & Kingstone's (2018) finding that the hands did not affect performance in this paradigm. In Experiment 3, participants' performance in detecting orientation versus color changes differed depending upon whether they held both hands near the display or placed their hands in their laps. Taken together, our pre-registered replications bolster evidence favoring the robustness of near-hand effects.

Acknowledgement: NSF BCS1556336, NIGMS P20-GM103505

53.323 **Posture Affects Affordance Perception of Reachability in Virtual Reality** Hannah L Masoner[1](hannah.masoner@usm.edu), Joseph D Clark[1], Catherine J Dowell[1], Tyler A Surber[1], Alen Hajnal[1]; [1]Psychology, University of Southern Mississippi

Tasks such as walking, reaching, and standing require differing levels of postural stability. Postural equilibrium is necessary to perceive the location of objects (Lee, Pacheco, & Newell, 2018). This study compared affordance

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(Gibson, 1979) judgements of reachability between tasks that place different constraints on maintaining balance. The method included a 3D virtual reality (VR) environment with a stimulus object placed at different distances from the observer. Using a within subjects design, participants were asked to make judgements on reachability while in a standard stance condition as well as two separate active balance conditions (yoga tree pose, and toe-to-heel pose). Feedback on accuracy was not provided, and participants were not allowed to attempt to reach. Response time, affordance judgments (reachable, not reachable), and head movements were recorded on each trial. Specifically, head movement time series were recorded by harnessing position data from the Oculus Rift VR goggles. Consistent with recent research on reaching ability (Weast & Proffitt, 2018), the reachability boundary occurred around 120% of arm length, indicating overestimation of action capability. Response times increased with distance, and were smallest for the most difficult yoga tree pose, suggesting that in order to maintain a difficult pose, responding had to be sped up. Head movement amplitude and total amount of movements increased with increases in balance demands. Surprisingly, the coefficient of variation was comparable in the two poses that had increased balance requirements, and was more extreme in a less constrained, ostensibly easier pose for the shortest and longest distances, indicating a pose by distance interaction. The insights gathered from this study will provide a fuller understanding of the perception of affordances in everyday tasks such as reaching and grasping.

53.324 **Graspable objects grab attention more than images do – even when no motor response is required** Pedro Sztybel[1111](sztybelpedro@gmail.com), Michael A. Gomez[1111], Jacqueline C. Snow[1111]; [1]The University of Nevada, Reno

Recent research from our lab has shown that real-world objects can bias attention and influence manual responses more strongly than computerized images. Specifically, using a flanker task, we showed that response times (RT) for real graspable objects were slower overall, and elicited greater flanker interference effects, compared with RTs for matched two-dimensional (2-D) or three-dimensional (3-D) images of the same objects; however, when the real objects were placed out of reach or behind a transparent barrier, overall RTs and flanker interference effects were comparable with images (Gomez, Skiba and Snow, 2017). A potential explanation for these results is that graspable objects (but not images) capture attention because they afford manual interaction, and the action required to respond to the central target (i.e., a button-press) conflicts with the motor plan generated by the irrelevant real object flanker (i.e., a grasp). This leads to the prediction that when a manual response is not required to complete a task, differences in attentional capture should remain, whereas overall RTs should be comparable across display formats. To test this prediction, we used an exogenous spatial cueing paradigm and compared capture effects for real objects versus matched 2-D and 3-D images of the same items, where the task required a verbal (instead of manual) response. We found that the real objects elicited a stronger spatial cueing effect compared to both the 2-D and 3-D images, but overall RTs were comparable across display formats. These findings replicate previous results from our lab showing that real-world graspable objects capture attention more so than 2-D or 3-D images, and further demonstrate that the attentional effect persists even when no motor response is required to complete the task.

Acknowledgement: NIH grant R01EY026701 awarded to J.C.S.

53.325 **Similarities and differences in the representation of real objects, 2-D images, and 3-D augmented reality displays: Insights from inverse multidimensional scaling** Desiree E Holler[1](DesireeHoller@gmail.com), Sara Fabbri[1,2], Jacqueline C. Snow[1]; [1]The University of Nevada, Reno, [2]University of Groningen, Netherlands

Images of objects are commonly used as proxies to understand the organization of conceptual knowledge in the human brain. However, recent studies from our laboratory have highlighted differences between images and real objects at the level of neural representations, as well as in their contribution to memory, attention, and decision-making. Asking an observer to make judgments about the similarities among a set of objects can provide unique insights into the nature of the underlying representations of those objects in human cortex (Mur et al, 2013). Here, we used inverse multidimensional scaling (Kriegeskorte and Mur 2012) to investigate whether the subjective properties that observers use to characterize objects during free-sorting are dependent on display format. Observers arranged 21 different objects so that the distances between them reflected their perceived dissimilarities. Critically, one group of participants sorted 2-D images of the objects on a computer monitor using a mouse drag-and-drop action; another group manually sorted objects presented using AR; the remaining group manually sorted real-world exemplars. Participants were free to use any dimension they liked to group the items. By correlating models based on the various sorting criteria, and the dissimilarity matrix obtained by the behavioral ratings, we identified the properties that observers used to separate the items in each format. We found that object representations depended on the format in which objects were displayed. 2-D images of objects were sorted primarily with respect to the conceptual property of typical location. AR objects were sorted according to their physical size and weight properties, but less so according to conceptual properties. Real objects, unlike 2-D images and AR stimuli, were sorted with respect to both their conceptual (typical location) and physical properties (size, weight). Real-world objects are coded in a richer, more multidimensional, property space compared to computerized images.

Acknowledgement: NIH grant R01EY026701 awarded to J.C.S

53.326 **Maintaining the ability to pursue moving targets during repeated interception tasks** Nathaniel V Powell[1](powein@rpi.edu), Scott T Steinmetz[1], Oliver W Layton[2], Brett R Fajen[1]; [1]Cognitive Science Department, Rensselaer Polytechnic Institute, [2]Department of Computer Science, Colby College

An important but often neglected aspect of locomotor interception is knowing which targets to chase and which to let go. Sometimes targets are moving too quickly to catch; others are catchable but only by sprinting, leaving oneself with temporarily diminished capabilities for pursuing future targets. The aim of this study was to investigate whether humans are perceptually attuned to the immediate and longer-term effects of fatigue on their ability to catch targets. On each trial, a target in a desktop virtual environment moved through a field and had to be caught before it reached a forest. Subjects were instructed to catch as many targets as possible in blocks lasting five minutes each. Fatigue was simulated by cumulatively decreasing the gain on the speed controller when it was maximally displaced. Subjects could also recover by resting, but the block timer continued to count down as they did so. In the Carryover condition, energy level carried over from one trial to the next, so subjects had to decide whether pursuing a target on one trial was worth the diminished ability to pursue the next target. Performance was compared to that in a No Carryover condition in which energy level was reset on each trial. Subjects refrained from pursuing catchable targets more often in the Carryover condition, revealing sensitivity to the influence of fatigue on their ability to catch future targets. There was also a third, Fixed Energy condition in which energy level remained constant throughout the entire block. Interestingly, behavior in No Carryover and Fixed Energy conditions was similar, suggesting that subjects were relatively insensitive to the effects of fatigue on the catchability of the current target. We consider the implications for the affordance-based control of locomotor interception, particularly for tasks that involve repeatedly intercepting moving targets.

Acknowledgement: ONR N00014-18-1-2283

53.327 **Does Avatar Presence Facilitate Affordance Judgments from Different Perspectives?** Morgan A Saxon[1](morgan.saxon@psych.utah.edu), Brandon J Thomas[1,2], Jeanine K Stefanucci[1], Sarah H Creem-Regehr[1]; [1]Department of Psychology, University of Utah, [2]Department of Psychology, University of Wisconsin-Whitewater

Previous research shows individuals are accurate at judging their own affordances as well as the affordances of others. In the current study, we used immersive virtual reality to investigate individuals' abilities to judge affordances from a perspective other than their own. In addition, we tested whether the presence of a human avatar facilitated participants' abilities to make those judgments. Within a virtual room, participants (N = 45) sat at a table and judged whether a ball was reachable from their own perspective (block 1) or another perspective (blocks 2 and 3, counterbalanced). To reliably evoke perspective-taking, we asked participants to make a judgment of whether the ball was reachable with either the right or left hand or not reachable with either hand. We varied ball distance and angle in all blocks. In blocks 2 and 3, either a chair or a chair with an avatar present also appeared at various angles (90°, 120°, 150°, 180°, 210°, 250°, 270°) around the table. We asked participants to imagine they were sitting at the position of the chair or the avatar at its current position to make the reaching affordance judgment. Results showed an effect for avatar presence, with participants responding faster when the avatar was present compared to when the chair was empty. We also found different reaction patterns as a function of degree of rotation, when the avatar was present versus absent. With the avatar, reaction times increased as angle of disparity from the viewer's location increased. Without the avatar, there was not as clear a response time function, with increased

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response time at 90 and 270 degree rotations. The results suggest that perspective-taking to judge reach affordances from a new viewpoint is facilitated by the presence of an avatar.

53.328 **The activation of structure- and function-based action representations in manipulable object naming: An EEG study**
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Previous ERP researches showed that structure-based action representation was faster-rising in early object processing stage, but more evanescent than function-based action representation whose activation maintained in semantic processing stage (Lee et al., 2018). But function-based action representation also activated in early object processing and maintain in semantic processing in object naming (Sim et al., 2015). It was unclear whether structure-based action representation still activated in early processing and decayed in semantic processing in object naming. Besides, it was uncertain whether the activation of two action representations is accompanied by mu rhythm desynchronization in sensorimotor area, which was observed in manipulable object process (Proverbio, 2012). With a priming paradigm, a hand action movie clip and a manipulable object were presented sequentially and participants were asked to name the object after an answer cue as accurately as possible. The hand actions, including structure- and function-based actions, were congruent or incongruent with the following objects. ERPs and ERD over central-parietal scalp were measured to examine brain activation in object naming. The results showed that: 1) in early processing, no action priming effect was found; in P300 window, only structure-based action priming effect was found: P300 amplitude was marginally significantly positive in congruent than that in incongruent condition; in semantic processing, bilateral structure-based action priming effects and right-lateral function-based action priming effects were found: N400 amplitude was significantly negative in congruent than in incongruent condition. 2) In addition, mu rhythm desynchronization was only found in function-based action representation over left central scalp. The results suggested that: 1) even though structure-based action representation did not activate in early processing, its activation was still faster than that of function-based action representation, and both maintained in semantic processing in object naming; 2) mu rhythm desynchronization in function-based action representation inferred distinct mechanism of two action representations.

Acknowledgement: This research was supported by the grant of the National Natural Science Foundation of China (Grant No. 61632004, 61773379, and 61375009) and the grant of the German Research Foundation (DFG) and the National Natural Science Foundation of China in project Crossmodal Learning (NSFC61621136008/ DFGTRR-169).

Binocular Vision: Surfaces

Tuesday, May 21, 8:30 am - 12:30 pm, Banyan Breezeway

53.329 **Slant perception in the presence of curvature distortion**
Jonathan Tong[1](tongj86@yorku.ca), Robert S Allison[2], Laurie M Wilcox[1]; [1]Department of Psychology and Centre for Vision Research, York University, Toronto, Ontario, Canada, [2]Department of Electrical Engineering and Computer Science, York University, Toronto, Ontario, Canada

In the absence of reliable and abundant depth cues, estimates of surface slant are often biased towards fronto-parallel. Here we investigate the effects of curvature distortions on perceived slant. In general, curvature distortions are predicted to decrease the precision of slant discrimination, and this uncertainty may, in turn, strengthen the fronto-parallel bias. Alternatively, curvature distortion might bias slant perception independently, or in the opposite direction, of the fronto-parallel bias. We rendered images of slanted, textured surfaces with and without radially symmetric distortions (pincushion and barrel) at low (≈1%) and high (≈5%) levels. Observers judged whether a test image (distorted or undistorted, with a variety of slants) was more slanted than a distortion-free surface with a 15° slant. We fit the psychometric data with a cumulative normal function and estimated bias and discrimination thresholds for each observer. Our results showed that 1% distortion had no measurable impact on slant discrimination. At 5%, both types of distortion significantly increased slant discrimination thresholds. However, only the pincushion distortion produced a systematic underestimation of perceived slant. Slant underestimation in the presence of pincushion distortion is consistent with the hypothesized effect of disparity smoothing operations. Under this hypothesis, slant should also be underestimated in the barrel distortion condition but it is not. To test the possibility that this type of curvature distortion introduces additional perceptual biases, in ongoing experiments we are measuring perceived slant magnitude in the presence and absence of curvature distortion. These suprathreshold estimates will provide a baseline for the fronto-parallel bias in isolation; additional biases in the distortion conditions could then be modelled as distortion-based effects.

Acknowledgement: NSERC grant CRDPJ 523632-18, CFREF Vision: Science to Applications program

53.330 **The Role of Binocular Vision in Stepping over Obstacles and Gaps in Virtual Environment**
Robert Allison[1, 2](allison@cse.yorku.ca), Jingbo Zhao[1, 2]; [1]Dept. of Electrical Engineering and Computer Science, York University, Canada, [2]Centre for Vision Research, York University, Canada

Little is known about the role of stereopsis in locomotion activities, such as continuous walking and running. While previous studies have shown that stereopsis improves the accuracy of lower limb movements while walking in constrained spaces, it is still unclear whether stereopsis aids continuous locomotion during extended motion over longer distance. We conducted two walking experiments in virtual environments to investigate the role of binocular vision in avoiding virtual obstacles and traversing virtual gaps during continuous walking. The virtual environments were presented on a novel projected display known as the Wide Immersive Stereo Environment (WISE) and the participant locomoted through them on a linear treadmill. This experiment setup provided us with a unique advantage of simulating long-distance walking through an extended environment. In Experiment 1, along each 100-m path were thirty virtual obstacles, ten each at heights of 0.1 m, 0.2 m or 0.3 m, in random order. In Experiment 2, along each 100-m path were thirty virtual gaps, either 0.2 m, 0.3 m or 0.4 m across. During experimental sessions, participants were asked to walk at a constant speed of 2 km/h under both stereoscopic viewing and non-stereoscopic viewing conditions and step over virtual obstacles or gaps when necessary. By analyzing the gait parameters, such as stride height and stride length, we found that stereoscopic vision helped people to make more accurate steps over virtual obstacles and gaps during continuous walking.

Acknowledgement: NSERC Discovery Grant, Canadian Foundation for Innovation, and the CFREF Vision Science to Applications (VISTA) program

53.331 **Contrast scaling of perceived depth from disparity depends on both global surface configuration and disparity gradient**
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The perceived depth from disparity in random-dot stereogram depends on both luminance contrast and the spatial frequency (SF) of depth modulation (Chen et al., 2016). Here, we varied the number of cycles to investigate whether this effect may be due to local disparity gradient or global surface configuration. The test stimuli were rectangular random dot stereograms (1.27 x 3.44 degree) with three kinds of surface configuration: (a) a low SF (0.29 cy/deg) single-cycle cosine bulge, (b) a high SF (0.87 cy/deg) single-cycle cosine bulge, and (c) a high SF (0.87 cy/deg) three-cycle corrugated surface. For each surface configuration, maximum test disparity ranged from -20 to 20 arcmin while luminance contrast ranged from 5% to 80%. The observers adjusted the length of a horizontal bar to match the perceived depth in the test stimuli. In all conditions, the perceived depth for both near and far disparities was an inverted-U shape matching function of physical disparity. As in our previous study, both the perceived depth magnitude and the disparity of the peak of the matching function increased sigmoidally with luminance contrast. Both the magnitude and peak disparity were the largest for high SF single-cycle bulge followed by the low SF single-cycle bulge, and then the three-cycle corrugated surface. Our results suggest that not only local disparity gradient but also global surface configuration affects disparity processing. Such effects can be captured by a multiple-stage model in which the perceived depth is determined by the weighted average of several nonlinear contrast gain control mechanisms, each with a different disparity selectivity. Furthermore, since more than one disparity lies in the channel receptive field, the response of the cells vary with disparity gradient, hence, generating different perceived depth for different surface configurations.

Acknowledgement: MOST(Taiwan) 107-2420-H-002-029-DR

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53.332 **The role of boundary contours in suprathreshold binocular perception of contrast and spatial phase**

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Boundary contours play a crucial role in representing smooth, texture-free binocular surfaces.However, less is known about their influence on perceived binocular contrast and spatial phase of surfaces with textures, such as grating surfaces. We investigated this by designing two generic binocular surface stimuli differing in boundary contour content (supplemental material). In Experiment 1, the (a) binocular boundary contour (BBC) stimulus had a central square region (1x1 deg) surrounded by a larger background (8x8 deg) with 3 cpd sinusoidal grating.The central square was created by phase-shifting the central grating region (20.0% contrast) 45 deg above the green horizontal reference lines in one half-image, and 45 deg below in the other half-image (50.1% contrast). The (b) monocular boundary contour (MBC) stimulus had a central square region with 20.0% contrast in one half-image (phase-shifted 90 deg relative to surrounding background grating), while the other half-image comprised the background grating with 50.1% contrast. We measured perceived binocular contrast of the central square region by varying contrast (QUEST) of a comparison stimulus.We found perceived contrast of the BBC stimulus reflected that of the grating patch with high contrast (50.1%).But surprisingly, perceived contrast of the MBC stimulus reflected that of the MBC grating patch (20.0%), rather than the high contrast (50.1%) of the uniform grating background in the fellow eye.In Experiment 2, both stimuli's contrast was set at 31.6%.We measured perceived spatial phase of the grating patch using the staircase method. We also found the spatial phase of the MBC grating patch had a dominant role in determining perceived spatial phase.However, for the BBC stimulus, perceived spatial phase of the central grating depended on both dichoptic grating patches. Overall, both experiments indicate MBC renders the grating patch dominant over the uniform grating without boundary contour for binocular surface representation.

Acknowledgement: NIH Grant EY023561 and EY023374

53.333 **Effects of context on the visual stability of depth edges in natural scenes**

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Binocular fusion relies on matching points in the two eyes that correspond to the same physical feature in the world. Not all features, however, create binocularly similar, or even binocularly paired, retinal projections. In particular, features without binocular projections frequently occur at depth edges. While unmatched features can impede fusion and result in interocular competition, the monocular features at depth edges are often perceptually stable. Previous work has shown that this visual stability breaks down if the stimulus is not geometrically plausible, suggesting that the visual system exploits geometric regularities when determining whether features are binocularly or monocularly visible. We investigated the hypothesis that natural depth edges contain not just geometric regularities, but also luminance regularities between neighboring monocularly and binocularly visible regions. We sampled a large set of stereoscopic image patches containing depth edges from a natural image database with co-registered distance measurements. Monocular regions in these patches tended to belong to the background and to share visual features with the adjacent binocular background, but not with the adjacent binocular foreground. In a perceptual experiment, observers rated the visual stability of each patch, which was used as a measure for lack of interocular competition. Stability was well predicted by the magnitude of the depth discontinuity and, more interestingly, by the magnitude of the luminance change across the edge. A large luminance change where the monocular region adjoined the binocular foreground predicted higher stability, whereas a large change where the monocular region adjoined the binocular background predicted lower stability. In other words, perception was more stable when the visual context was statistically likely. Together, these results suggest that the visual system uses ecologically-valid assumptions in determining whether features are monocularly or binocularly visible. This strategy may reduce interocular competition during natural vision and facilitate stable perception of depth edges.

53.334 **Perceptual grouping disrupted by neural processing at different levels of the visual system**

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Grouping separate regions with similar feature components is critical for forming coherent percepts of whole objects and complete scenes. When these components are ambiguous, they all may be perceived as identical in all regions despite different neural representations for each region (Kovács et al., PNAS 1996; Slezak & Shevell, JOSA A 2018). In general, perceptual ambiguity may be resolved by monocularly-driven or binocularly-driven neural mechanisms. This study presented two discs, each one designed to induce ambiguity at a different level of neural representation, to determine if a grouping process can act on different kinds of competing neural representations. Alternatively, the difference in neural level of representation may inhibit grouping. METHOD Two equiluminant chromatic discs were presented above and below a fixation cross, one using standard binocular rivalry (SBR) and one using interocular-switch rivalry (ISR; Christiansen et al., JOV 2017). Observers reported when both discs appeared the same color. This "mixed-method" measurement was tested in conjunction with conditions presenting both discs using only one method (either both ISR or both SBR, the latter with separate conventional and patchwork trials (as in Kovács et al., PNAS 1996)). To assess the null hypothesis of no grouping, independence predictions were determined by measuring percepts of the top or bottom disc presented alone. RESULTS/CONCLUSIONS All five observers showed significant grouping for discs presented in the same method, no matter whether SBR or ISR (14 of 15 contrasts significant, each at $p< 0.05$). On the other hand, four of the five observers showed no significant difference between the independence prediction and the "mixed-method" measurements ($p>0.05$). These results support the view that grouping consistently occurs when two rivalrous discs are resolved at the same neural level, but less so or not at all when the discs are resolved by neural processes at different levels of the visual system.

Acknowledgement: Supported by NIH EY-026618

53.335 **High processing load of foveal crowding affects binocular summation but can be eliminated by target's tagging**

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Introduction: In perceptual crowding, a letter that is easily recognized on its own becomes unrecognizable if surrounded by other letters. It's widely agreed that crowding is robust in the periphery but is almost absent in the fovea. However, recently it was shown (Lev, Yehezkel & Polat, 2014) that crowding occurs in the fovea, when the stimulus is presented for a very short time. Study of crowding in amblyopic eyes (Bonneh, Sagi & Polat, 2003), found that tagging the target with color reduced crowding. In the current study we tested whether tagging the target with color letter reduce crowding in the fovea of subjects with normal vision and whether crowding affects binocular summation. Methods: Letter E with different orientations was briefly presented (40 ms) at the fovea (n=10), either in isolation (single condition) or surrounded by an array of other randomly rotated E letters (crowded condition), with the same or distinct color of the target (pop-out condition). All conditions were mixed by trials. The stimuli were presented via stereoscopic glasses to test binocular summation. Event-related potential (ERPs) were recorded during the experiment. Results: We found a remarkable crowding effect at the fovea, that was significantly reduced for the color target in the pop-out condition. Interestingly, while binocular summation was as expected about 40% it was significantly reduced and almost absent under crowding condition. We found a difference in time and amplitude of some of the ERP components for the crowded conditions, especially in the occipital electrodes. Conclusions: our results are consistent with the notion that the crowding effect produces high processing load and a bottleneck on visual processing, which interferes with other processes such as binocular summation. Interestingly, tagging the target with a distinct color can eliminate or reduce the crowding effect and recover binocular summation.

Acknowledgement: ISF (1825/16)

53.336 **An unexpected spontaneous Pulfrich phenomenon in amblyopia**

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The binocular viewing of a fronto-parallel pendulum with a reduced luminance in one eye results in the illusory tridimensional percept of the pendulum following an elliptical orbit in depth, the so-called Pulfrich

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phenomenon (Pulfrich, 1922). A small percentage of mild anisometropic amblyopes who have rudimentary stereo are known to experience a spontaneous Pulfrich phenomenon, which posits a delay in the cortical processing of information involving their amblyopic eye. In order to characterize this posited delay, we used a paradigm where a cylinder rotating in depth, defined by moving Gabor patches at different disparities (i.e. at different interocular phases), generates a strong to ambiguous depth percept. This paradigm allows one to accurately measure a spontaneous Pulfrich effect (i.e. PSE≠0) and to determine how it depends on the spatio-temporal properties of stimulus. We observed a spontaneous Pulfrich phenomenon in amblyopia which has been posited to be due to an interocular delay associated with amblyopic processing. Surprisingly, the posited delay was not always associated with amblyopic processing, was not a consequence of the reduced contrast sensitivity of the amblyopic eye and displayed a large variability across amblyopic observers. Increasing the density, decreasing the spatial frequency or increasing the speed of the stimulus tend to reduce the posited delay. As previously observed in controls, this delay can also be reduced or increased by a monocular manipulation of the contrast or the luminance of the stimulus. The spontaneous Pulfrich phenomenon see by some amblyopes is variable and depends on the spatio-temporal properties of the stimulus which complicates any explanation in terms of a fixed processing delay.

Acknowledgement: Canadian Institutes of Health Research (228103) and ERA-NET NEURON (JTC 2015) to RFH

53.337 **The Origins of Human Complex Arithmetic Abilities: Involvement of Evolutionarily Ancient Brain Circuits** William Saban[1](williamsaban@gmail.com), Asael Y. Sklar [2], Ran R. Hassin [3], Shai Gabay [1]; [1]Department of Psychology and the Institute of Information Processing and Decision Making (IIPDM), University of Haifa, Israel., [2]Department of Psychology, Hebrew University, Jerusalem, Israel., [3]Department of Psychology, and the Center for the Study of Rationality, Hebrew University, Jerusalem, Israel.

Humans exhibit exclusive complex arithmetic abilities, which are attributed to our exceptionally large neocortex. However, ubiquitous-primitive mechanisms (i.e., subcortical) are involved in basic numerical abilities both in humans and other species. Those basic numerical skills are the foundation for humans' advanced arithmetic abilities. Hence, the remaining outstanding question is whether subcortical brain regions are not only involved in rudimentary numerical skills but also have a functional role in complex arithmetic calculations? In four different experiments, we explored whether primitive monocular (mostly subcortical) channels have a functional role in arithmetic calculations. Participants did a verification task in which they were asked to evaluate arithmetical statements composed of three digits and a solution (e.g., 9-5-3=1) as either correct or incorrect. Using a stereoscope, the equations were displayed in three Numbers eye-of-origin conditions: (i) the whole equation was presented to a single eye or (ii) the calculation term (left side of the equation) was presented to one eye and the solution to a different eye or (iii) one digit of the calculation term was presented to a different eye than the rest of the digits. The pattern of results demonstrates that presenting one digit of the calculation term to a different eye hamper performance. In contrast to most literature, the current findings provide a converging evidence for the causal relation between a unique human cultural product, such as arithmetic calculations abilities, and primitive-ubiquitous subcortical brain regions. We propose that human's complex arithmetic abilities are founded upon lower evolutionarily ancient brain circuits.

53.338 **How ambiguity helps to understand metaperception - Similar EEG correlates of geometry and emotion processing** Ellen Joos[1,2,3,4](ellen.joos2014@gmail.com), Anne Giersch[2], Lukas Hecker[2,3,4], Julia Schipp[2,3,4], Ludger Tebartz van Elst[2,3], Juergen Kornmeier[2,3,4]; [1]INSERM U1114, Cognitive Neuropsychology and Pathophysiology of Schizophrenia, University of Strasbourg, France, [2]Department of Psychiatry and Psychotherapy, Medical Center, University of Freiburg, Germany, [3]Faculty of Medicine, University of Freiburg, Germany, [4]Institute for Frontier Areas of Psychology and Mental Health, Freiburg, Germany

The sensory information is incomplete, noisy and to varying degrees ambiguous. The human perceptual system has to resolve this ambiguity to construct stable and reliable representations of the world. Recent EEG studies found large amplitude differences of two event-related potential components 200 and 400 ms after onset of ambiguous compared to disambiguated stimulus variants ("ERP Ambiguity Effects"). Importantly, the ERP Ambiguity Effects so far generalized over very different stimulus categories (geometry, motion, Gestalt perception) and are interpreted as correlates of metaperceptual processing. In the present study we tested whether the ERP Ambiguity Effects also occur with ambiguity at higher levels of complexity, namely with ambiguity in emotion. Thus we compared ERP contrasts between ambiguous and disambiguated variants of geometric cube stimuli (low-level ambiguity) and of emotional faces (high-level ambiguity). We used smiley faces as emotional stimuli in which ambiguity was created through the mouth curvature. Thus we had maximal experimental control over the stimulus parameter inducing either happy or sad emotions. We replicated findings of the ERP Ambiguity Effects for geometric stimuli and found very similar ERP Ambiguity Effects with the emotional smiley faces. In a control condition we verified that the smileys were perceived as faces. Conclusively, the ERP Ambiguity Effects generalize across very different stimulus categories and complexity levels of ambiguity. They may reflect high-level metaperceptual reliability estimations of perceptual outcomes, beyond sensory details. We will discuss our results in the context of predictive coding theories and of potential relations to perceptual features in psychiatric disorders.

Acknowledgement: We thank Neurex (IdEx Strasbourg, France), DFG (KO 4764/1-1 and TE 280/8-1) and DFH (German French University) for financial support.

53.339 **Resolution of multiple ambiguous feature representations: Does it depend on whether features are bound to a single object?** Ryan Lange[1,2](rlange@uchicago.edu), Steven K Shevell[1,2,3]; [1]Department of Psychology, University of Chicago, [2]Institute for Mind and Biology, University of Chicago, [3]Ophthalmology & Visual Science, University of Chicago

Purpose and Background: How does the visual system resolve multiple ambiguous features' neural representations? Is resolution of features' representations facilitated when the features are integrated within a single object, compared to resolution of the same feature representations in separate objects? When two visual stimuli share one ambiguous feature (e.g., color ambiguity from chromatic rivalry in both members of a pair of discs, or orientation ambiguity in a pair of Necker cubes), both stimuli are seen as identical more often than chance (Babich and Standing, 1981; Slezak and Shevell, 2018). This occurs also with a pair of stimuli having two ambiguous features (orientation and color; Lange and Shevell, OSA FVM 2018). Experiments here test the following question: In one or two pairs of objects, is perceived identity for both of two ambiguous features greater when those two ambiguous features are integrated components of each object, compared to when they are distributed across separate objects? Methods: Four observers completed two sessions, viewing in one session a pair of Necker cubes presented in red-green chromatic interocular-switch rivalry (cISR; Christiansen, D'Antona, and Shevell, 2017), and in the other session a pair of non-rivalrous gray Necker cubes adjacent to red-green cISR discs. In both sessions, observers reported via button presses when both rivalrous colors appeared identical and also when both Necker cubes' orientations appeared identical. The proportion of viewing time with identical color-and-cube-orientation percepts was compared between sessions. Results and Conclusions: For three of four observers, identical-color-and-orientation proportions were not significantly different between the two sessions (always $p > 0.1$, tested separately for each observer). For one observer, identical-color-and-orientation proportions were significantly lower for cubes presented in red-green cISR ($p< 0.0001$). Thus, there was no evidence to support the hypothesis that integration of different features in a single object facilitated resolution of those ambiguous features.

Acknowledgement: Supported by NIH EY-026618

53.340 **Seeing the fruit on the trees: Amplified perceptual differences from ambiguous neural representations**Jaelyn Peiso[1,2](jaepeiso@gmail.com), Steve Shevell [1,2,3]; [1]Institute for Mind & Biology, University of Chicago, [2]Department of Psychology, University of Chicago, [3]Department of Ophthalmology & Visual Science, University of Chicago

PURPOSE Grouping processes aid in the resolution of ambiguity that results from competing incompatible visual inputs. Can a grouping process act on representations from ambiguous objects when the ambiguity is created in different feature dimensions (e.g., only orientation or only chromaticity)? METHODS Two separate gratings were made ambiguous by binocular rivalry of two features, orientation and color, to determine if grouping processes can act across ambiguity created by different rivalrous features. Three observers viewed 1.5º dichoptic equiluminant chromatic square-wave 4-cpd gratings presented in interocular-switch rivalry, swapped at 3.75 Hz (Christiansen et al., JOV 2017). Each trial had two separate gratings, one above and one below fixation, with one of the gratings rivaling in only orientation (e.g., green-45º

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and green-135º) and the other in only chromaticity (e.g., green-45º and red-45º). Four percepts were measured: top and bottom gratings identical in only color (e.g., green-45º and green-135º), top and bottom gratings identical in only orientation (e.g., green-45º and red-45º), top and bottom gratings identical in both color and orientation (e.g., green-45º and green-45º), and top and bottom gratings different in both color and orientation (e.g., red-45º and green-135º). RESULTS All observers perceived gratings different in both color and orientation (e.g., green-45º and red-135º) more often than chance. They also perceived only identical orientation (e.g., green-45º and red-45º) more often than chance. Only one observer perceived gratings identical in color and orientation more often than chance. CONCLUSION These results suggest a disambiguating process that can enhance the difference between two ambiguous percepts. A difference-enhancing process, whereby the percepts of separate objects are resolved to be different in both features, may be an alternative to traditional grouping processes. Note that top and bottom gratings were consistently different in color more often than chance, suggesting that color disambiguation may enhance perceptual differences, rather than similarities.

Acknowledgement: Supported by NIH EY-026618

Scene Perception: Sets, gist, rapid categorization, temporal dynamics

Tuesday, May 21, 8:30 am - 12:30 pm, Banyan Breezeway

53.341 **The visual system precisely represents complex scene ensembles** Vignash Tharmaratnam[1](vignash.tharmaratnam@mail.utoronto.ca), Jason Haberman[2], Jonathan S. Cant[1]; [1]Department of Psychology, University of Toronto Scarborough, [2]Department of Psychology, Rhodes College

Ensemble perception exploits visual redundancy to quickly and accurately extract summary statistics across multiple visual domains. While ensemble processing has typically been investigated using features, objects, and faces, no known experiment has explored the summary statistical coding of sets composed of multiple scenes, despite a neuroanatomical link between scene and ensemble perception (Cant & Xu, 2012). The present study examined summary statistical processing of scene ensembles using two well-established global scene properties: Scene content (i.e., the perceived naturalness or manufacturedness of a scene) and spatial boundary (i.e., how open or closed a scene appears). In a pilot study, participants gave ratings of scene content and spatial boundary for single scenes, and these ratings were used to derive predicted values of average scene content and spatial boundary for scene ensembles presented to a new group of participants in the main experiment (Leib et al., 2016). Within this experiment, we varied set size (n = 1, 2, 4, or 6 scenes in an ensemble) and presentation duration (125, 250, 500, and 1000 ms) and asked participants to rate the average content and spatial boundary of scene ensembles. We found that participants' ratings were well correlated with the predicted ensemble values at all durations, demonstrating that ensemble statistical processing can occur for multidimensional high-level stimuli, and that such scene-ensemble processing occurs both efficiently and accurately in a fraction of a second. Moreover, we found that participants were integrating more than just 1 scene into their average ratings, as the correlation between actual and predicted ensemble ratings significantly increased across increasing set sizes. These findings demonstrate that statistical summaries can be extracted not only for features, objects, and faces, but also for complex visual scenes. This is consistent with the finding that the processing of ensembles and scenes are mediated by shared neural substrates.

Acknowledgement: Supported by an NSERC Discovery Grant to J.S.C

53.342 **Perceiving Category Set Statistics On-the-fly** Shaul Hochstein[1](shaulhochstein@gmail.com), Noam Khayat[1], Marina Pavlovskaya[2], Yoram Bonneh[3], Nachum Soroker[2], Stefano Fusi[4]; [1]ELSC Brain Research Center & Life Sciences Institute, Hebrew University, Jerusalem, [2]Loewenstein Rehabilitation Center & Tel Aviv University, [3]Bar Ilan University, [4]Neuroscience Department, Columbia University, New York

A bombardment of information overloads our sensory, perceptual and cognitive systems, which must integrate new information with memory of past scenes and events. Mechanisms employed to overcome sensory system bottlenecks include selective attention, Gestalt gist perception, categorization, and the recently investigated ensemble encoding of set summary statistics. We explore compensatory cognitive processes focusing on categorization and set ensemble summary statistics that relate objects sharing properties or function. Without encoding individual details of all individuals, (or as a shortcut to representing these details), observers perceive category prototype and boundaries or set mean and range, and perhaps higher order statistics as well. We found that observers perceive set mean and range, automatically, implicitly, and on-the-fly, for each presented set sequence, independently, and we found matching properties for category representation, suggesting a similar computational mechanism underlies the two phenomena. But categorization depends on a lifetime of learning about categories and their prototypes and boundaries. We now developed novel abstract "amoeba" forms, which are complex images similar to categories, but have simple ultrametric structure that observers can categorize on-the-fly (rather than depending on pre-learned categories). We find that, not only do observers learn the amoeba categories on-the-fly, they also build representations of their progenitor (related, but not equivalent, to set "mean" or category prototype), as well as category boundaries (related to set range and inter-category boundaries). These findings put set perception in a new light, related to object, scene and category representation.

Acknowledgement: Israel Science Foundation (ISF)

53.343 **Representational form of perceptual average** MyoungAh Kim[1](makjn4029@gmail.com), Sang Chul Chong[2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

The visual system can effectively represent a complex scene by extracting summary statistical information from groups of similar objects, such as mean. However, not much attention has been given to understanding the form of mean representation, e.g., whether mean size is represented as a single size. Here, we explored this idea by examining how mean size estimation bias and precision change depending on the disparity between two comparing ensembles, by varying set size and variance. Observers were presented with a set of multiple circles followed by a probe display that contained either a single circle or a set of multiple circles. They were asked to report the mean size of the former display by adjusting the size of the single circle or the overall size of multiple circles in the probe display. We first examined how estimating mean sizes using sets with different number of items influenced performance, by varying set size disparity between the stimulus and probe displays. Next, we manipulated size variance in both the stimulus and probe displays (low or high variance) and examined how variance congruency influenced mean size estimation. Performance was measured by calculating the percentage error from the actual mean size, as well as the variance of responses, as a proxy for perceptual precision. Results showed that mean size error and response variance reduced as set size disparity decreased between the stimulus and probe displays. Moreover, they were significantly reduced when size variance was congruent between the two displays as opposed to when they were different. The fact that bias and precision of mean estimation are contingent on characteristics of the probe displays suggests that mean representation includes an ensemble of statistical properties.

Acknowledgement: This research was supported by the Brain Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (NRF-2017M3C7A1029658)

53.344 **Different time courses for object individuation and estimation of object quantities** David P Melcher[1], Andreas Wutz[2,3]; [1]University of Trento, [2]Center for Cognitive Neuroscience, University of Salzburg, [3]Picower Institute for Learning and Memory, MIT

Our visual world consists of objects located in complex scenes. Here, we examine the time course of two core mechanisms involved in scene processing: object individuation and ensemble estimation. We need individuation to precisely define unique objects in a visual scene, whereas feature estimation for an ensemble of items supports a more global scene layout description. We directly compared the temporal dynamics of object individuation and estimation using a combined forward-simultaneous masking procedure to effectively control stimulus duration. Our main finding was that object individuation took between 100-200 ms to reach its typical capacity limits (subitizing range), whereas the ability to estimate object quantity was independent of temporal factors and reached plateau performance at even the shortest stimulus duration (33 ms). Our findings support the claim that object individuation and estimation are distinct visual mechanisms with different temporal dynamics that complement each other during scene analysis. These two processes may balance the need for both a fast but also a stable representation of our visual surroundings during active exploration of complex scenes.

53.345 **Does the Brain's Sensitivity to Statistical Regularity Require Attention?** Evan G Center[1,2](ecenter2@illinois.edu), Kara D Federmeier[1,2], Diane M Beck[1,2]; [1]Department of Psychology, University of Illinois, [2]Beckman Institute, University of Illinois

Previous work in our lab shows that the N300 event-related potential component is sensitive to statistical regularity (e.g., exemplar representativeness) under conditions of full attention, but the degree to which this effect depends on attention remains unknown. We address this gap by measuring brain responses to unattended natural scene stimuli. Twelve subjects played an attentionally demanding continuous motion tracking game at fixation using a joystick while images of "good" and "bad" exemplars of natural scenes (beaches, cities, forests, highways, mountains, and offices) were presented in the background. Good exemplars were rated by a large sample of independent observers as highly representative of their category whereas bad exemplars were rated as belonging to the category but poorly representative of it. We also manipulated exemplar category frequency within block by using a completely randomized trial structure in Experiment 1 (50% good exemplars) and a scene category blocked trial structure in Experiment 2 (80% good exemplars). All subjects participated in both experiments. Preliminary results replicate our prior finding of a larger N300 in response to bad compared to good exemplars, and further extend this effect to ignored stimuli. The results indicate that full attention is not necessary to assess statistical regularity in scene structure. Moreover, the N300 effect seems to be larger when we combine temporally global statistical regularity (exemplar representativeness) with temporally local statistical regularity (predictability within the experiment: Expt. 1 vs. 2). Together, these results suggest that the N300 may index a form of implicit template matching that benefits from both immediate context and longer-term prior experience.

53.346 **Searching for the gist of the prostate** Todd Horowitz[1](todd.horowitz@nih.gov), Melissa Treviño[1], Marcin Czarniecki[2], Ismail B Turkbey[3], Peter L Choyke[3]; [1]Behavioral Research Program, National Cancer Institute, [2]MedStar Georgetown University Hospital, [3]Molecular Imaging Program, National Cancer Institute

Humans can extract the gist of a visual scene in a fraction of a second, categorizing it as, say, indoor or outdoor, open or closed. Expert radiologists can do this for complex medical images, such as those generated by prostate multiparametric magnetic resonance imaging (mpMRI). MpMRI combines anatomical information from T2-weighted (T2W) sequences, and functional sequences such as conventional diffusion-weighted imaging (DWI) and the apparent diffusion coefficient (ADC). Standard workstation formats present these imaging modalities side-by-side. The goal of this study was to study the nature of mpMRI gist in different modalities. Which modality generates the strongest gist? Are anatomical or functional sequences more useful? Do these modalities provide independent gist information? We tested three groups of five radiologists with prostate mpMRI experience. Each group was shown 100 images from a single modality (T2W, DWI, or ADC). The same cases were used across groups to allow comparison across modalities. Lesions (Gleason scores 6-9) were present in 50% of the images. Images were taken from the base, mid, or apex regions of the prostate. Stimuli were presented for 500 ms, followed by a sector map of the prostate. Participants were first asked to localize the lesion on the sector map (even if they did not see a lesion), then indicate whether or not they thought a lesion was present, and then provided a confidence rating. All three groups detected lesions better than chance [d' mean(sd): T2W 0.83(0.51); DWI 0.80 (0.29); ADC 1.16(0.31)]. These results suggest that both anatomical and functional information contribute to mpMRI gist. Furthermore, there was little consistency from modality to modality as to which cases produced the best performance, indicating that each modality contributes unique information.

53.347 **Is Rapid Efficient Scene Perception Also Deep, and Does Attention Help?** Thomas Sanocki[1](sanocki@usf.edu), Han Lee[1]; [1]University of South Florida

Humans perceive natural scenes with great efficiently, if the task is simple (e.g. categorization or gist). Does human efficiency extend to deeper scene perception, involving a wide bandwidth of perceptual experience? We examined this issue while also examining an outstanding issue in attention: Does attention facilitate the encoding of complex perceptual representations during rapid scene perception? Existing research indicates that attention, attracted by an exogenous cue, aids some basic visual processes. But it is not clear that it will aid the encoding of a high-level representation such as that of a complex scene. We adapted the Fei-Fei full report method. Observers viewed a brief scene (in the outer fovea) and wrote what they saw on each trial. We used cartoon-scenes, to encourage rapid scene perception. The scene was presented for 100 ms, preceded by an exogenous attention cue for 75 ms. The cue was a picture frame in either the same location as the picture or the opposite location (invalid cue) in Experiment 1. In Experiment 2, the cue was the same-location frame or no cue at all during the period. The reports were scored by judges blind to condition, and incorrect content was subtracted from correct content. In Experiment 1, the mean corrected score was 8.4 meaningful words with an invalid cue, and 23.3% more correct words with the valid cue (p= .02). In Experiment 2, the mean corrected score was 9.8 meaningful words with no cue, and 13.3% more correct words with the valid cue (p= .03). Thus, in each case a valid attention cue led to better scene perception. This indicates that attention increases the depth of rapid scene perception, producing a more complete understanding of the information in the scene.

53.348 **Stereopsis Improves Rapid Scene Categorization** Matt D Anderson[1](ma19g13@soton.ac.uk), Wendy J Adams[1], Erich W Graf[1], James H Elder[2]; [1]Centre for Vision and Cognition, Psychology, University of Southampton, UK, [2]Centre for Vision Research, Department of Psychology, Department of Electrical and Computer Science, York University, Canada

Theories of rapid scene categorization have emphasised the importance of computationally inexpensive image cues such as texture (Renninger & Malik, 2004) and spectral structure (Oliva & Torralba, 2001). Although binocular disparities provide reliable depth information, stereopsis is typically thought to be sluggish (Tyler, 1991; Kane, Guan & Banks, 2014; Valsecchi, Caziot, Backus, & Gegenfurtner, 2013), and therefore unhelpful during early scene processing.Recent work, however, suggests that stereopsis improves object recognition following brief (33 msec) presentations (Caziot & Backus, 2015). We investigated whether disparity information facilitates the categorization of briefly presented real-world scenes. Subjects viewed greyscale or colour images from the Southampton-York Natural Scenes dataset (Adams et al., 2016), presented monoscopically (same image to both eyes), stereoscopically, or in reversed stereo (inverted disparity-defined depth).Images were presented for 13.3, 26.6, 53.2, or 106.5 msecs, with backward masking. Subjects identified the semantic (e.g., beach / road / farm) or 3D spatial structure (e.g., open / closed off / navigable route) category, in addition to the viewing condition (mono / stereo / stereo-reversed). Disparity information facilitated semantic categorization, but only for grayscale images, reflecting redundancy across disparity and colour segmentation cues. Strikingly, the stereoscopic advantage emerged for 13.3 msec presentations, suggesting that disparity cues are encoded rapidly in complex scenes. Colour also facilitated semantic categorization, but only for presentations of 26.6 msecs or longer. Disparity and colour both improved 3D spatial structure categorization. Interestingly, however, observers were only able to distinguish the viewing condition of images presented for 53.2 msecs or longer – much later than the onset of the disparity advantage for categorisation. Our findings contradict previous claims that stereoscopic depth cues are extracted from real-world scenes after monocular cues (e.g., Valsecchi et al., 2013), and suggest that stereopsis improves the recognition of briefly presented scenes.

53.349 **Priming of scene gist through sequential expectations: Both prediction and target/prime image similarity contribute to rapid scene gist categorization** Maverick E Smith[1](ms1434@ksu.edu), Yuhang Ma[1], Kenzie J Kriss[1], Katherine E Kolze[1], Lester C Loschky[1]; [1]Kansas State University

Past research has argued that scene gist, a holistic semantic representation of a scene acquired within a single fixation, is extracted using purely feed-forward mechanisms. As such, scene gist recognition studies have presented scenes from multiple categories in randomized sequences. We tested whether rapid scene categorization could be facilitated by priming from sequential expectations. We created more ecologically valid, first-person viewpoint, image sequences, along spatiotemporally connected routes (e.g., an office to a parking lot). Participants identified target scenes at the end of rapid serial visual presentations. Critically, we manipulated whether targets were in coherent or randomized sequences. Target categorization was more accurate in coherent sequences than in randomized sequences. Furthermore, categorization was more accurate for a target following one or more images within the same category than following a switch between categories. Accuracy was also higher following two primes from the same category than following only one between scene categories (e.g., multiple office primes facilitated recognition of a hallway). Likewise, accuracy was higher for targets more visually similar to their immediately preceding primes. This suggests that prime-to-target visual similarity may explain the coherent sequence advantage. We tested this hypothesis in a second experiment, which was identical except that target images were removed from the sequences, and participants were asked to predict the scene category of the

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missing target. Missing images in coherent sequences were more accurately predicted than missing images in randomized sequences, and more predictable images were identified more accurately in Experiment 1. Importantly, partial correlations revealed that image predictability and prime-to-target visual similarity independently contributed to rapid scene gist categorization accuracy.

53.350 **Diagnostic Objects Contribute to Late -- But Not Early-- Visual Scene Processing** Julie S. Self[1](self.julie@gmail.com), Jamie Siegart[1], Munashe Machoko[1], Enton Lam[1], Michelle R. Greene[1]; [1]Program in Neuroscience, Bates College

Humans instantaneously and effortlessly obtain semantic information from visual scenes, yet it remains unclear which scene features drive this identification. This study examines the possibility that a subset of objects are central to scene categorization. Many models of object usage in scenes assume that all objects contribute equally to scene category. However, some objects are more diagnostic of their environments. For example, while "chairs" can be found in many types of scenes, "refrigerators" are evocative of kitchens, and are therefore diagnostic of the scene category. Using a labeled scene database, we defined diagnostic objects as those found nearly exclusively in a single scene category ($p(category|object) > 0.9$). We obscured all diagnostic objects in each image using localized phase scrambling (diag- condition) and compared these images with both unmodified images, and images with a similar amount of non-diagnostic information obscured (rand- condition). Observers (N=14) viewed 996 images for 250 ms each and performed 2AFC categorization, while 64-channel EEG was recorded. Observers were most accurate (0.91) for the intact images, but were also significantly more accurate for the rand- (0.90) compared with the diag- (0.86, $p< 0.001$, d=0.87). Observers were also 69 ms slower to classify the diag- images compared with the rand- ($p< 0.0001$, d=0.37). EEG waveforms were submitted to a linear classifier trained on unmodified images in order to determine the time-resolved decoding accuracy of diag- and rand- conditions. We found decodable information starting around 60 ms post-image onset for both experimental conditions. Decoding accuracy was significantly lower for diag- images starting 143 ms after image onset, suggesting that while the diag- images did not disrupt initial visual processing, diagnostic objects contributed to later semantic processing.

Acknowledgement: National Science Foundation (1736274) grant to Michelle R. Greene

Faces: Wholes, parts, features

Tuesday, May 21, 8:30 am - 12:30 pm, Banyan Breezeway

53.351 **A free and open-source toolkit of three-dimensional models and software to study face perception** Jason S Hays[1](jhays006@fiu.edu), Claudia Wong[1], Fabian Soto[1]; [1]Florida International University

A problem in the study of face perception is that results can be confounded by poor stimulus control. Ideally, experiments should precisely manipulate facial features under study and tightly control irrelevant features. Software for 3D face modeling provides such control, but there is a lack of free and open source alternatives specifically created for face perception research. Here, we provide such tools by expanding the open-source software MakeHuman. We present a database of 27 identity models and 6 expression pose models (sadness, anger, happiness, disgust, fear, and surprise), together with software to manipulate the models in ways that are common in the face perception literature, allowing researchers to: (1) create a sequence of renders from interpolations between two or more 3D models (differing in identity, expression, and/or pose), resulting in a "morphing" sequence; (2) create renders by extrapolation in a direction of face space, obtaining 3D "anti-faces" and similar stimuli; (3) obtain videos of dynamic faces from rendered images; (4) obtain average face models; (5) standardize a set of models so that they differ only in facial shape features, and (6) communicate with experiment software (e.g., PsychoPy) to render faces dynamically online. These tools vastly improve both the speed at which face stimuli can be produced and the level of control that researchers have over face stimuli. We show examples of the multiple ways in which these tools can be used in face perception research, and describe human ratings of stimuli produced with the toolkit. Furthermore, by using Markov Chain Monte Carlo (MCMC) with participants, we can sample from the distribution of realistic faces to define completely novel identities and expressions that still fit what people consider realistic.

53.352 **Extracting modes of variation of natural facial motion using PCA** Ben B Brown[1](ben.brown@nottingham.ac.uk), Alan Johnston[1]; [1]University of Nottingham

PCA has frequently been applied to dimensionality reduction of static images of faces, encoding them as linear combinations of relatively few spatially global components ("eigenfaces"). Here we report a technique for applying PCA to dynamic videos of facial motion, which has been used previously to identify the most informative regions with respect to overall facial configuration (Berisha, Johnston, & McOwen, 2010), and more recently to investigate viewpoint invariance, covariance of the face with vocal tract and voice during speech, and objective assessment of emotional tone from expression. Rather than simply analysing pixel values, key to our approach is an initial 'morphing' stage whereby each frame is described relative to a reference frame; specifically we use a biologically plausible motion model (the Multi-channel Gradient Model; Johnston, McOwen, & Buxton, 1992) to find the non-rigid deformation that morphs each frame to the reference. These vector fields amount to a description of the posture of the face independent of its texture. To avoid 'ghosting' at edges image texture is warped to the reference. PCA is applied to a representation of the warp plus warped texture. A sequence of frames generates a trajectory in this PCA space. This provides a means of describing the temporal structure of expressive 'streams' (as during speech for example). By collating multiple similar sequences one can apply PCA to trajectories in the space yielding a 'second order' space whose components reflect variation in temporal structure. We can also generate new sequences via backprojection including exaggerated 'caricatures', or sequences with quantitatively specified properties following e.g. LDA in the space. Such sequences offer potential as empirically controllable stimuli for visual experiments, while projection into 'LDA-augmented' spaces allows automated scoring of expression.

Acknowledgement: National Institute for Health Research

53.353 **More Makeup, More Attractiveness? Self-applied Heavy Cosmetics Yield Higher Attractiveness Ratings than Light Cosmetics** Erick R. Aguinaldo[1](ERAguinaldo@csu.fullerton.edu), Jessie J. Peissig[1]; [1]Department of Psychology, College of Humanities and Social Sciences, California State University, Fullerton

Research over the past few decades has confirmed the role of cosmetics in increasing ratings of facial attractiveness (Cash, Dawson, Davis, Bowen, & Galumbeck, 1989; Etcoff, Stock, Haley, Vickery, & House, 2011; Russell, 2003, 2009). However, many studies have varied makeup application through computer manipulation or professional makeup artists. These representations may not accurately reflect everyday makeup use. The current study varied makeup application in a more ecologically valid manner, wherein individuals photographed for facial stimuli applied their own makeup. In the current study, we collected three sets of facial stimuli from 35 individuals. Individuals were photographed with no makeup, as well as self-applied light and heavy makeup across two different sessions. To test for differences in perceived facial attractiveness across no, light, and heavy makeup conditions, a separate group of 24 participants were asked to rate the attractiveness of the faces using a Likert-like scale from 1 to 7, with 1 being very unattractive and 7 being very attractive. The study showed significant differences in attractiveness ratings between the light and heavy makeup conditions, such that faces with heavy makeup (M = 3.95, SD = 0.05) were, on average, rated as more attractive than faces with light makeup (M = 3.77, SD = 0.05), $t(22) = 1.96$, $p < .001$. These results differ from previous findings that faces with light makeup are rated as more attractive than faces with heavy makeup (Tagai, Ohtaka, & Nittono, 2016). Our study suggests that when cosmetics are self-applied, faces with heavy cosmetics may be perceived as more attractive than faces with light cosmetics.

Acknowledgement: This work was supported by a Maximizing Access to Research Careers grant to CSUF from the National Institutes of Health [2T34GM008612-23].

53.354 **Hair color modulates skin appearance** Richard Russell[1](r-russell@gettysburg.edu), Carlota Batres[1,2]; [1]Psychology Department, Gettysburg College, [2]Psychology Department, Franklin and Marshall College

Introduction: Apparent contrast can be suppressed or enhanced when presented within surrounding images.This contextual modulation is typically accounted for by models of contrast gain control.Recently we reported that skin appearance is affected by contextual modulation (Russell et al. VSS 2018).Here we report two studies demonstrating that skin appearance is affected by background color and by hair color.Methods and Results: In Study 1, controlled images of 45 German women from the FACES database

Tuesday AM

were presented surrounded by either a black or a skin-colored oval-shaped mask such that only the internal features of the face were visible.In Study 2 we selected 41 faces from the FACES database and presented them unmasked, but with their hair either darkened or lightened in the L* dimension. In both studies participants rated how even and how wrinkled the skin appeared.Thus in both studies we investigated the effect of surrounding the skin with image regions that had high or low contrast with the facial skin.In Study 1 skin appeared more even and less wrinkled when surrounded by a dark background than a skin-colored background.In Study 2 skin appeared more even but no less wrinkled when surrounded by dark hair than by light hair.Across both studies, increased contrast with surrounding image regions resulted in more even-looking skin.However, increased contrast from an oval mask but not from darker hair resulted in skin appearing less wrinkled. Conclusions: We found evidence for contextual modulation of skin appearance by the image region surrounding the face, whether it was hair or an image mask.The finding that hair color affects apparent skin evenness suggests that artificially coloring the hair could offer an indirect route by which a person can influence the appearance of their skin.

53.355 **Characteristics of color discrimination on a face image** Yoko Mizokami[1](mizokami@faculty.chiba-u.jp), Mako Yoshida[1], Kumiko Kikuchi[2], Yoshihisa Aizu[3], Hirohisa Yaguchi[1]; [1]Chiba University, [2]Shiseido Research Center, [3]Muroran Institute of Technology

Skin color is essential for obtaining various information on our mind and body such as health, age, and face impression. Previous studies have reported that people show high sensitivity to changes in the redness of the skin. It was also reported that a reddish skin looks whiter than yellowish skin (Yoshikawa et al. 2012). These results suggest that people have a unique perception of the face and skin color. This perception specific to face and skin color would be due to the property of skin color determined by pigments components. In this study, we examined the color discrimination of face color in the direction of change in the amount of melanin and hemoglobin which are main pigment components consisting of skin color. We also tested the color discrimination on the a*b* axes in the CIELAB space. We used a Japanese female face with an averaged skin color obtained by measuring the skin of 694 Japanese females as a reference stimulus. Color changes due to melanin and hemoglobin change in the CIELAB space was calculated based on skin reflectance data obtained by the Monte Carlo Simulation (MCS) and the spectra of the D65 illuminant. Then, the color of a skin image was modulated in the direction of increase and decrease of each pigment or a*b* axes, and they used as test stimuli. A reference stimulus and a test stimulus were presented side by side on a CRT monitor. Observers adjusted the color of the test stimulus along one of modulation directions and determined a boundary which was discriminable from the reference stimulus. Our result showed better discrimination for changes in reddish direction in both the pigment change and a*b* axes, suggesting that people have more sensitive to color change accompanying the increase of hemoglobin.

Acknowledgement: JSPS KAKENHI JP16H01663 & JP18H04183

53.356 **Human perception of localized skin features** Matjaz Jogan[1](mjogan@its.jnj.com), Benjamin Serbiak[1], Laura Higgins[1]; [1]Johnson & Johnson

Facial color appearance is an important source of social information. A change in facial skin color can modulate both perceived health and attractiveness, and humans are better at discriminating color of faces than of non-face stimuli. Here we studied how well can humans discriminate changes in color of localized skin features. Four face stimuli in standardized illumination and pose were modified by separately changing the redness (a*), yellowness (b*) and chroma of random clusters of localized spots centered on Laplacian of Gaussian (LoG) maxima. Modified face stimuli were then paired with the original stimulus and observers had to decide which of the two showed a perceivable local change in color. N = 6 observers completed three blocks (a*, b* and chroma changes) of trials regulated by an adaptive staircase procedure. Using a maximum likelihood fit of psychometric curves we characterized the discrimination thresholds for increase or decrease in a*, b* and chroma, respectively. For 75% correct responses the color discrimination threshold was smallest for the increase in redness (Da* = 9.54). Higher were the thresholds for an increase in yellowness (Db* = 13.40) and an increase in greenness (Da* = -14.93), while the threshold for the increase in blueness (Db* < 0) was too high to be reliably measured using our stimulus range with a minimum Db* of -30. Observers were twice more sensitive to an increased chromaticity compared to a decreased chromaticity. Our results suggest that the human visual system is most efficient at detecting increases of chromaticity and in particular increases in local redness, and less efficient at detecting discolorations or changes towards blue and green, both colors that are not associated with skin tone.

53.357 **Identity specific orientation tuning for faces revealed by morphing Angelina into Jessica** Gabrielle Dugas[1](dugg06@uqo.ca), Justin Duncan[1, 2], Caroline Blais[1], Daniel Fiset[1]; [1]Département de Psychoéducation et de Psychologie, Université du Québec en Outaouais, [2]Département de Psychologie, Université du Québec à Montréal

Many recent studies have revealed that face recognition heavily relies on the processing of horizontal spatial orientations. However, most of those studies used tasks where it is difficult to dissociate the impact of physical face information from that of identity-specific information. To investigate this issue, we used a method designed to precisely control the physical difference between stimuli, and verified the horizontal tuning for faces of identical distances with regard to low-level properties but of different perceptual distance with regard to identity. Ten participants each completed 2,880 trials in a 2-ABX match-to-sample task. On each trial, the participants saw a target and two response alternatives, both sampled with the same orientation bubbles (Duncan et al., 2017). One response choice was visually identical to the sample (i.e. the correct response) whereas the other was either on the same side (within-identity [WI]) or on the other side (between-identity [BI]) of the categorical barrier. Thus, the physical distance between the target and the different (WI or BI) alternative was always the same, but the perceptual distance was not. As expected, WI trials were more difficult than BI trials for all participants, as indicated by the higher number of bubbles needed for the former (WI: M=101.66, SD=83.50) than the latter (BI: M=15.85, SD=14.94). Orientation tuning in the BI and WI conditions was revealed by computing a weighted sum of the orientation filters across trials, using participant accuracies as weights. In the BI condition, horizontal orientations between 62 and 101degrees were significantly associated with accuracy (Zcrit=2.101; Zmax=4.25, $p< 0.05$, peak at 84 degrees); whereas no orientation reached the threshold in the WI condition (Zmax=1.41, $p>0.05$). Comparing horizontal tuning between the two conditions using a paired sample t-test reveals an identity-specific horizontal tuning for faces, $t(6) = 2.8$, $p < 0.05$.

Acknowledgement: NSERC

53.358 **Horizontal selectivity during face perception in the visual periphery** Matthew V Pachai[1](mattpachai@gmail.com), Mitchel Downham[1], Jennifer K E Steeves[1]; [1]Department of Psychology, York University

Several reports have demonstrated selective processing of horizontally-oriented spatial frequency components during face-related tasks (e.g. Goffaux & Dakin, Front Psychol, 2010; Pachai et al, Front Psychol, 2013), but these studies were all conducted using foveal stimuli, and it remains unclear whether the same patterns will hold in the periphery. We know that diagnostic information is rapidly extracted from peripheral faces, as faces are detected faster than other categories of objects at 8° eccentricity (Crouzet et al, J Vis, 2010), and observers typically direct their first saccade to an optimal landing point on a face (Peterson & Eckstein, PNAS, 2012). Therefore, to investigate whether peripheral face processing is also horizontally-selective, we had observers complete a 4-AFC face discrimination task with targets presented either in the fovea or at 8° eccentricity, filtered to retain either horizontal or vertical frequency components. We observed no significant interaction between eccentricity and filter orientation in this task, suggesting that horizontal selectivity is deployed in the periphery as it is in the fovea. In a second experiment, we investigated whether face crowding is horizontally selective. Specifically, we had observers complete a same-different discrimination task with one face presented at the fovea and one presented at 8° eccentricity. On every trial, the peripheral face was presented alone or flanked by six different faces. Across trials, these faces were filtered to retain horizontal, vertical, or all frequency components. We observed lower performance when the peripheral face was flanked, but no difference in the magnitude of crowding exerted by horizontal, vertical, or unfiltered flankers. Together, these results suggest that horizontal selectivity is deployed in the periphery, but that the mere presence of upright flankers is sufficient to induce face crowding. We are conducting follow-up studies to explore the implications of this result.

Acknowledgement: National Sciences and Engineering Research Council (NSERC) Canada-First Research Excellence Fund: VISTA (Vision: Science to Applications)

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53.359 **Right hemisphere horizontal tuning during face processing**
Justin Duncan[1, 2](duncan.justin@courrier.uqam.ca), Caroline Blais[1], Daniel Fiset[1]; [1]Département de psychoéducation et psychologie, Université du Québec en Outaouais, [2]Département de psychologie, Université du Québec à Montréal

Left visual field (LVF) superiority refers to greater face processing accuracy and speed, compared to faces presented in the right VF (e.g., Sergent & Bindra, 1981). It is generally attributed to right hemisphere dominance (e.g., Kanwisher et al., 1997), but few mechanisms have been proposed for this phenomenon (e.g., global/local or low/high spatial frequency processing differences). Recent forays in the face processing literature have however revealed a critical role for horizontal spatial orientations (e.g., Goffaux & Dakin, 2010; Pachai et al., 2013). In line with these results, we verified whether orientation tuning might differ across hemispheres. Thirty participants completed two tasks measuring tuning profiles with orientation bubbles (Duncan et al., 2017). The first task was a 10 AFC identification, to generate a reference profile. The second task introduced lateralized presentations. In this task, a filtered probe face half (one of ten familiar individuals) was presented to either the LVF or RVF, while the other side viewed an average face half (randomized across trials). A target was then presented bilaterally, and participants indicated whether the probe and target were the same person. Central fixation was enforced with eye tracking (M = 97.7%, SD = 3.1% compliant trials) during the probe presentation (60 ms). Classification images were generated to extract diagnostic orientations. The statistical threshold (Zcrit = 2.101, $p < 0.05$) was established with the Stat4CI toolbox (Chauvin et al., 2005). As expected, horizontals predicted the best accuracy in the reference task (Z = 3.38). This relationship was also observed for the LVF (Z = 3.45), but not for the RVF (Z = –1.92). These results provide novel evidence for right hemisphere horizontal tuning for faces.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

53.360 **Asymmetric representation of sex from body shape**
Paul Downing[1](p.downing@bangor.ac.uk), Marco Gandolfo[1]; [1]School of Psychology, Bangor University

We efficiently infer others' states and traits from their appearance, and these inferences shape our social behaviour. One key trait is sex, which is strongly cued by body shape. We investigated the perceptual representations of the body shape of the two sexes. Specifically we tested a hypothesis, drawn from previous findings in sex-discrimination tasks, that the mental encoding of male and female body shapes is asymmetrical, such that female bodies are coded with reference to a male default. If so, following the logic of Treisman's search asymmetry approach, then in a search task female targets should be found more efficiently amongst male distractors than vice versa. This pattern was confirmed, in participants of both sexes, for body silhouettes seen from side and frontal views, and for simplified geometric icon figures. In two control experiments, we showed that the search asymmetry favouring female bodies emerged from whole body perceptual processes and was not explained by lower level stimulus properties. These findings demonstrate an organising principle of the encoding of body shape in support of inferring a socially relevant trait.

53.361 **Contextual Modulation in High-Level Vision: Evidence for a Spatial Viewpoint Illusion in the Perception of Faces**
Kieran J Pang[1](kieranpang.work@gmail.com), Colin W G Clifford[1]; [1]School of Psychology, UNSW Sydney, New South Wales, Australia

Contextual modulation, the shift in perceptual properties of a target as a function of its surroundings, has been previously demonstrated to be analogous across temporal and spatial dimensions. This relationship has been widely investigated in low-level vision, holding true for properties such as orientation, colour, and motion. However, in high-level vision, while contextual modulation by time has been evidenced, such as through facial viewpoint adaptation, the effects of spatial context are generally unexplored. The present study series utilized an unbiased two-alternative forced choice paradigm to measure the presence and magnitude of a novel viewpoint illusion, an effect taken to be spatially analogous to viewpoint adaptation. Per trial, participants were tasked to select one of two face sets, each consisting of one centred target identity surrounded by six distinct faces, depending on which target was oriented more directly forward. The flankers of one set faced to the left of the observer, while the respective faces of the other set mirrored this, oriented to the right. The orientations of the two target faces deviated equally in either direction away from a base orientation, as selected by a Bayesian staircase procedure. A small repulsive effect of approximately 0.5° was observed and subsequently replicated. That is, judgements of a centre face's viewpoint were shifted from its true orientation, in a direction opposite to the orientation of faces present in the surround. This effect was eliminated following inversion of the spatial surround, indicating that it was not driven by aggregated low-level effects. The results of this study provide evidence that contextual modulation in the spatial domain is present beyond low-level vision, and additionally open the field to investigating the role of spatial interactions in the processing of other high-level facial properties with established adaptation effects, such as emotion, identity, and gaze.

53.362 **The speed of individual face recognition**
Talia L Retter[1,2](tlretter@nevada.unr.edu), Caroline Michel[1], Fang Jiang[2], Michael A Webster[2], Bruno Rossion[1,3]; [1]Psychological Sciences Research Institute, Institute of Neuroscience, UCLouvain, Belgium, [2]Department of Psychology, Center for Integrative Neuroscience, University of Nevada, Reno, USA, [3]Centre Hospitalier Regional Universitaire, France

Neurotypical human adults can often recognize the identity of a face at a glance. Yet, the minimal and optimal presentation duration at which individual faces can be discriminated from one another, beyond low-level image changes, remains largely unknown. Here, we used a frequency-tagging sweep design with increasing presentation duration to examine firstly the duration at which a face individuation response arises. Responses were recorded with 128-channel EEG from 16 participants with ascending 77-s sequences of 11 presentation durations from 25 to 333 ms (40 to 3 Hz), throughout which the same unfamiliar face was repeated with changes in size and luminance at every presentation; a different unfamiliar facial identity was presented within this sequence every 1 s (1 Hz). In a second behavioral experiment with the same participants, we presented identity changes non-periodically within fixed-rate 30-s sequences while participants performed an explicit individual face discrimination task. A neural individual face recognition response, tagged at 1 Hz and its specific harmonics, emerged over the occipito-temporal cortex at the 50-ms presentation time (25- to 100-ms across individuals), with a maximal response at about 170 ms presentation time. This corresponds to a delay of approximately 20 ms relative to the minimum, and 80 ms relative to the maximum, responses to generic face vs. non-face categorization, measured previously with a similar sweep design. Importantly, behavioral accuracy correlated with individual participants' weighted neural response amplitude only in a mid-frequency presentation range. These results present a step towards quantifying performance of individual as opposed to generic face categorization in the human brain, and extend the finding that individuals' weighted EEG amplitudes at mid-frequency ranges predicts behavioral performance.

Acknowledgement: Belgian National Foundation for Scientific Research [FNRS grant number FC7159] Integrative Neuroscience Center of Biomedical Research Excellence [COBRE: grant number P20 GM103650]

53.363 **The Speed of Demography in Face Perception**
Stefan Uddenberg[1, 2](stefan.uddenberg@yale.edu), Clara Colombatto[1], Brian Scholl[1]; [1]Department of Psychology, Yale University, [2]Department of Psychology, Princeton University

When we look at a face, we cannot help but 'read' it: beyond simply processing its identity, we also form robust impressions of both transient emotional states (e.g. surprise) and stable personality traits (e.g. trustworthiness). But perhaps the most fundamental and salient traits we extract from faces reflect their social demographics — e.g. race, age, and gender. Our interpretations of these properties have deep consequences for how we interact with other people. But just how are such features extracted by perceptual (and cognitive) processing? Curiously, despite a vast amount of work on higher-level social properties (such as competence and dominance), there has been very little work looking at the visual perception of basic demographic properties. Across several experiments, we tested how quickly demographic properties are extracted when viewing faces. Observers viewed unfamiliar full-color photographs of faces for variable durations, after which they were masked. We then correlated percepts of race, age, or gender from those faces with the same percepts that occurred during independent unspeeded (and unmasked) judgments. The results clearly demonstrated that demographic features are extracted highly efficiently: observers showed near-perfect agreement with their own unspeeded judgments (and with the ground truth) with only 50 ms of exposure — and even (in the cases of race and gender) by 34 ms. This was true even when the property to be reported wasn't revealed until the face had disappeared. We also replicated these results in an independent group of observers who viewed faces that were tightly cropped and matched for mean luminance, thus controlling for several lower-level visual properties. Critically, we also observed much slower and less accurate performance for inverted faces, signaling a role for holistic processing. Collectively, these results demonstrate that the visual system is especially fast and efficient at extracting demographic features from faces at a glance.

Acknowledgement: SU was supported by an NSF Graduate Research Fellowship. BJS was supported by ONR MURI #N00014-16-1-2007.

53.364 **Why does aperture viewing disrupt face perception?**
Jennifer J Murphy[1](jennifer.murphy@kcl.ac.uk), Katie L. H Gray[2], Richard Cook[3, 4]; [1]Social, Genetic and Developmental Psychiatry Centre, Institute of Psychiatry, Psychology, and Neuroscience, King's College London, London, U.K., [2]School of Psychology and Clinical Language Sciences, University of Reading, Reading, U.K., [3]Department of Psychological Sciences, Birkbeck, University of London, London, U.K., [4]Department of Psychology, University of York, York, U.K.

Perceptual decisions are more accurate when observers view faces in their entirety than when dynamic viewing windows reveal target faces incrementally. These findings accord with holistic theories of face processing that assert that the opportunity to process multiple regions in parallel conveys a particular advantage when viewing upright faces. However, aperture viewing could also make it harder for observers to extract the vertical image structure (the 'facial barcode') thought to play a critical role when interpreting faces. The present study sought to distinguish these possibilities. In Experiment 1, observers judged the gender of faces briefly viewed in their entirety, or through a dynamic aperture that moved across the image vertically, from top to bottom, or vice-versa. In Experiment 2 the aperture moved horizontally, from left to right, or vice-versa. We found evidence of a whole-face advantage irrespective of whether the aperture hindered (Experiment 1) or allowed the extraction of the barcode (Experiment 2). In both experiments, the opportunity to process faces in their entirety aided the perception of upright faces, disproportionately. Our findings suggest that the perceptual advantage conveyed by whole-face processing extends beyond the extraction of the vertical image structure.

Acknowledgement: ESRC

53.365 **Direct Evidence that Inversion of Faces Disrupts Configural Processing**
Emily X Meschke[1](emeschke@usc.edu), Irving Biederman[2,3]; [1]Computational Neuroscience, University of Southern California, [2]Neuroscience, University of Southern California, [3]Psychology, University of Southern California

Inversion of a face can be readily shown to interfere with the matching or recognition of that face. Often this disruption is attributed to the inability to employ a configural representation whereby the whole face can be assimilated and judged as an integrated representation. However, direct evidence for this explanation has been lacking. Configural effects are enabled by the overlap of large receptive fields (r.f.s) centered at varied positions throughout the face which serve to magnify the impact of small metric differences distinguishing similar faces (Xu et al., 2014). Subjects judged whether a briefly presented sequence of two similar computer-generated faces, both upright or both inverted, with an intervening mask depicted the same person. When different, the faces could differ in the one of three areas of the face–upper, middle, or lower–with changes such as the height of the eyebrows, the length of the nose, or the width of the mouth. Fixation for a given trial was centered on the eyes, nose, or mouth, as the position of the faces was vertically shifted from trial to trial (but not within trials) (Fig. 1). The different feature could thus be 0 (< 1º), 1 (1-2º), or 2 (3-4º) positions, from fixation. For upright faces, there was little effect of distance from fixation in detecting a differing feature; for inverted faces accuracy fell with distance of that feature (Fig. 2). Accuracy on different trials, for both upright and inverted faces, were highly correlated (rs ~ .95) with the magnitude of the difference in the faces as scaled by the Gabor-jet dissimilarity measure (Fig. 3), with the benefit of dissimilarity greater for the upright faces. The greater cost of distance in inverted faces can be interpreted as a diminished benefit of a configural representation enabled by large r.f.s.

Acknowledgement: Harold W. Dornsife Research Fund

53.366 **Holistic processing of faces in the absence of awareness**
Shiwen Ren[1] (294004264@qq.com), Hanyu Shao[1], Sheng He[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences,, [2]University of the Chinese Academy of Sciences, Beijing, China, [3]Department of Psychology, University of Minnesota, United States of America

It is widely acknowledged that holistic processing is a key characteristic of face perception, however, it is unclear whether such holistic processing requires awareness of face parts. To address this question, we investigated the interactions between a visible half face and an invisible half face. In the first experiment, we tested whether discrimination of face identity of the top half face could be influenced by the bottom half face which was rendered invisible through Continuous Flash Suppression (CFS). For a series of test faces generated from morphing between two distinct faces, results show that the invisible bottom half faces contributed to subjects' face discrimination performance. This is essentially a demonstration of the "composite face effect" with invisible bottom half faces. In the second experiment, we tested whether a visible half face could influence the processing of the other half face presented under CFS suppression, as measured by the time it took to break from CFS suppression. We found that the visible half faces indeed facilitated the invisible half faces in breaking CFS suppression when the two halves were aligned compared to when they were misaligned. Visible eyes had stronger influence on invisible nose/mouth than the other way around. The two experiments together support that holistic processing of faces can occur between visible and invisible face parts.

Visual Memory: Long term memory

Tuesday, May 21, 8:30 am - 12:30 pm, Banyan Breezeway

53.367 **A new category-based image set to study image memorability**
Lore Goetschalckx[1](lore.goetschalckx@kuleuven.be), Johan Wagemans[1]; [1]Laboratory of Experimental Psychology, Brain and Cognition, KU Leuven

Images differ in their memorability in consistent ways across observers. What makes an image memorable is not fully understood to date. Most of the current insight is in terms of high-level semantic aspects, related to the content. For example, images of people are typically more memorable than images of landscapes. However, research still shows consistent differences within semantic categories, suggesting a role for factors at other levels of processing in the visual hierarchy. To investigate this role, category-based image sets are needed, with lots of exemplars per category, allowing to zoom in on within-category variability in memorability. We present a large, new category-based image set quantified on memorability. The set consists of five broader memorability-relevant semantic categories (animal, sports, food, landscapes, vehicles), with 2K exemplars each, further divided into different subcategories (e.g., bear, pigeon, cat, etc. for animal). The images were sourced from existing image sets (e.g., ImageNet). Care was taken to avoid major influences of more high-level image aspects (e.g., recognizable places, text). To quantify the set on memorability, we used a repeat-detection task on mTurk. Participants watched a sequence of images (600ms stimulus duration, 800ms interstimulus interval) and responded whenever they recognized a repeated image. To ensure enough spacing, we inserted filler images taken from Flickr. Each image was seen by 99 participants and its memorability score was computed as the hit rate across participants. The results show high consistency of memorability scores even within each of the five categories (mean split-half α from .59 to .77). Our work replicates previous work showing that consistent memorability differences persist at a within-category level and offers a tool to study the factors driving this variability. In addition, our 10K memorability image set can benefit studies looking to investigate neural or behavioral correlates of memorability while controlling for the semantic label.

Acknowledgement: This work was supported by a personal fellowship by the Research Foundation – Flanders (FWO) awarded to Lore Goetschalckx (Grant 1108116N), and by a Methusalem grant awarded to Johan Wagemans by the Flemish Government (METH/14/02).

53.368 **Recognition-induced forgetting of temporally related visual long-term memories**
Yoolim Hong[1](hong.503@osu.edu), Ashleigh M. Maxcey[1], Andrew B. Leber[1]; [1]The Ohio State University

Long-term storage of visual object representations is neither veridical nor stable. For instance, recognition-induced forgettingshows that an object becomes more prone to forgetting when a semantically related object is practiced. Here, we ask whether relating to the practiced object by virtue

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of temporal grouping, rather than semantic grouping, leads to forgetting. To impose temporal grouping, we employed a modified recognition-induced forgettingparadigm in which sequentially presented objects were grouped into triplets. To elicit forgetting, we had participants practice the second object in the triplet. We later tested if memory became impaired for the first/third items in these triplets, compared to control objects. In preliminary experiments, we found this forgetting effect only for objects presented in the third position (i.e., right after the practiced objects). These results may have been weak due to relatively little experience with each triplet. To bolster memory for temporal associations, participants initially studied each triplet multiple times. Participants then returned within 1-4 days for the second session. In the initial study phase of the second session, participants studied some of the trained triplets from the first session. Next, in the recognition-practice phase, participants made source recognition judgments, reporting if they had seen each presented object during the study phase of the current day's session. Correct hits were middle objects from half of the triplets presented from the initial study phase on the second day. In the final test phase, source memory for all studied objects was tested. We found a robust forgetting effect for objects in the same triplets as practiced objects, relative to a baseline comprised of objects in the same serial positions of non-practiced triplets. These results induced via visual episodic source memory suggest that recognition-induced forgettingis a more ubiquitous effect than previously believed.

Acknowledgement: NSF BCS-1632296 to ABL

53.369 **Forgetting unpleasant visual memories** Ashton Schneider[1](ammaxcey@gmail.com), Ashleigh Maxcey[1]; [1]Psychology Department, Ohio State University

Is it harder to forget an emotionally arousing visual stimulus than the kind of common household objects we use in vision science? Here we answered this question by having subjects remember emotionally arousing pictures in a recognition-induced forgetting task. Recognition-induced forgetting occurs when accessing one memory leads to the forgetting of related memories. Recognition-induced forgetting studies to date have demonstrated forgetting with everyday objects but here we asked whether negatively arousing images were also susceptible to forgetting. To this end, we conducted a typical recognition-induced forgetting experiment but included emotionally arousing images as well as emotionally neutral images. First, in the study phase, subjects studied images for a later memory test, including neutral everyday objects (e.g., dressers) and negatively arousing objects (e.g., rotten teeth). Then, in the practice phase, subjects were asked to recognize a subset of the studied images. Finally, in the test phase, memory for all images was tested. We found non-practiced negatively arousing images received an expected boost in memory strength. However negatively arousing images were still susceptible to recognition-induced forgetting. That is, recognizing an image of rotten teeth in the practice phase led to the forgetting of other studied rotten teeth. We replicated this result in a second experiment with images that were rated even more negatively arousing (e.g., dead bodies). These results suggest that it is just as easy to forget emotionally charged pictures as the simple objects more commonly used in vision science.

53.370 **Orienting attention within long-term memories** Nora M Roüast[1,2](nora.rouast@psy.ox.ac.uk), Anna-Katharina Bauer[1,2], Nahid Zokaei[1,2], Anna C Nobre[1,2]; [1]Department of Experimental Psychology, University of Oxford, [2]Oxford Centre of Human Brain Activity, University of Oxford

Selective attention has been shown to operate within the context of working-memory representations. Cues that retrospectively predict the location or features of relevant memoranda (retro-cues) confer significant benefits to performance. Intuition suggests that it may be equally possible to focus selectively on specific attributes of long-term memory. In this experiment, we adapted the logic of the retro-cue design to test whether orienting spatial attention facilitated recognition of specific items within stable, long-term contextual memories. In a learning phase, we exposed participants to novel object-scene pairings. Participants identified the location of two unique objects within each of the scenes, and were asked to remember both object location and identity for a short delay period (5 seconds). Importantly, the objects were always placed at different sides of the screen center. Learning of 64 objects-scene pairings was repeated over three blocks. After a distracting 20-minute break, participants performed a recognition task. The scene appeared without its associated objects, followed by a spatially informative (left or right) or neutral retro-cue. Informative (valid) cues indicated the side on which the to-be-probed objects were learned. Two items were then presented on an empty screen, and participants indicated which of the two had been previously embedded in the scene. The forced-choice response between two objects (one remembered, one novel) showed facilitation of object recognition by valid spatial retro-cues relative to neutral cues. Our results suggest that it is possible to orient attention selectively within long-term memories. Our task design may provide an effective way to manipulate and measure the consequences of orienting attention to different aspects of memoranda within long-term contextual memories.

Acknowledgement: Economic and Social Research Council (UK), British Academy, Wellcome Trust

53.371 **The effect of time and repeated retrieval on long-term memory representations** Maria V. Servetnik[1](servetnikmaria@gmail.com), Igor S. Utochkin[1]; [1]National Research University Higher School of Economics

It has been demonstrated (Brady, Konkle, Gill, Oliva & Alvarez, 2013) that the limit of fidelity for feature representations is stable across memory subsystems. However, it is known that long-term memory is different from working memory when it comes to temporal processes (Cowan, 2008). Specifically, consolidation processes (Born & Wilhelm, 2012), as well as the act of retrieval (Karpicke & Roediger, 2007), influence contents of long-term memory. We examined the influence of time and retrieval on feature representations in long-term memory using the continuous report paradigm (Wilken & Ma, 2004; Zhang & Luck, 2008). The experiment consisted of three stages. During the first stage, all participants were presented with 330 images of real-world objects and required to remember each object and its color. During the second stage, immediately after the study, all the participants were presented with grayscale objects. The experimental group had to choose each object's color on a color wheel, whereas the control group had to distinguish between old and new objects in a 2AFC task. In the third stage, which took place 24-26 hours after the second, all the participants had to choose the color of each object on a color wheel. The responses given by subjects were analyzed using mixture models of a uniform and a von Mises distribution (Zhang & Luck, 2008). The obtained results showed that the fidelity in long-term memory was not influenced by time or retrieval and support the conclusion by Brady et al. (2013) that the fidelity limit in memory subsystems is caused by a higher-order limitation. Additionally, our data show that repeated retrieval in long-term memory leads to occurrence of false memories — specifically, real memories of the presented color are replaced with the participants' wrong answers during first retrieval.

53.372 **Regularity-induced attentional biases and their mnemonic consequences** Brynn E Sherman[1](brynn.sherman@yale.edu), Nicholas B Turk-Browne[1]; [1]Department of Psychology, Yale University

Our experiences contain both statistical regularities (e.g., the route and scenery on your walk home) and idiosyncratic details (e.g., the time you ran into an old friend on the sidewalk). Despite the commonalities among our experiences, we are able to form rich memories of these unique events. Prior work has demonstrated that attention is captured by and oriented to regularities (e.g., Zhao et al., 2013), yet attention also powerfully influences what we encode and subsequently remember. Together, these facts pose a paradox: How can we encode unique details of our environment if attention is drawn to the regularities in our environment? To address this question, we adapted temporal and spatial visual statistical learning paradigms to include: (a) trial-unique information embedded in the context of regularities and (b) surprise memory tests of the trial-unique information. In the temporal domain, we found that memory is suppressed for predictive items (e.g., first items in a temporal pair), suggesting that attentional orienting to predicted information may suppress the encoding of current information. In ongoing work in the spatial domain, we replicated previous work showing that attention is facilitated by regularities, as measured here by faster response times in structured displays. Additionally, we obtained preliminary evidence that memory is enhanced for information that co-occurs with regularities, suggesting that the attentional enhancement for regularities can spread over space. These data highlight interactions between statistical learning and episodic memory and suggest that these interactions may be mediated by attention.

Acknowledgement: NSF GRFP NIH R01 MH069456

53.373 **Examining limits of encoding into visual long-term memory** D. Alexander Varakin[1](donald.varakin@eku.edu), Derek McClellan[1]; [1]Department of Psychology, Eastern Kentucky University

Past research suggests task-relevant objects are better encoded into visual long-term memory than task-irrelevant objects. McClellan, Varakin, Renfro, and Hays (2018, VSS) demonstrated that the number of task-relevant object categories during study moderates this effect. When participants counted or memorized one or two object categories, task-relevant objects were better recognized on a subsequent memory test than task-irrelevant objects.

However, when participants counted or memorized five object categories, the memory advantage for task-relevant over task-irrelevant objects was not significant. The current experiment replicates and extends these findings. Participants (N = 194) first viewed a series of objects while performing a cover task.Whereas our past participants either counted or memorized objects, participants in the current study pressed a button whenever task-relevant objects appeared. The number of task relevant object categories was one, two, three, or five. As in past work, participants completed a yes/no recognition memory test that consisted of one task-relevant category and one task-irrelevant category. Similar to the results of McClellan et al. (2018), with recognition sensitivity as the dependent variable, there was an interaction between task-relevance and the number of relevant categories at study ($p < .05$). When one or two categories were relevant at study, the effect size of task-relevance was about $d = 0.77$ ($ps < .001$). When three or five categories were task relevant, effect sizes were smaller, $d = .42$ and $d = .49$ ($ps = .005$ and $.002$), respectively. These results reinforce the idea that limits of attentional selection and working memory influence encoding into VLTM. However, the results do not align with the idea that the limit is 3 or 4 items. First, the effect of task-relevance decreased between two and three task-relevant categories. Second, though diminished, there was still a statistically significant effect of task-relevance on VLTM when five categories were task-relevant during study.

53.374 **Arbitrary Groupings Modulate Visual Statistical Learning** Leeland L Rogers[1](Llrogers@psych.udel.edu), Su Hyoun Park[1], Timothy J Vickery[1]; [1]University of Delaware

Visual statistical learning (VSL) occurs when stimuli consistently co-occur in space or time. Subsequent to such exposure, even in the absence of awareness, subjects recognize such associations. The roles of stimulus similarity, categories, and tasks in shaping VSL are poorly understood and understudied. In previous work from our lab (Vickery, Park, Gupta & Berryhill, 2018), we found that subjects learned same-category pairings better than different-category pairings during exposure to temporal VSL streams containing such contingencies. This only occurred when the task was to categorize stimuli. It was not clear, however, whether visual similarity or categorization played the predominant role in this effect. In the current work, participants saw a stream of either fractal images (Experiment 1) or face and scene images (Experiment 2). The stream of images was composed of AB pairs of stimuli, such that image A always preceded image B within the stream. Subjects were instructed to learn arbitrary group mappings, with half of images associated with one group ('z' key response) and the other half with the other ('m' key response). Half of the pairs were within-group while the other half were between-group. In Experiment 1, subjects showed much greater recognition for within- than between-group pairings ($p < .01$), despite the fact that similarity was equalized by random assignment of fractal image to pairing and group. Experiment 2 replicated this effect ($p < .001$). In addition, Experiment 2 pairs were also equally composed of same or different natural category (face or scene) images equally divided between same and different arbitrary groupings ('z' and 'm' categories). Natural categories still played a role ($p < .001$), with better recognition for within-category pairings (no interaction between grouping and category). Our results strongly suggest that both arbitrary groupings and natural categories play strong roles in determining the strength of VSL.

Acknowledgement: NSF OIA 1632849 NSF BCS 1558535

Visual search: Dynamic fields, individual differences

Tuesday, May 21, 8:30 am - 12:30 pm, Pavilion

53.401 **And just like that, everybody searches optimally: how changing task irrelevant details remove individual differences in visual search** Alasdair DF Clarke[1](a.clarke@essex.ac.uk), Anna Nowakowska[2], Amelia R Hunt[2]; [1]Department of Psychology, University of Essex, UK, [2]School of Psychology, University of Aberdeen, UK

It has long been established that the difficulty of determining whether a target is present or not among a set of distracters depends on the heterogeneity of said distracters. If they are homogeneous then the target will be detected effortlessly via peripheral vision; if they are heterogeneous then a series of saccades will be required.Previous research has uncovered large, stable individual differences in how observers search arrays of line segments when the distracters have low variance on one side, and high variance on the other [Nowakowska, Clarke & Hunt, 2017]. While a small number of observers follow the optimal strategy (saccade to high variance side on target absent trials), many others perform at chance, or even 'counter-optimal.'Here, we present a new series of experiments (N = 60 in total) in which we replace the line segments with different classes of items (icons, mosaics, polygons).An Eyelink 1000 was used, and each experiment involved around 200 trials, half of which contained the target. The suitability of the each class of stimuli was validated in a pilot study to confirm that the target, when present, is clearly visible when on the homogeneous half of the display, and only visible after careful inspection on the heterogeneous side.The results show that search behaviour can change dramatically when we vary surface-level details of the task. When observers are faced with an array of computer icons (i.e., applications and folders), they all search optimally, ignoring the homogeneous side and directing their attention to the heterogeneous side of the display. Oriented line segments are visual primitives, assumed to generalize to more complex objects. Yet they produce highly variable and sub-optimal search, while complex objects are searched with near-perfect efficiency.

53.402 **Reduction of attentional bias through gradual signal change** Injae Hong[1,2](injae.hong@yonsei.ac.kr), Min-Shik Kim[1], Su Keun Jeong[2]; [1]Department of Psychology, Yonsei University, [2]Korea Brain Research Institute

Probability cueing effect refers to an attentional bias toward a highly probable target location. Previous studies have shown that such bias occurs through accumulation of incidents over time and stays robust when once learned (Jiang, Swallow, Rosenbaum, & Herzig, 2013).However, the probability distribution in the real world could dynamically change across time and it would be beneficial for the visual system if the bias can be readjusted. Here, we investigated whether a gradual change in the probability distribution can influence the learning of a spatial bias. Participants were instructed to search for a target among multiple distractors under acondition where a target was more likely to appear in one of four quadrants in the display. For the half of the participants, the probability of target presence in the frequent quadrant gradually decreased until the probability distribution reachedeven for all four quadrants (gradual group). For the remaining participants, the probability distribution remained the same throughout the learning phase (constant group). Importantly, the total number of attentional shifts to the target-frequent quadrant was kept the same for both gradual and constant groups. To test whether participants acquired statistical knowledge of target locations, we asked them to perform a search task in which a target appeared equally often in all four quadrants. Results showed that the spatial bias was weakened in the gradual group than in the constant group even though both groups experienced the same amount of statistical information during the learning phase. In sum, we found that the learning of statistical knowledge can be modulated through gradual signal change toward a frequent target location. The current finding suggests that the temporal change of experience is more likely to have an impact on the learning of a spatial bias than the total amount of experience.

Acknowledgement: 18-BR-01-07 & IBS-R001-D1-2018-b01

53.403 **Adapting target selection in dynamically changing visual scenes** Nils Bergmann[1](nils.bergmann@uni-marburg.de), Jan Tünnermann[1], Anna Schubö[1]; [1]Cognitive Neuroscience of Perception and Action, Department of Psychology, Philipps University Marburg, Germany

When multiple attentional control settings are available, observers often use suboptimal strategies in visual search. We used a variant of the adaptive choice visual search task (Irons & Leber, 2016) to examine the dynamical adaptation of feature search and singleton detection mode, search modes known to be susceptible to suboptimal selection (Bacon & Egeth, 1994). In a visual search task, participants were free to select one of two shape targets in each trial. One of the targets was always colored; the other one was always gray. The amount of colored and gray distractors varied systematically from displays in which either the gray or the color target was a color singleton. These singleton displays were connected by transition phases in which the number of colored and gray distractors predictively changed across trials from displays containing only gray to displays containing only colored distractors. As the target shape was known in advance, we assumed that participants could use feature search to find either target in all trials, whereas they could use singleton detection mode in trials with only few colored or gray items. We examined the proportion of chosen gray and colored targets during the trial sequence. Results showed that participants selected the color and gray target most frequently when it was a singleton, yet target selection was far from optimal.During the transition phase participants were more likely to switch to the target that was a singleton at the end of the transition. The extent to which the participants adapted their target choice to the trial sequence differed among individuals and was correlated

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with individual working memory capacity. Overall, these findings suggest that observers dynamically switch to singleton detection mode when optimal but that switching between search modes differs among individuals.

Acknowledgement: This research was supported by the Deutsche Forschungsgemeinschaft (German Research Foundation SFB/TRR 135, TP B3 and RTG 2271).

53.404 Concurrent attentional template activation during preparation for multiple-colour search

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Visual search is guided by attentional templates for target-defining features. Using a new rapid serial probe presentation (RSPP) paradigm and N2pc components as electrophysiological markers of attentional capture, we recently showed that templates for a specific target colour are transiently activated during the preparation for individual search episodes (Grubert & Eimer, 2018). Here, we used similar RSPP procedures to assess the preparatory activation of multiple target templates in two-colour search tasks. Circular search displays (presented every 1600 ms) contained a colour-defined target among five differently coloured distractors. Brief circular probe displays that included a target-colour singleton among grey items were flashed in rapid succession (every 200 ms) throughout each block, at a different eccentricity than the search displays. N2pcs were measured to each successive target-colour probe in the interval between two search displays. Probe N2pc amplitudes increased during the preparation period and were largest for probes directly preceding the next search display, reflecting transient template activation. This temporal pattern was observed not only when all search targets had a single constant colour but also when targets were defined by one of two equiprobable colours (two-colour search), demonstrating the concurrent activation of two colour templates. To assess whether such multiple template activation states can be adjusted strategically, we ran two additional two-colour search tasks where one target colour was more frequent (80%/20%), and where target colours alternated between search displays so that the upcoming target colour was fully predictable (ABAB). Probe N2pcs revealed identical template activation for both colours in the 80%/20% task, and an activation of the target colour template that was irrelevant for the next search display in the ABAB task. These results demonstrate that while multiple preparatory target templates can be activated simultaneously, there are remarkable limitations in the top-down strategic control of these template activation states.

Acknowledgement: This work was supported by grant ES/K006142/1 from the Economic and Social Research Council (ESRC), UK.

53.405 Noise and motion: A new visual search paradigm with multiple random dot kinematograms (RDKs)

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The visual search paradigm is a standard lab approach to examine how we find behaviourally relevant objects in a complex environment. Typically in this paradigm items are static and noiseless. This approach strongly contrasts with our dynamic and noisy natural environment.To understand visual search in a more natural environment, we developed a novel search paradigm with multiple random dot kinematogram (RDK) apertures. To our knowledge, ours is the first such study with humans to explore the influence of motion and noise on visual search. In our design, participants were asked to search for an RDK aperture with a specific direction of coherent motion (e.g. left) among a varying number of RDKs (5, 10, 15) containing movement in the opposite direction In addition, we manipulated the level of coherence (65%, 80%, 90%) of the RDKs in a blocked fashion. The target motion was only present on half the trials, and interestingly, we found that search slopes for target-present trials were negative, most strongly the highest noise condition. Such negative slopes are similar to those seen in texture segmentation paradigms, where perceptual grouping processes allow the perception of a global 'texture region.' Here, the target causes a local texture gradient, facilitating attentional capture. This contrast is more pronounced with larger set sizes. As the negative slope is larger with higher levels of noise, we stipulate that participants rely more on this 'texture' effect with increasing noise. We also compared our findings to a static, colour pop-out version of the task (i.e., similar item size, display geometry, etc.). Results suggest the searches were performed differently, implying that motion may be unique in the way it guides visual search.

53.406 Do people's visual ability skill predict search efficiency under difficult search conditions?

Jing Xu[1](jingxu9@illinois.edu), Kirk Ballew[1], Alejandro Lleras[1], Simona Buetti[1]; [1]Psychology Department, University of Illinois, Urbana Champaign, [2]Psychology Department, University of Illinois, Urbana Champaign, [3]Psychology Department, University of Illinois, Urbana Champaign, [4]Psychology Department, University of Illinois, Urbana Champaign

Richler, Wilmer and Gauthier (2017) proposed a Novel Object Recognition Test (NOMT) to measure people's ability to identify a novel visual object among other visual objects that closely resemble it. This task indexes a global visual ability involving making fine comparisons between a stored representation in memory and visual objects that closely resemble it. Across studies, it shows good reliability and is a measure distinct from other psychometric measures like IQ and working memory capacity. We hypothesized that the comparison made between the mental representation and the visual objects in the NOMT test might rely on the same resource that is used in inefficient visual search. In inefficient visual search, people compare each distractor in the display with the target template in mind and reject the distractors until they find the target. Previously work found no meaningful correlation between people's NOMT scores and their efficiency in a fixed-target parallel visual search task (Xu, Lleras, and Buetti, 2018). There is reason to believe that different results might be observed in inefficient search. Indeed, Alvarez and Cavanagh (2004) showed that there is a correlation between the efficiency at which participants can search through stimuli of a given category and the number of objects of that category that they can hold in short term memory. This suggests that the efficiency in inefficient visual search might be related to a participant's ability to do fine visual discriminations. The current study investigated this possibility using an individual differences approach. We measured people's visual search ability under two very difficult search conditions as well as participants' NOMT score and their feature-VSTM capacity to control for gross (non-fine) visual working memory ability. The findings help clarify the different roles feature-VSTM and visual skill play in predicting performance in visual search.

53.407 Visual Foraging with Dynamic Stimuli

Jan Tünnermann[1](jan.tuennermann@uni-marburg.de), Anna Schubö[1]; [1]Cognitive Neuroscience of Perception and Action, Department of Psychology, Philipps University Marburg

Foraging is a key behavior in virtually all organisms. In many animals---and especially in primates---foraging is supported by active vision and selective attention. Therefore, computer-based virtual foraging tasks are valuable tools to assess attentional control. In foraging paradigms, participants "harvest" visual elements from limited patches ("berry picking", cf. Wolfe, 2013) or select elements from multi-element displays containing different target types and distractor elements. When participants have to forage "cryptic" targets (defined by feature conjunctions), they minimize the amount of switching between different target types (Kristjánsson, Jóhannesson, & Thornton, 2014). We extended this visual foraging paradigm by adding dynamic stimuli, which randomly move across a tablet PC screen and have to be collected with a pen.In addition to comparing performance with static and moving displays, we manipulated the ratio of different target types, which becomes possible because of the motion in the display: The complex motion pattern allows to "refill" collected targets without the participants noticing the replacement. In this way, the ratio between two targets types which have to be collected can be held constant or manipulated to assess whether participants make use of different target frequencies. The results show that both static and moving targets defined via simple features led to frequent random switching between target types. Conjunction targets, static or moving, led to longer runs during which the same target type was selected, in agreement with earlier research. Moreover, participants tended to forage the more plentiful target type when target frequencies were manipulated. In sum, our results extend earlier findings of prolonged runs with conjunction targets known from static displays and show that target speed, spatial target distribution, and target ratios can alter attentional strategies as well.

53.408 **When do you find the next item?: Using occluders to uncover the time course of visual foraging** Anna Kosovicheva[1](anna.kosov@gmail.com), Jeremy M. Wolfe[2,3]; [1]Department of Psychology, Northeastern University, [2]Brigham and Women's Hospital, [3]Harvard Medical School

When searching for multiple instances of a target, observers might wait until they collect one target before beginning to look for the next. Alternatively, they could be searching ahead. We developed a novel procedure for tracking attention during visual foraging search. Subjects collected 4, 7, or 10 T shapes among 20, 17, or 14 Ls. Both targets and distractors were intermittently occluded by filled squares, in a regular on-off cycle, each with a randomly selected phase. There were three visibility conditions: 1s-on/3s-off, 4s-on/4s-off, and continuously visible. Subjects were instructed to click on targets as quickly as possible, regardless of whether they were visible or occluded when clicked. Since targets must be visible in order to be located, we can infer when a target was found from its history of visibility. Averaged across visibility conditions, peak visibility for targets was 719 ms before the click on that target location. Importantly, peak visibility for the next target occurred 30 ms before the click on the current target. These results are consistent with eye tracking data in unoccluded search. Here, subjects first fixate a target 610 ms before the corresponding click, and fixate the next target 66 ms after the click on the current item. The peak of the visibility distribution shifts toward later time points when fewer targets remain in the display, and it takes longer to find the next target. In a control experiment, all items were randomly shuffled between locations on each click, forcing observers to re-start the search after each click. Here, the peak of the visibility distribution for the next item was 374 ms after the click on the current target. Together, these results indicate that observers search for and find the next item before collecting the current item.

53.409 **What not to look for: electrophysiological evidence that searchers prefer positive template** Jason Rajsic[1](jason.rajsic@vanderbilt.edu), Geoffrey F Woodman[1]; [1]Department of Psychology, College of Arts and Sciences, Vanderbilt University

When we search for objects, we often know what we are looking for. However, sometimes we need to search when all we know is what we don't need (e.g., looking for something in the buffet that you haven't eaten yet). Prior behavioral research has shown that these negative searches are less efficient than search for targets with known features. In addition, when search tasks allow for either strategy, searchers elect to attend stimuli with known features. Here, we used event-related potentials to measure whether searchers choose to form positive templates when the option is available, even if instructed otherwise. Participants completed blocks of positive searches and negative searches where, before each search, a bilateral pair of colors was shown. The cued color in each pair always informed participants of the target color (positive search) or non-target color (negative search). The other color in the pair was random. In this context, we measured similar contralateral negativities to the two cues, showing that both cue types were stored in working memory as templates. As expected, negative searches were slower and less accurate than positive searches. A separate group of participants completed the same task with a critical change: every color-cue pair contained the same two colors that were used in subsequent search arrays. This meant that the non-cued color always matched the to-be-ignored color in positive search blocks, and the non-cued color always matched the to-be-attended color in negative search blocks. Contralateral negativities flipped sign in negative search blocks, demonstrating that searchers instead formed positive templates using the non-cued color. Behavioral data corroborated this conclusion. This provides new evidence that positive searches are preferred, and that the CDA reflects searchers' decisions to use a cue.

Acknowledgement: NIE, NIMH, NIH

53.410 **The role of executive functions in foraging throughout development** Inga M Ólafsdóttir[1](imo4@hi.is), Steinunn Gestsdóttir[1], Árni Kristjánsson[1]; [1]University of Iceland

In visual foraging paradigms participants search for multiple targets among distractors. Studying visual attention from a different angle than traditional single target visual search tasks may provide a deeper understanding of the dynamics of the visual attentional system. Foraging tasks allow, for example, the study of how attention is allocated over time and how observers attend to multiple targets of various types. To date, little is known about the way foraging abilities develop. In this study, the foraging of five age groups, children aged six, nine, twelve, and fifteen, along with adults, was measured, in addition to performance on various tasks measuring four subdomains of executive functions; inhibition, working memory, attentional flexibility, and planning. Executive functions are a a complex network of cognitive processes that underlie action planning and goal directed behaviors, and have been shown to be connected to attentional orienting. Foraging abilities improve dramatically between ages six and twelve, when they start to plateau. This is evident by increasingly faster foraging, more frequent switching between target types, and lower switch costs. In addition, the foraging performance of 15 year old children and adults seems to rely predominantly on visual working memory, whereas the foraging of six and nine year old children is connected to more global measures of executive functions. The connection of foraging and executive functions of the twelve year old participants lies in between the other groups, with a connection with both global measures and visual working memory. Foraging is proving to be a promising way of studying visual attention and its development yielding insights that more traditional visual attention tasks miss.

Acknowledgement: The University of Iceland Research Fund

53.411 **Intelligence, Impulsivity and Selective Attention have something to tell us about Hybrid Foraging performance** Adrián R. Muñoz-García[1](adrian.munnoz@uam.es), Jeremy M. Wolfe[2], Beatriz Gil-Gómez de Liaño[2,3]; [1]Universidad Autónoma de Madrid, [2]Harvard Medical School-Brigham & Women's Hospital, [3]University of Cambridge

The modulation of Visual Search (VS) performance by intelligence has not yet been established. However, it has been found that for hybrid foraging there may be a significant correlation with fluid intelligence, Gf (given by the APM Raven test). In hybrid foraging tasks observers must collect multiple visual instances of several types of targets held in memory. The juggling of memory and visual search in hybrid foraging may involve strategies drawn more heavily than simple visual search on intelligence and attentional processes. In the present work we tested that possibility by asking participants (n=34) to perform easy feature foraging (looking for green/blue squares among red/yellow squares), and more difficult conjunction foraging (looking for green circles and blue squares among green squares and blue circles). We also collected measures of IQ using the Reynolds Intellectual Screening Test – RIST for IQ (including verbal and non-verbal intelligence), and attentional function (inattentiveness, impulsivity, sustained attention, and vigilance) using the Conners Continuous Performance Test CPT. Results show that IQ and attention are correlated with conjunction hybrid foraging: When general IQ is higher, RTs are lower ($p=.02$) on trials when observers switch responses between target types. Also, False Alarms are reduced as non-verbal IQ increases ($p=.005$). Finally, impulsivity and inattentiveness may also be weakly correlated with conjunction foraging measures: More inattentiveness weakly correlates with more misses ($p=.06$), and with higher RTs for conjunction foraging ($p=.05$). Surprisingly, higher levels of impulsivity correlate with more hits in conjunction foraging ($p< .01$, for all comparisons). Taken together, the results show that complex cognitive processes and maybe personality may impact foraging behavior.

53.412 **An exploration of trait variables predicting the goal-directed control of visual attention** Molly R McKinney[1](mckinney.230@osu.edu), Heather A Hansen[1], Jessica L Irons[1], Andrew B Leber[1]; [1]Psychology Department, Arts & Sciences, The Ohio State University

When approaching a visual search, there are many strategies you can use to bias your attention – some more optimal than others. Vast individual differences in strategy exist and many individuals fail to use the optimal strategy. What factors might contribute to these individual differences? To address this question, we used the Adaptive Choice Visual Search task (Irons & Leber 2016), a paradigm designed to investigate how individuals choose their strategies. Participants are presented with a display of colored squares and tasked with finding one of two targets (red or blue) on each trial, and can freely choose which target they find. Across trials, the ratio of red to blue squares changes, so the optimal strategy is to search for the target color with the fewest squares. To explore what factors may influence optimal strategy usage, we collected self-report measures probing reasoning abilities (ICAR) and mindfulness (MAAS), and will collect academic transcripts (including course grades, GPA, SAT & ACT scores) as part of an ongoing study to determine if these measures, isolated or combined, predict performance. Initial results reveal that individuals with low MAAS scores show a significantly larger increase in optimality across blocks than individuals with high MAAS scores do, showing mindfulness may assist in utilizing the optimal strategy. Further, individuals with high ICAR scores (using a median split) find and utilize the optimal strategy significantly sooner than their low-scoring counterparts. Given the effortful demands of the ICAR, this suggests that either greater reasoning ability or more willingness to invest in an effortful

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task can contribute to more optimal strategy usage. Additional analyses will assess these self-report measures in company with the academic transcript data, for a more in-depth look at the interaction of these factors in the use of goal-directed control during visual search.

Acknowledgement: NSF BCS-1632296

53.413 **Opposing effects of stimulus-driven and memory-driven attention in visual search** Koeun Jung[1](jungke1225@gmail.com), Suk Won Han[1], Yoonki Min[1]; [1]Department of psychology, Chungnam University

A recent study (Jung, Han, & Min, in press) reported that the extent to which attentional control is strained is a critical factor for observing stimulus-driven attentional capture in visual search. Expanding this study, we tested whether memory-driven attentional capture is also dependent on cognitive mechanism underlying visual search tasks. In our experiment, a group of participants performed a dual task, consisting of a working memory and a visual search task (memory-driven attention group), whereas the other performed only a visual search task (stimulus-driven attention group). Each group was further divided into two groups depending on the search task performed. For visual search tasks, we utilized two different search tasks; Landolt-C and orientation feature search tasks. For the former, participants searched for an outlined square with a top- or bottom-gap among left- or right-gap squares. For the latter, participants looked for a right- or left-tilted line among vertical lines. In a half of the total trials, a memory-matching/salient singleton distractor was present. In the remaining trials, no such a memory-matching/singleton distractor was present. As results, attentional capture by the singleton distractor was found under feature search task, $p< .01$. On the contrary, the task-irrelevant distractor did not capture when participants performed the Landolt-C search, $p> .45$. The memory-driven group showed a different pattern. A task-irrelevant, memory matching distractor captured attention when participants performed Landolt-C search task, $p< .001$. However, no memory-driven attentional capture was found under the feature search, $p > .72$. Our results demonstrate that the nature underlying visual search tasks is an important factor for observing both stimulus-driven and memory-driven attention. However, the specific patterns of the capture were opposite. These findings point to the role of interplay between the extent to which attentional control is strained and working memory in attentional capture.

Motion: Motion in depth, optic flow

Tuesday, May 21, 8:30 am - 12:30 pm, Pavilion

53.414 **Temporal integration of isolated 3D motion cues** Jake A Whritner[1](jake.whritner@utexas.edu), Thaddeus B Czuba[1], Lawrence K Cormack[1], Alexander C Huk[1]; [1]Center for Perceptual Systems, University of Texas at Austin

INTRODUCTION. Previously, we have shown that 3D motion is integrated over time by a distinct mechanism that is more sluggish than the integrator for frontoparallel motion (Katz et al., 2015). Here, we enquire whether the two primary binocular cues to 3D motion—changing disparity (CD) and interocular velocity difference (IOVD)—have distinct temporal integration profiles. Given the evidence that the CD and IOVD mechanisms operate at relatively low and high stimulus speeds, respectively, we reasoned that they might have different integration times as well. METHODS. We varied stimulus duration (67-1067 ms) and measured response accuracy during a 3D discrimination task. Observers viewed either an IOVD- or CD-only stimulus moving towards or away in depth and reported direction of motion via key press. For the IOVD-isolating condition, we modified the novel stimulus of Sheliga et al. (2016). This stimulus comprises binocular Gabor patches that have opposite, unambiguous directions of drift in the two eyes, yet always have an ambiguous interocular phase disparity, producing pure IOVDs with no net CD. For the CD-only condition, the baseline Gabor phase changed randomly on each frame while the interocular phase difference was gradually incremented, producing pure CDs with no net IOVD. RESULTS & DISCUSSION. Sensitivity to CD improved gradually over the first 500 ms, whereas IOVD sensitivity saturated in less than half that time. These results support the hypothesis that CD and IOVD cues use separate underlying mechanisms, and that the former is much more sluggish (perhaps not being a true motion mechanism at all). Furthermore, we have introduced a class of stimuli that isolate one cue or the other while being otherwise matched along many other stimulus dimensions. Extensions to this paradigm will allow for better characterization of the sensory- and decision-related contributions to the time course of integration.

Acknowledgement: NIH NEI R01-EY027023 (to ACH, Wyeth Bair, and Adam Kohn), NIH T32 EY21462-6 (JAW, TBC)

53.415 **Perception of Ambiguous Motion Biased by Dimensional Cues** Joshua E Zosky[1](joshua.e.zosky@gmail.com), Michael D Dodd[1]; [1]Department of Psychology, University of Nebraska - Lincoln

Visual motion perception is a difficult process to study in isolation given the intrinsic connection to object perception. One frequently used method of studying motion perception is random dot kinematograms (RDK) where a plane of moving dots are presented in various proportions of coherent motion. Though valuable, the majority of studies using RDK lack the complexity of higher-order perception. In the current study, a novel approach to motion detection was used to determine how later perceptual processes, primarily depth cues, can influence early motion signals. Here, we demonstrate that the presentation of task irrelevant, three-dimensional rotating stimuli can strongly influence the perception of task-central ambiguous motion. Participants observed a rotating orb constructed of surface-coordinate dots and a surrounding polygon. Participants were tested on whether they perceived motion congruous to the orb versus the task-irrelevant polygon. On each trial participants indicated the direction of orb rotation as well as any changes in the direction of rotation over the course of the trial. After initial response, trials continued briefly while the polygon would update to its secondary direction. Any secondary responses were also collected. Trials were split by a blank perceptual refresh screen. Trials were balanced across multiple factors: number of dots (1, 10, 100, 1000), direction of orb rotation (left or right), direction of polygon rotation (left or right), secondary direction of polygon rotation (left or right). Critically, the perception was biased by the direction of the polygon despite the fact that it was irrelevant to the primary motion decision. This suggests that motion detection is directly influenced by later perceptual processes including depth cues.

Acknowledgement: NSF/EPSCoR grant #1632849

53.416 **Testing for a lingering monocular basis in 3D motion perception** Neil D Shah[1](neil.d.shah@utexas.edu), Jake A Whritner[1], Lawrence K Cormack[1], Alexander C Huk[1]; [1]Center for Perceptual Systems, University of Texas at Austin

INTRODUCTION. When an object moves through the 3D environment, the projections upon the retinae of the left and right eyes contain different velocities. This interocular velocity difference has been established as a primary source of information for computing 3D motion direction. Here, we investigate a particularly important geometric case: When an object moves towards one of the eyes, small changes in the horizontal component of its 3D direction can result in a flip of the retinal direction. METHODS. We used motion adaptation as a psychophysical probe for whether the visual system encodes such changes in 3D direction as subtle changes (consistent with a generic representation of 3D velocity), or as categorically distinct whenever the retinal direction flips (consistent with a representation of 3D velocity still fundamentally rooted in the monocular velocities). Observers stereoscopically viewed an adaptation cue slightly off of the ocular axis followed by probes at the surrounding angles interspersed with top-up periods. They reported a comparison (clockwise or counter-clockwise) of the probe direction relative to the adaptation direction; some of the probe directions involved a flip of monocular direction. RESULTS & DISCUSSION. 3D direction discrimination accuracy was generally a linear function of the presented 3D direction. However, the slope of this relation increased (i.e., indicating greater sensitivity) as the 3D direction of the probe stimuli flipped retinal direction in one eye. This implies a distinct adaptation state that is dependent on monocular direction and not just 3D direction. This lingering monocular basis of the 3D motion representation means that the neural "read out" underlying perception is still significantly grounded in monocular retinal velocity, rather than being wholly abstracted into a simple and generic 3D motion signal.

53.417 **'Explaining Away' Cue Conflicts for Motion-in-Depth** Ross Goutcher[1](ross.goutcher@stir.ac.uk), Lauren Murray[1], Brooke Benz[1,2]; [1]Psychology, Faculty of Natural Sciences, University of Stirling, [2]Psychology, University of Edinburgh

When an object moves towards or away from an observer, the visual system is presented with multiple cues to its motion-in-depth, including changes in both retinal image size and relative disparity. When these cues are put into conflict, the resulting stimulus is consistent with an object moving in depth while changing in physical size. We examined the conditions under which

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observers ‘explain away’ such conflict between cues as due to a change in object size. Participants were presented with two intervals, each containing a textured, fronto-parallel surface with motion-in-depth described by a triangular waveform. One interval contained a stimulus where changing size and changing disparity cues specified the same motion-in-depth. These cues were then placed into conflict in the target interval by introducing differences in the amplitude, phase or wavelength of the motion-in-depth waveform. Participants were asked to detect the interval containing the object that changed in physical size, with 75% correct thresholds measured for each conflict type. Thresholds for conflicts in amplitude, phase and wavelength were translated into equivalent changes in physical size. Participants correctly discriminated the target interval when cue conflict was consistent with size variation of around 4-6% of the object’s simulated size. Size change thresholds were largely comparable across conflict types, although phase differences were slightly easier to detect. In subsequent experiments, we examined the effects of conflict on the perception of speed-in-depth. Results suggest a limited effect of perceived size change on speed-in-depth discrimination. To account for performance across these tasks, we generated likelihood functions describing the probability of changes in image size or disparity, given object size and speed. We show that the ‘explaining away’ of motion-in-depth cue conflicts can be described in terms of either discrepancies between cues, or through discrepancies between predicted and measured image size changes over time.

53.418 **Functional architecture and mechanisms for 3D direction and distance in middle temporal visual area.** Thaddeus B Czuba[1](czuba@utexas.edu), Lawrence K Cormack[1], Alexander C Huk[1]; [1]Center for Perceptual Systems, Depts of Neuroscience & Psychology, The University of Texas at Austin

Experimental stimuli are often constrained to what can be presented on a flat monitor. While approximating retinal input in this way has laid the foundation for understanding mechanisms of visual processing, the majority of visual information encountered in the real world is 3D. Although cortical area MT has been one of the most thoroughly studied areas of the primate brain, recent evidence has shown that MT neurons are selective for not only 2D retinal motions, but also exhibit selectivity for 3D motion directions (Czuba et al., 2014; Sanada & DeAngelis, 2014). We’ve shown that a model of MT that incorporates the projective geometry of binocular vision is predictive of human perceptual errors in 3D motion estimation (Bonnen et al., 2018). Importantly, perceptual errors and neural response predictions are strongly influenced by viewing distance(VD). We therefore measured the responses of MT neurons in awake macaque to binocular 3D moving dot stimuli rendered with full geometric cues using a motorized projection display that allowed us to precisely and dynamically control physical viewing distance in a range of 30–120 cm. Tuning for 3D direction was widely evident in neurons and similar at different VDs (regardless of disparity tuning). Many neurons with 3D direction tuning changed in overall response level across viewing distances. Moreover, we observed orderly transitions between interdigitated regions of 3D and 2D selectivity across linear array recordings tangential to the cortical surface. Interestingly, regions of 3D selectivity were not necessarily co-localized with classic disparity selectivity. Robust selectivity for 3D motion & space in MT extends beyond simple interaction of known selectivities, and may reflect a transition of information from retinal input space to environmental frames of reference. This finding reinforces the importance of stimuli that more fully encompass both the geometry of retinal projection & statistical regularities of the natural environment.

Acknowledgement: NIH R01-EY027023, NIH R01-EY020592, NIH T32 EY21462

53.419 **Encoding- and decision-related brain activity during a motion judgment task** Peter J Kohler[1](pjkohler@stanford.edu), Elham Barzegaran[1], Brandon E Davis[2], Anthony M Norcia[1]; [1]Department of Psychology, Stanford University, [2]Department of Psychological and Brain Sciences, Washington University in St. Louis

We have previously used steady-state VEPs to show that responses in visual cortex are strongly suppressed when motion stimuli produce inter-ocular velocity differences (Kohler et al., 2018), regardless of whether these differences give rise to movement in depth (MID). Here we used an event-related VEP design to explore how activity evoked by lateral movement and MID unfolds over time. Participants (n=20) viewed stereoscopically presented random-dot patterns in which a central region moved in one of four directions. Dots underwent single-shot apparent motion on every trial: in-phase motion between the two eyes produced lateral movement (left/right), while anti-phase motion gave rise to MID (towards/away). Participants indicated movement direction as quickly and accurately as possible using the keyboard arrow keys. For lateral movement, accuracy was at ceiling and reaction time (RT) was ~800ms, while MID produced lower accuracies (~80%) and longer RTs (~1000ms). We used reliable components analysis to extract maximally correlated signal components from the EEG data (Dmochowski et al., 2012). A medio-frontal component appeared to capture decision-related activity, exhibiting a ramp-like shape that was shallower for MID, consistent with a longer integration period leading to slower RTs. An additional component, centered over occipital cortex, appeared to primarily capture encoding-related activity. Lateral movement and MID produced indistinguishable positive peaks at ~70ms, but diverged at later negative (~180ms) and positive (~350ms) peaks. MID responses were enhanced (more negative) around the negative peak (100-200ms) and suppressed (less positive) leading up to the second positive peak (250-350ms). This late-onset suppression is consistent with the finding that suppression depends on second-order processes, including extraction of relative motion and relative disparity (Kohler et al., 2018). The current results provide a time-resolved electrophysiological analogue to psychophysical data showing that temporal integration underlying decision making is near-perfect for lateral motion, but sub-optimal for MID (Katz et al., 2015).

53.420 **Neural correlates of path integration during visually simulated self-motion** Constanze Schmitt[1](constanze.schmitt@physik.uni-marburg.de), Milosz Krala[1], Frank Bremmer[1]; [1]Dept. Neurophysics and Marburg Center for Mind, Brain and Behavior – CMBB, University of Marburg, Germany

Navigation through an environment requires knowledge not only about one’s direction of self-motion (heading), but also about traveled distance (path integration). We have shown before (e.g. Churan et al., J.Neurophysiol., 2017) that visual optic flow can be used to reproduce the distance of a previously perceived self-motion. In our current study, we employed EEG in human participants to identify neural correlates of such path integration behavior. Visual stimuli were presented on a computer monitor (42° * 24°) 68 cm in front of our participants and simulated self-motion across a ground plane. Stimuli were presented in one of three conditions: passive, active and replay. First, we presented a simulated forward self-motion (passive). Then, participants were asked to use a gamepad to reproduce double the previously observed travel distance (active). Third, the resulting visual stimulus from the active condition was recorded and, after three of such passive-active pairs, played-back in random order to our participants, but without an additional behavioral task (replay). Participants fixated a central target during all stimulus presentations. When aligning event related potentials (ERPs) to visual motion on- or offset, we found attenuated responses in the active condition as compared to the replay and passive condition. These differences were expected in the framework of predictive coding. We then aligned EEG data from the active condition on a trial-by-trial basis to the point in time, when the participants had reproduced half of their travel distance (subjective single distance). In about half of the participants, a wavelet based time-frequency analysis revealed an enhancement in the alpha band around this time-point on central and parietal midline electrodes. No such peak was observed when aligning data to the real, i.e. objective single distance. We consider this activation a neural marker for subjective spatial position and path integration during visually simulated self-motion.

Acknowledgement: Deutsche Forschungsgemeinschaft (IRTG-1901 and CRC/TRR-135)

53.421 **Temporal dynamics of heading perception and identification of scene-relative object motion from optic flow** Li Li[1](ll114@nyu.edu), Mingyang Xie[1, 2]; [1]Neural Science Program, NYU-ECNU Institute of Brain and Cognitive Science, New York University Shanghai, Shanghai, PRC, [2]Institute of Cognitive Neuroscience, East China Normal University, Shanghai, PRC

During self-motion, the visual system can perceive the direction of self-motion (heading) and identify scene-relative object motion from optic flow (flow parsing). However, little is known about temporal dynamics of heading perception and flow parsing. Here we addressed this question by examining how the accuracy of heading perception and flow parsing changes with exposure time to optic flow. A stereo display simulated forward translation at 0.3m/s through a cloud of 58 red wireframe objects (depth: 0.69-1.03m) placed on one side of the image plane (56º×33º). Five display durations (100ms, 200ms, 400ms, 700ms, & 1000ms) were tested. For heading perception, on each trial, heading was randomly chosen from -10° (left) to 10° (right). Participants were asked to indicate their perceived heading using a mouse-controlled probe at the end of the trial. For flow parsing, on each trial, heading was fixed at 0° and a yellow dot probe (diameter: 0.25º; depth: 0.86m) moved vertically for 100ms in the scene. Objects were placed on the opposite side of the probe in the image plane to remove local motion cues around the probe. The speed (2º/s) and eccentricity (4º) at the midpoint of the probe's motion were equated across display durations. A nulling motion component was added to the probe's motion using an adaptive staircase to determine when participants perceived the probe to move vertically in the scene. This added motion component was used to compute the accuracy of flow parsing. Across 12 participants, while the accuracy of heading perception increased with exposure time, the accuracy of flow parsing decreased with exposure time to optic flow. The opposite trend of temporal dynamics of heading perception and flow parsing suggests that although these two processes both rely on optic flow, they involve separate neural substrates that compete for the same limited attention resource.

Acknowledgement: Supported by research grants from the National Natural Science Foundation of China (31741061), Shanghai Science and Technology Committee (15DZ2270400, 17ZR1420100), and NYU-ECNU Joint Research Institute at NYU Shanghai

53.422 **When Gravity Is Not Where It Should Be: Effects On Perceived Self-Motion** Meaghan McManus[1](mcmanus1@yorku.ca), Laurence R Harris[1]; [1]Centre for Vision Research, York University

When gravity cues are unavailable, visual information is weighted more strongly (Harris et al., 2017 Microgravity 3:3). This suggests that if gravity information were ignored visual information might similarly be enhanced. When immersed in an upright visual scene, supine or prone viewers often experience a visual reorientation illusion (VRI) where they feel upright, and visually-induced self-motion (vection) is enhanced (McManus & Harris, 2016 IMRF). VRIs may reflect a conflict resolution between visual and non-visual uprights in which vision becomes dominant. Here we investigated the connection between VRIs and vection using virtual environments that varied the level of conflict between the cues. Targets were simulated in an Oculus Rift (CV1) at 10-80m. When the target disappeared, participants were virtually accelerated either through a hallway with strong orientation cues or a star field with no cues to orientation, while standing, supine or prone. They indicated when they reached the remembered target location. The hallway was more effective than the starfield at evoking a VRI (hallway 65%, starfield 50%) especially when prone (prone 82%, supine 47%). In the hallway there was a main effect of posture on target distance ($p< 0.01$) and vection was enhanced more while prone than when supine ($p< 0.01$). A separate ANOVA found no effect of posture in the starfield ($p< 0.05$). We conclude that change in visual weighting (indicated by perceived travel distance) is most likely to be caused by conflict between a prone posture and strong visual cues to upright. This conflict is most likely to evoke both a VRI and enhanced vection. If the posture/vision conflict is reduced by bending only the head while leaving the body upright, enhanced self-motion is also experienced only with the head prone (nose towards the ground) (McManus & Harris, 2017 IMRF).

Acknowledgement: LRH is supported by a Discovery Grant from the Natural Sciences and Engineering Research Council (NSERC) of Canada and the Canadian Space Agency. MM holds a research studentship from the NSERC CREATE program.

53.423 **Computational investigation of sparse MT-MSTd connectivity and heading perception** Oliver W Layton[1](oliver.layton@colby.edu), Scott Steinmetz[2], Nathaniel Powell[2], Brett R Fajen[2]; [1]Department of Computer Science, Colby College, [2]Department of Cognitive Science, Rensselaer Polytechnic Institute

Seminal work has shown how humans can be highly accurate in judging their direction of self-motion (heading) from optic flow, to within 1° (Van den Berg, 1992; Warren, Morris, & Kalish, 1988). Remarkably, accuracy only decreases to ~3° in displays containing as few as two moving dots, which suggests that a sparse flow field is sufficient to drive the underlying neural mechanisms. Indeed, receptive field models fit with only a few input connections do a good job at capturing single neuron data in MSTd (Mineault, Khawaja, Butts & Pack, 2012), an area of primate cortex that has been shown to be causally linked with heading perception (Gu, Deangelis, & Angelaki, 2012). This is difficult to reconcile with many biologically inspired models of heading perception that rely on full-field (e.g. radial) connection templates to integrate motion across the visual field. In the present study, we used neural modeling to investigate how sparse connectivity between areas MT and MST may shape heading perception. We found that sparse connectivity yields heading estimates more consistent with human heading judgments than a densely connected model under a range of dot density and noise conditions. The model builds on the Competitive Dynamics model (Layton & Fajen, 2016), which relies on the pattern tuning of active MSTd heading cells to recover object motion in a world-relative reference frame. We leveraged sparse connectivity to efficiently simulate large numbers of MSTd cells tuned to complex combinations of speed, direction, and disparity inputs, which allows the model to accurately estimate object motion in natural cluttered environments, not just under idealized conditions. Our findings support the intriguing possibility that the sparse connectivity structure of MSTd may influence heading and object motion perception.

Acknowledgement: ONR N00014-18-1-2283

Eye Movements: Transsaccadic vision

Tuesday, May 21, 8:30 am - 12:30 pm, Pavilion

53.424 **The role of color in transsaccadic object correspondence** Lindsey Bailey[1](ghc535@vols.utk.edu), Michaela Thordarson[1], Caglar Tas[1]; [1]Department of Psychology, University of Tennessee-Knoxville

Executing saccades result in shifts of objects' retinal locations. However, our visual system isefficient in correcting these shifts and enabling us to perceive a stable world. Transsaccadic object correspondence was originally tested with the intrasaccadic target displacement paradigm (Bridgeman, et al., 1975) in which the saccade target's spatial location is shifted during the saccade. Participants are asked to report the direction of the shift. Previous studies have consistently found that perception of shift detection is poor unless the target object's continuity is disrupted during the saccade. For instance, disrupting the target's continuity by removing it for a brief period after the saccade (i.e., blanking the target) results in significantly more accurate reports of shift direction (Deubel et al., 1996). Other studies have shown that changing target's surface features, such as shape (Demeyer et al., 2010), contrast polarity (Tas et al., 2012), or changing the target's identity (Tas et al., 2012) result in similar improvements in displacement detection performance. However, a more recent study has found that orientation does not improve performance, suggesting that not all features may contribute to transsaccadic object correspondence (Balp et al., 2018). In the present study, we tested whether color changes can disrupt target's continuity and result in improved displacement detection performance. We employed thetarget displacement paradigm where the target's continuity is not disrupted (no-blank), its continuity is disrupted with a blank, or its continuity is disrupted with a color change. We also manipulated the magnitude of color change (ranging from 15° to 180°). Preliminary results suggest that small color changes (e.g., 15°) are not sufficient to disrupt target's continuity. However, as the magnitude of color change increased, displacement detection performance improved. These results demonstrate that not all features are consulted for transsaccadic object correspondence, and only salient changes disrupt visual stability across saccades.

53.425 **Transsaccadic prediction of real-world objects** Corinna Osterbrink[1,2](co.osterbrink@uni-bielefeld.de), Arvid Herwig[1,2]; [1]Department of Psychology, Bielefeld University, Bielefeld, Germany, [2]Cluster of Excellence, Cognitive Interaction Technology, Bielefeld University, Bielefeld, Germany

During a saccade, a target object's retinal position and spatial resolution change. Nevertheless, we do not perceive these changes, but instead experience a stable percept of our environment. One mechanism of how the brain deals with these saccade induced changes is that it forms associations between presaccadic peripheral and postsaccadic foveal input of saccade-target objects. Based on these transsaccadic associations the visual system can predict visual features across saccades. Up to now, studies investigating how transsaccadic feature prediction affects peripheral perception have focused primarily on simple visual features (e.g., spatial frequency, size and shape). They could show that peripheral perception is biased toward previously associated foveal input. The present study tested whether also complex visual features constituting real-world objects (fruits and balls) are predicted across saccades. In an eyetracking experiment, twenty-four participants first underwent an acquisition phase, in which they learned new object-specific transsaccadic associations. Six out of twelve objects were systematically swapped to an object of the opposite category (from fruit to ball or vice versa) during saccades. In the following test phase, participants were briefly presented peripheral saccade target objects and had to identify which object they saw. Objects which had previously been swapped during the acquisition phase were more often perceived as belonging to a different category compared to objects which stayed the same during acquisition. These category errors occurred mainly because participants confused the peripherally presented object with its transsaccadically associated foveal counterpart. This result indicates that transsaccadic prediction is object-specific and not limited to a small set of simple visual features.

Acknowledgement: Grant of the German Research Council (Deutsche Forschungsgemeinschaft DFG) Grant He6388/1-2 to Arvid Herwig

53.426 **Spatiotopic memory is more precise than retinotopic memory in the context of natural images** Zvi N Roth[1](zviroth@gmail.com), Noah J Steinberg[1], Elisha P Merriam[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health

Background: Neural responses throughout visual cortex encode stimulus location in a retinotopic reference frame, and memory for stimulus position is most precise in retinal coordinates. Yet perception is spatiotopic: during natural vision, objects appear stationary despite eye movements. The purpose of this study was to test the accuracy of retinotopic and spatiotopic memory under different stimulus conditions. Method: We measured the accuracy of retinotopic and spatiotopic memory after saccadic eye movements under three different stimulus conditions. Observers fixated a dot and memorized the location of a brief peripheral memory cue. After a delay, the fixation dot changed position. Once observers made a saccade to the new fixation dot location, they were instructed to use a computer mouse to identify the location of the memory cue location. Observers were instructed to identify either the retinotopic or spatiotopic coordinate of the cue. In one condition, the display background was uniformly grey. In a second condition, a salient visual mask was flashed immediately after stimulus onset. In a third condition, a large background image of a natural scene appeared before the onset of the trial and remained on the screen until the end of the trial. Results: Retinotopic memory was more accurate than spatiotopic memory following an intervening saccade, replicating earlier observations. This accuracy advantage was eliminated when a salient visual mask was presented after cue onset, suggesting the retinotopic advantage was in part due to a retinal afterimage of the cue. Finally, we found that spatiotopic memory was more precise than retinotopic memory in the presence of images of natural scenes, suggesting that visual landmarks can be used by the visual system to maintain a representation of stimulus position across eye movements. Conclusions: Our results underlie the importance of visual landmarks in visual motor integration.

53.427 **Effects of Saccade Size, Target Position, and Allocentric Cues in Transsaccadic Motion Perception** Amanda J Sinclair[1], Kelsey K Mooney[1], Steven L Prime[1]; [1]Psychology, Arts and Science, University of Saskatchewan

During each saccade the image of the world shifts across our retina yet we have little trouble keeping tracking of object locations in our surroundings. Transsaccadic perception of moving objects remains unclear. Previous transsaccadic perception studies investigating how well observers detect an object's intrasaccadic displacement have used either stationary stimuli or moving stimuli over relatively small, orthogonal saccades relative to motion direction (Gysen et al. 2002). Here, we extend this literature by examining transsaccadic motion perception using smoothly translating motion targets (dot) over different saccade directions, amplitudes, and background conditions. Subjects were required to make a saccade when a fixation point moved from center screen to a different location. On some trials, the dot jumped forward or backward during the saccade. Subjects made a 2AFC response to indicate if they detected a displacement or not. Eye movements were measured using the SMI RED eye tracker. The first experiment we systematically varied saccade amplitude and direction to determine how different saccade metrics might influence subject accuracy in detecting intrasaccadic displacement of moving stimuli. We also examined the extent to which displacement size and relative post-saccadic location of the motion stimulus might influence detection performance. In the second experiment we varied the number and stability of allocentric cues presented in the background during the same transsaccadic tracking task as experiment one. In experiment one we found subjects were most accurate in detecting intrasaccadic displacement of moving targets when: 1) Saccades were small, retinal eccentricity of target was small, and target displacement was large. The second experiment confirmed these findings and we also found that allocentric background cues aided participant's performance when they were stable or moving in the same direction as the target. Our novel findings suggest the same basic processes are involved in transsaccadic perception for both static and dynamic stimuli.

Acknowledgement: NSERC

53.428 **Trans-saccadic integration occurs across the visual field** Emma E.M. Stewart[1](emma.e.m.stewart@gmail.com), Alexander C Schütz[1]; [1]AG Allgemeine und Biologische Psychologie, Philipps-Universität Marburg, Marburg, Germany

In order to optimize the uptake of visual information, humans need to transfer and integrate information across saccadic eye movements. Recently, it has been shown that pre- and post-saccadic information at the saccade target is integrated in a near-optimal manner (Ganmor, Landy, & Simoncelli, 2015; Wolf & Schütz, 2015). The spatial specificity of integration is unknown and there is divergent evidence as to whether related trans-saccadic processes such as pre-saccadic shifts of attention and predictive remapping of receptive fields are specific to the saccade target, or are widespread across the visual field. To test the spatial distribution of trans-saccadic integration, participants had to execute horizontal saccades, and we measured integration performance at six locations across the visual field: at the saccade target, above the saccade target, beyond the saccade target, above and beyond the saccade target, in-between initial fixation and saccade target, and above initial fixation. Saccades were always made to the saccade target, while a randomly-oriented Gabor was presented predictably at one of the tested locations. The Gabors were presented either pre-saccadically, post-saccadically, or both (trans-saccadic trials), and participants used a free-rotation task to respond to the perceived orientation of the Gabor. Performance was measured as the smallest angular distance between the presented and reported stimulus orientation. Results showed that performance on trans-saccadic trials was better than pre- or post-saccadic performance alone, for all locations except for the location above initial fixation. This demonstrates that integration can occur across the visual field in the direction of the saccade: a spatial profile that reflects regions where remote distractor effects are most prominent. This suggests that in terms of integration, the saccade target may not receive preferential processing, and that trans-saccadic integration may be a more general mechanism used to reconcile information across saccades for the whole visual field.

Acknowledgement: This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 676786).

53.429 **Transsaccadic Motion Tracking in a Time-to-Contact Task** Gloria Sun[1](sun.gloria@usask.ca), Steven L. Prime[1]; [1]Department of Psychology, College of Arts & Science, University of Saskatchewan

Transsaccadic perception describes our perceived visual stability despite images shifting across the retina due to saccadic eye movements. Visual stability is thought to be maintained across saccades due to spatial updating mechanisms that track object locations over the saccade. However, transsaccadic research has focused on static objects; few studies have examined how we track moving objects during a saccade. Niemeier, Crawford, and Tweed (2003) found that intrasaccadic spatial displacements of visual stimuli are easier to detect when saccades are perpendicular to the direction of the displacement, compared to saccades parallel to displacement. Here, we examined whether similar effects of saccade direction influence transsaccadic motion tracking in a predicted-motion time-to-contact (TTC) task. Subjects maintained fixation on a cross while tracking a moving dot which translated across the screen towards a line. During movement, the dot would become occluded behind a grey bar. Subjects then estimated when the occluded dot had reached the line via a button press. During the fixation task, participants maintained fixation on a stationary fixation cross. In the saccade task, the cross moved to a new location when the dot disappeared behind the occluder, prompting a saccade. Saccades were either parallel or orthogonal to dot motion. Dot motion (right or left) and line location on occlude (near, middle, or far) were also varied. Eye position was monitored using a SMI RED-m eyetracker. Results showed that the effect for line location was only significant in the saccade task, and that error increased with increased line distance, suggesting that saccades introduce error in TTC estimations. In the fixation task, TTC estimations were most accurate when subjects fixated on the same side of the screen from which the dot originated. These novel findings provide insight into people's accuracy in predicting the future location of objects across saccades.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

Tuesday AM

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53.430 **Transsaccadic object updating depends on visual working memory:An fNIRS study** Kaleb T Kinder[1](kkinder5@vols.utk.edu)**,** Bret T. Eschman[1]**,** Shannon Ross-Sheehy[1]**,** Aaron T. Buss[1]**,** Caglar A. Tas[1]; [1]Department of Psychology, University of Tennessee-Knoxville

A natural consequence of executing a saccade is having two separate representations of the target object: pre-saccadic and post-saccadic. To perceive the world as stable, the visual system must integrate these two representations of the saccade target. Previous research suggests that transsaccadic object updating may depend on visual working memory (VWM) processes (Currie et al., 2000; van der Stigchel & Hollingworth, 2018). In the present study, we recorded functional near-infrared spectroscopy (fNIRS) data and tested whether transsaccadic updating is associated with neural signatures of VWM dynamics by disrupting object continuity in a blanking paradigm. Todd and Marois (2004) previously showed that bilateral posterior parietal cortex (PPC) activation increases as the number of items in VWM increases. If disruption of object continuity results in two object representations (pre- and post-saccadic), and if these representations are stored in VWM, then we expect to find a similar increase in PPC activation. On each trial, participants were instructed to execute a saccade to a color disk. On half of the trials, object continuity was disrupted by removing the target from the screen for 250ms after the initiation of the saccade. On some trials the target's color was also changed by 45° during the saccade. Participants were asked to report the color of either the pre-saccadic or the post-saccadic disk. Preliminary data showed stronger bilateral PPC activation when the target object was blanked compared to when it was not. Moreover, this effect was stronger when the object's color was also changed. These findings suggest that disrupting the target's continuity with both blanking and color-change resulted in two separate VWM representations. Additionally, the lack of PPC activation for when stability was not disrupted (no-blank trials) suggests that there was only one VWM representation present, supporting the object-mediated updating account of transsaccadic perception (Tas et al., 2012).

Acknowledgement: This work was supported by NIH R01HD092485 to ATB.

53.431 **Functional connectivity for updating grasp plans across saccades: An fMRIa study.** Bianca R. Baltaretu[1,2,3](brb@yorku.ca)**,** Simona Monaco[1,6]**,** Jena Velji-Ibrahim[1,2,4]**,** Gaelle N. Luabeya[1,2,3]**,** J. D. Crawford[1,2,3,4,5]; [1]Centre for Vision Research, York University, Toronto, ON, CA, [2]Vision: Science to Applications (VISTA) program, York University, Toronto, ON, CA, [3]Department of Biology, York University, Toronto, ON, CA, [4]Department of Kinesiology, York University, Toronto, ON, CA, [5]Department of Psychology, & Neuroscience Diploma Program, York University, Toronto, ON, CA, [6]Center for Mind/Brain Sciences, University of Trento, Trento, IT

The cortical mechanisms associated with grasping and spatial updating have been investigated separately, but no study has investigated the functional connectivity associated updating grasp plans across saccades. Here, we identified potential network nodes using an fMRI adaptation task, and then performed a functional connectivity analysis. Based on a previous perceptual experiment (Dunkley et al., 2016), we hypothesized that supramarginal gyrus (SMG) would be a central hub for updating grasp orientation signals across saccades. Participants (n=17) fixated looked to the left or right of a central oblong object that was briefly presented at one of two orientations. During grasp preparation, participants either maintained fixation ('Fixation' condition) or moved gaze to the other LED ('Saccade'). The object was then re-presented at either the same ('Repeat') or other ('Novel') orientation. Lastly, participants grasped the object and returned to rest. Analysis of the Novel/Repeat and Saccade/Fixation conditions revealed a cluster of parietal regions specifically sensitive to object changes that occurred across saccades, including intraparietal cortex, superior parietal cortex, and right SMG. To further test our hypothesis, we used a separate localizer to identify peak saccade activity in left and right SMG which we used as seed regions for a psychophysiological (PPI) analysis during the Saccade / grasp preparatory period of the main task. Right SMG activity was significantly correlated with activity in the right frontal eye field (FEF), left supplementary eye field (SEF) and right superior parietal lobe (SPL), extending into posterior-anterior intraparietal sulcus (p-aIPS). Left SMG activity was significantly correlated with activity in right FEF, left SEF, primary motor cortex, left SPL, p-aIPS (trending), and the medial occipitotemporal sulcus. These results confirm that, when saccades occur during grasp preparation, SMG activity integrates object orientation across saccades and is functionally correlated with a network of cortical areas that includes both saccade and grasp areas .

Acknowledgement: 1: NSERC Brain-in-Action CREATE Program, 2: NSERC Discovery Grant, 3: Canada Research Chair Program, 4: OGS/QEII-GSST

Perceptual Organization: Shapes, objects, contours, surfaces

Tuesday, May 21, 8:30 am - 12:30 pm, Pavilion

53.432 **The extrapolation effect: an illusory experience of extended feature space beyond reality** Marnix Naber[1](marnixnaber@gmail.com)**,** Tijn Knaap[1]**,** Stefan Van der Stigchel[1]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University

A target object that changes location across space appears ahead of a reference object in case the latter is shortly flashed at the same position. This perceptual mismatch is called the flash-lag effect and also occurs when targets change along feature dimensions other than spatial space, such as luminance. We show that a comparable extrapolation effect (EE) is observed when the reference is constantly visible instead of shortly flashed and when the target physically stops to change after it reaches full reference similarity. This novel design removes perceptual uncertainty, processing delays, and postdictive effects that may arise during the comparison of target and reference. The EE is most evident when a target stimulus differs strongly from its background on a feature such as luminance, and slowly increases in similarity towards the background reference as a function of time. At the moment the target stimulus stops changing and is physically similar to its background (e.g., equiluminant), the target appears to continue to change along the varied feature space. For example, the target appears brighter than its gray background after it changed from black to gray. The temporal dynamics of the EE are distinct from light adaptation. We also demonstrate that target contrast appears higher or lower after contrast increased or decreased towards a medium background contrast, respectively. Because the EE occurs with a predictable, fixed, endpoint reference rather than an unpredictable, temporary, flash reference, we conclude that the EE cannot be explained by attentional delays, perceptual latencies, postdiction, or temporal averaging. Instead our observations support the proposition that the visual system extrapolates changes in feature space. This is likely a general property of perception, either with the function to prepare for future events or as an epiphenomenal overshoot of changes in activity of neurons that are tuned to the moderated features.

53.433 **Independent mechanisms for implicit ensemble learning and explicit ensemble perception?** Sabrina Hansmann-Roth[1]**,** Árni Kristjánsson[1,2]**,** David Whitney[3]**,** Andrey Chetverikov[4]; [1]Icelandic Vision Lab, University of Iceland, [2]Faculty of Psychology, National Research University, Higher School of Economics, Moscow, Russian Federation, [3]Department of Psychology, The University of California, Berkeley, [4]Visual Computation Lab, Center for Cognitive Neuroimaging, Donders Institute for Brain, Cognition and Behavior

Features of objects in the environment can be represented as probability distributions or with summary statistics. Previous visual search studies have shown how previously learned properties of distractor distributions influence search times. The underlying distribution shape was assessed through role-reversal effects upon search time. This implicit ensemble statistical learning method has therefore revealed learning of feature distribution shape, while ensemble perception studies have not been able to capture the learning of higher order statistics (Atchley & Anderson, 1994, Dakin & Watt 1996). In this study we directly compared ensemble perception with this new method of implicit ensemble statistical learning for judgments of mean, variance and distribution shape. Observers learned statistical information in a block of 3-4 learning trials and were then presented with two distractor sets of varying mean, variance or distribution shape. They were encouraged to select the set that appeared more similar to the previously presented ones. These results were compared with the results from the implicit method. The explicit comparison resulted in much noisier estimates of representations of mean and variance than implicit distribution learning. Moreover, we were not able to find representations of the distribution shape with the explicit method while the representation of the distribution shape could be assessed through the implicit learning method. Interestingly, both methods showed that variance was largely overestimated for all observers and was not a result of a response bias towards the more variant set. These results highlight the efficiency of the implicit feature learning method and hint at independent mechanisms for the implicit learning of ensemble information and explicit perception of summary statistical information in scenes. We speculate that these differences reflect the functional distinctness of implicit and explicit information: implicit information about objects is crucial for acting in the environment while explicit ensemble perception determines the appearance of objects.

Acknowledgement: Rannis, Icelandic Research Fund

53.434 **Number and cumulative area are represented as integral dimensions** Lauren S Aulet[1](lauren.s.aulet@emory.edu), Colin R Jacobs[1], Stella F Lourenco[1]; [1]Department of Psychology, Emory University

Though it is well known that non-numerical magnitudes, such as cumulative area, element size, and density influence the perception of numerosity (Gebuis & Reynvoet, 2012; Leibovich et al., 2017), it is unclear whether these interactions reflect independent representations that interface vis-à-vis other systems (e.g., language) or, conversely, a holistic perception in which numerosity is not fully separable from other magnitudes. To dissociate these accounts, the present study drew from classic work on the perception of multidimensional stimuli in which perceived similarity for stimuli composed of integral dimensions is best explained by Euclidean distance and separable dimensions by city-block distance (Garner & Felfoldy, 1970). In Experiment 1, we utilized a restricted classification task (Ward et al., 1986) in which adult participants (n = 20) provided explicit similarity judgments about dot arrays that varied parametrically in number and cumulative area (CA). We found that similarity in this multidimensional space was best explained by Euclidean distance, suggesting that number and CA are integral dimensions akin to other classic integral dimensions (brightness/saturation) and in contrast to classic separable dimensions (shape/color), also tested here. In Experiment 2, we extended these findings by ruling out a possible effect of explicit categorization. Participants (n = 20) completed a match-to-sample task in which similarity was assessed implicitly as the degree of interference from distractor stimuli on reaction time. Consistent with Experiment 1, we found that similarity for dot arrays that varied in number and CA was best modeled by Euclidean distance, suggesting integrality. Again, number and CA were comparable to another example of integral dimensions (radial frequency contours) but different from separable dimensions (thickness/curvature) dimensions, also assessed here. Taken together, these findings provide support for integral representations of number and CA, suggesting a perception of magnitudes in non-symbolic sets that are processed holistically as unitary percepts.

Acknowledgement: This work was supported by a National Institutes of Health (NIH) institutional training grant (T32 HD071845) to LSA.

53.435 **Inferring transformations from shape features** Filipp Schmidt[1](filipp.schmidt@psychol.uni-giessen.de), Yaniv Morgenstern[1], Roland W Fleming[1]; [1]Department of Experimental Psychology, Justus Liebig University Giessen

Objects can be altered by a wide variety of shape-transforming processes, such as bending, denting, twisting or stretching. Estimating what transformations have been applied to an object solely from its shape, is important for many other tasks (e.g., inferring material properties). Despite this, little is known about which cues observers use to infer shape transformations. Here, we sought to identify geometrical features that drive the identification of nonrigid deformations. We generated and rendered a large set of transformed unfamiliar 3D objects by shifting their mesh vertices around using smooth 3D deformation vector fields. Then, we compared observers' inferences to predictions derived from 2D and 3D shape features. In the first experiment, we defined a transformation space spanned by weighted combinations of three transformation types ("twist", "shear", and "squeeze"). In each trial, observers viewed a test object generated at one of six positions in the transformation space. They adjusted the transformation applied to a different object, using the mouse to navigate within the triangular transformation space, until it matched the test. Observers showed remarkable invariance in their ability to infer transformations across objects. In the second experiment, we generated a more diverse set of stimuli by subjecting a larger variety of objects to 6 vector field transformations. For this set, there was more variance in performance with respect to transformation ground truth of the test object. We compared human responses to a computational model based on 2D and 3D shape features, finding that observers base their judgments on combinations of shape features that are reliable indicators of the transformation. These findings demonstrate that visual inferences of transformation processes rely on processes of perceptual organization and on hallmark transformation features, similar to visual processing in object perception.

Acknowledgement: This research was supported by an ERC Consolidator Award (ERC-2015-CoG-682859: "SHAPE") and by the DFG (SFB-TRR-135: "Cardinal Mechanisms of Perception")

53.436 **From Early Contour Linking to Perception of Continuous Objects:Specifying Scene Constraints in a Two-Stage Model of Amodal and Modal Completion** Susan B Carrigan[1](susancarrigan@ucla.edu), Philip J Kellman[1]; [1]Department of Psychology, University of California, Los Angeles

A variety of research suggests that contour interpolation in modal and amodal completion depends on two stages of processing. A first stage involves contour linking between all pairs of relatable edges terminating in junctions. Whether these interpolations lead to perceived continuous edges in final scene descriptions (and perception) depends on a second stage in which certain object and scene constraints are implemented. "Path detection" is an example of first stage contour linking without illusory contour connections in the final percept. Here, we test and quantify second stage constraints that determine which first-stage connections appear in perception. The key assumptions are that recognition depends on shape descriptions conferred on complete objects, and that contour linkages that are not represented in final descriptions will not produce complete objects or shapes without scrutiny. We developed a novel paradigm inspired by a figure from Bregman (1981). A 2AFC task required participants to detect and recognize a whole alphanumeric character set in a field of randomly arranged alphanumeric character fragments. In the standard condition, partly occluded black fragments were amodally completed behind a gray, blob-like occluder. In a set of comparison conditions, manipulations of border ownership cues (rotation of the occluder, deletion of the occluder, outline fragments) resulted in significantly reduced performance. Fragments with opposite luminance contrast polarity substantially reduced performance, as did a blur (spatial frequency) difference across fragments, whereas opposite color contrast polarity of equiluminant fragments did not disrupt performance. These results support the two-stage theory of contour completion and suggest that border ownership cues, fragment luminance contrast polarity, and spatial frequency differences across fragments are among those cues taken into account in the second stage.

53.437 **Electrophysiological investigation of posterior curvature-biased patches in monkeys** Xiaomin Yue[1](yuex@mail.nih.gov), Sophia Robert[1], Marissa Yetter[1], Leslie G Ungerleider[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, National Institutes of Health

Curvature is one of many visual features shown to be important for visual processing. For instance, curved features provide sufficient information for categorizing animate vs. inanimate objects without top-down processingin both human (Zachariou et al., 2018) and nonhuman primates (Yue et al., 2018). Theresults from our fMRI study in rhesus monkeys (Yue et al. 2014) have shed light on some of the neural mechanisms underlying curvature processing. We described a network of visual cortical areas selective for curvature, one of which, the posterior curvature-selective patch (PCP), is located in dorsal V4. The fMRI responses in the PCP correlated significantly with curved Gabor filter values calculated from experimental images. The current study investigated whether the PCP contains a columnar organization for curvature, similar to the columnar organization for orientation in V1 and that for direction-of-motion in MT. We conducted electrophysiological recordings in awake, behaving macaques (n = 2) as they viewed curved Gabors manipulated along three feature dimensions: degree of curvature, orientation, and size. With electrode penetrations tangential to the surface of PCP, we found that both orientation and an interaction between orientation and the degree of curvature of the stimuli significantly predicted the penetration distance of electrodes parallel to the surface of PCP in one of two macaques. This finding suggests that there may be curvature columns perpendicular to the surface, with orientation varying across columns within the same layer. Additional data with electrode penetrations perpendicular to the surface of PCP along with further analysis of data collected from the second monkey will provide clearer and more direct evidence forwhether a columnar structure forthe degree of curvature and orientation exists within PCP. The outcome of this study will advance our understanding of how middle-level visual features, such as curvature, are represented within macaque visual cortex.

Acknowledgement: NIMH intramural research program

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53.438 **Why is contour integration impaired in schizophrenia? New insights from a cross-diagnostic parametrically varying behavioral task** Brian P Keane[1,2,3](brian.keane@gmail.com), Laura P Crespo[1,2], Dillon T Smith[1,2], Deanna M Barch[4,5,6], Michael W Cole[7], Bart Krekelberg[7], Brendon M Coughlin[2], Thomas V Papathomas[3,8], Attila J Farkas[3], Steven M Silverstein[1,2,3]; [1]Department of Psychiatry, Rutgers, The State University of New Jersey, [2]University Behavioral Health Care, Rutgers, The State University of New Jersey, [3]Center for Cognitive Science, Rutgers, The State University of New Jersey, [4]Department of Psychology, Washington University in St. Louis, [5]Department of Psychiatry, Washington University in St. Louis, [6]Department of Radiology, Washington University in St. Louis, [7]Center for Molecular and Behavioral Neuroscience, Rutgers, The State University of New Jersey, [8]Department of Biomedical Engineering, Rutgers, The State University of New Jersey

Background. Schizophrenia patients poorly integrate disconnected oriented elements into cohesive contours and shapes; the impairment worsens as the stimulus is globally scaled down in size (d=1.7; Keane et al., 2016). What stimulus features drive this scaling effect and how specific is it to schizophrenia? Addressing this issue will yield clues for building behavioral tasks that flag current or impending psychosis; it will also clarify the visual mechanisms disturbed. Methods. We compared schizophrenia patients (SZ; N=5), bipolar disorder patients (BD; N=9) and well-matched healthy controls (N=7) on a task in which subjects sought to identify the screen quadrant location of an integrated eight-element circular target. Task difficulty was staircase controlled and depended on the number of noise elements co-presented with the target. There were 16 different conditions corresponding to the crossings of four parameters that would change with spatial scaling: (1) Gabor spatial frequency (6 or 12 cycles/deg), (2) Gabor width (Gaussian envelope SD of 2.4 or 4.8 arcmin), (3) target eccentricity (2.3 or 4.7 degrees), and (4) target radius (.74 or 1.5 deg). Results. Subject group interacted with spatial frequency, eccentricity, and Gabor width (four-way interaction,$p< .01$); it also interacted with eccentricity, radius, and spatial frequency (four-way interaction, $p< .05$). Comparing controls and BDs, there were no group differences or interactions (ps>.05). Comparing SZs to controls and to BDs, there was the same four-way interaction with spatial frequency, eccentricity, and Gabor width (both $p< .05$). More specifically, increasing Gabor width improved performance more for lower than for higher spatial frequency Gabors; increasing eccentricity accentuated this two-way interaction for controls and BDs but not for SZs. Conclusion. Potentially all aspects of spatial scaling jointly contribute to contour integration deficits in SZ perhaps because of inadequate sampling within parafoveal relative to peripheral retinotopic locations. These deficits appear to be SZ-specific and thus cannot be attributed to general psychopathology (e.g., anxiety, medication)

Acknowledgement: K01MH108783

53.439 **Recursive Networks Reveal Illusory Contour Classification Images** Philip J Kellman[1](Kellman@cognet.ucla.edu), Gennady Erlikhman[1], Nicholas Baker[1], Hongjing Lu[1]; [1]Dept. of Psychology, University of California, Los Angeles

Classification images (CIs) derived from human responses show strong evidence that humans use the shape of illusory contours in the "fat/thin" illusory figure discrimination task (Gold, Murray, Bennett, & Sekuler, 2000). Previously, we found that a convolutional neural network (CNN), Alexnet, failed to perceive illusory contours from partial circle inducing elements, a process readily and automatically performed in the human visual system. One limitation of Alexnet is its inclusion of only feedforward connections. We explored a different network architecture, a denoising autoencoder, in which a noisy input image is encoded or compressed to a more abstract (compact) representation and then decoded to reproduce the original image without noise. Although feed-forward, the encoding/decoding process can be taken to resemble a form of feedback in that the final, decoded representation is the result of information being sent "backward" from a higher-level, abstract representation (the encoded representation). By passing an image repeatedly through the autoencoder, a type of recurrent processing can be approximated. This recursive architecture perhaps resembles more closely human-like processing of visual information between low-level and middle-level visual areas. This network was trained on noisy fat/thin images with real contours. When given images with illusory contours, it "filled-in" the contours in the decoded image. Recurrent processing improved the clarity of the reconstructed contours. This denoised image was then fed into a five-layer convolutional network for making fat/thin classification decision. Noise patterns were then used to form CIs. Our simulation showed that the resulting CIs from the autoencoder network recovered the illusory contours, showing similar results as humans. This result suggests that recursive processing simulating both feedforward and feedback connections may be important in illusory contour perception or in recognition from partial information.

Acknowledgement: NSF grant BCS-1655300 to HL

53.440 **Age-related Differences in Edge Discrimination through Kinetic Occlusion** Benjamin A Miller[1](bmill007@ucr.edu), George J Andersen[1]; [1]Psychology, University of California Riverside

The occlusion of objects in visual scenes provides valuable information about the environment and kinetic occlusion, the change in occlusion information over time, is particularly important for the formation of edge boundaries of objects as we navigate real-world scenes. Research has shown that increased age impacts our sensitivity to spatial properties of edge boundaries, reducing the ability to integrate discrete elements into cohesive contours (Roudaia, Bennett, & Sekuler, 2011). Other work has shown reductions in older adults' ability to discriminate 2D shapes based on kinetic occlusion information (Andersen & Ni, 2008). In the current study we compared college aged adults to older adults (M age= 77.4) on an edge discrimination task, asking them to distinguish a curved from a straight edge. The displays consisted of two sequentially presented stimuli, one with a curved left boundary and one with a straight boundary. The stimuli appeared as stationary opaque objects in the center of the screen with a continuous background texture translating horizontally. Curvature sensitivity thresholds were derived using a QUEST adaptive staircase procedure in a four (density of background texture) by three (speed of texture translation) design. Results indicated a main effect of age with older adults demonstrating significantly lower sensitivity to curvature than the younger adults.The main effect of both density and speed of the moving background texture was significant for both age groups, with increases in either resulting in increased curvature sensitivity. There was no significant interaction between age and either density or speed. However, when comparing conditions with matched rates of accretion and distinct density and speed values, it was found that younger adults appeared to benefit at the highest levels of density more so than did older adults. This result indicates a possible deficit in older adults' ability to spatially integrate occlusion information to perceive edges.

53.441 **Bouba and Kiki inside objects: Sound-shape correspondence for objects with a hole** Sung-Ho Kim[1](sunghokim@ewha.ac.kr); [1]Department of Psychology, Ewha Womans University

Holes are perceptually organized as a background region, but people can perceive the shapes of holes as well as other figural regions. Reflecting this paradox of holes in figure/ground organization, recently there has been an ongoing controversy on whether and under what conditions holes can own shape. The current study investigated whether the global shape representation of a closed region is reversed when it changes from an object to a hole, in a more direct manner than previous studies did, using the so-called Bouba/Kiki phenomenon, a well-known example of sound symbolism. We presented observers with two ring-like cardboard cutouts having the identical circular outer contour but differing in the shape of the inner contour—one with a flower-shaped hole in it, and the other with a star-shaped hole, and observers matched them with two nonsense words, Bouba/Kiki. Since the sign of contour curvature is defined relative to a material figural side, sharp concavities and rounded bulges in, for example, a flower-shaped object turn into sharp convexities and rounded indentations in an object with a flower-shaped hole. In Experiments 1, however, we found that shape-name matching for holed objects is based on their interior shapes, but not those of materially defined inner edges. Experiments 2-3 replicated the same results even when the shapes appeared like faces of animal characters such that the material outlines of holes had ecological meanings (e.g., teeth or lips). Finally, Experiment 4 showed that shape-name matching for "C"-shaped stimuli also can be interior shape-based if the opening of the interior region is relatively small. These findings suggest that the interior shapes of holes (or negative parts in general) are automatically accessible, default, global representations of holed objects, supporting the idea that the shapes of holes are encoded as integral parts of their host objects.

53.442 **Considering the Characterization of Complex Properties of Objects** Evan N Lintz[1](evan.lintz@huskers.unl.edu), Matthew R Johnson[1]; [1]Department of Psychology, University of Nebraska-Lincoln

A number of psychology and neuroscience studies have used "simple versus complex" objects as a manipulation, and brain areas such as the lateral occipital complex (LOC) have shown greater activation in response to more complex objects. However, although everyone has certain intuitions about visual complexity, it is a concept that is difficult to formally define or empirically measure. As object complexity increases, so does the

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potential for low-level confounds such as the number of lines that define its shape, average luminance, spatial frequency, etc. In this study, we sought to examine what object properties might contribute to complexity and how that complexity affects responses in visual brain regions, while controlling for low-level differences between objects as much as possible. In order to do so, we presented a unique type of block-design fMRI task in which "simple" and "complex" shapes were formed entirely from illusory contours (ICs). All shapes appeared inside circles of a rotating, randomly generated plaid, a region of whose interior rotated in the opposite direction, with the object edges defined by the boundaries of the different rotation directions. Critically, these plaids were designed to saturate the neural and BOLD response to low-level visual properties, so that any differences in activation would be due solely to the shape of the IC. In addition to the base plaid (no IC shape), seven conditions of IC shapes were presented, varying in symmetry, regularity, and the number of edges and corners. Randomly generated irregular decagons were the most "complex" shapes; simpler shapes included circles, squares, regular decagons, and regular ten-sided stars, equated with the irregular decagons in diameter and/or area. We found that basic shapes elicited a weak response; however, as shape complexity increased, we observed increasing activation in extrastriate cortex, especially lateral occipital areas.

Acknowledgement: Supported by NSF/EPSCoR grant #1632849 to MRJ and colleagues

53.443 **Speaking about seeing: Verbal descriptions of images reflect their visually perceived complexity** Zekun Sun[1](zekun@jhu.edu), Chaz Firestone[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

How does what we say reflect what we see? A powerful approach to representing objects is for the mind to encode them according to their shortest possible "description length". Intriguingly, such information-theoretic encoding schemes often predict a non-linear relationship between an image's "objective" complexity and the actual resources devoted to representing it, because excessively complex stimuli might have simple underlying explanations (e.g. if they were generated randomly). How widely are such schemes implemented in the mind? Here, we explore a surprising relationship between the perceived complexity of images and the complexity of spoken descriptions of those images. We generated a library of visual shapes, and quantified their complexity as the cumulative surprisal of their internal skeletons — essentially measuring the amount of information in the objects. Subjects then freely described these shapes in their own words, producing more than 4000 unique audio clips. Interestingly, we found that the length of such spoken descriptions could be used to predict explicit judgments of perceived complexity (by a separate group of subjects), as well as ease of visual search in arrays containing simple and complex objects. But perhaps more surprisingly, the dataset of spoken descriptions revealed a striking quadratic relationship between the objective complexity of the stimuli and the length of their spoken descriptions: Both low-complexity stimuli and high-complexity stimuli received relatively shorter verbal descriptions, with a peak in spoken description length occurring for intermediately complex objects. Follow-up experiments went beyond individual objects to complex arrays that varied in how visually grouped or random they were, and found the same pattern: Highly grouped and highly random arrays were tersely described, while moderately grouped arrays garnered the longest descriptions. The results establish a surprising connection between linguistic expression and visual perception: The way we describe images can reveal how our visual systems process them.

Acknowledgement: JHU Science of Learning Institute

Color and Light: Surfaces, materials

Tuesday, May 21, 8:30 am - 12:30 pm, Pavilion

53.444 **Perceived transmittance and perceived contrast in variegated checkerboards** Marianne Maertens[1](marianne.maertens@tu-berlin.de), Guillermo Aguilar[1]; [1]Technische Universität Berlin

We examine the question whether physically different transparent media can be meaningfully mapped onto one perceptual dimension of perceived transmittance (Robilotto and Zaidi, 2004). We rendered images of variegated checkerboards that are composed of checks of varying reflectances. Part of the checkerboard was covered by a transparent medium that varied in reflectance and transmittance. We used Maximum Likelihood Conjoint Measurement (MLCM) to derive perceptual scales of perceived transmittance for different transparent media. In a single trial we presented two checkerboards next to each other that were identical except for the region covered by the transparent medium. Observers' task was to judge which of the two media was more transparent. We estimated four scales of perceived transmittance for four different transmittance values. The scale values of each scale decreased monotonically with increasing reflectance of the transparent medium. All observers show a perceptual trade-off between the two physical parameters indicating perceptual equality of transparent media with different transmittance and reflectance. Scales in different conditions were captured surprisingly well by the logarithm of the root-mean-square contrast of luminances within the area of transparency. In a second part of the experiment we presented observers with the same stimuli but reduced to the area of transparency. These stimuli varied in mean luminance and in contrast, but all cues to transparent overlay were eliminated. Observers judged which of the two stimuli had higher perceived contrast. The scales derived for the reduced stimuli were identical to those observed with the full stimuli, indicating that perceptual judgments of perceived transparency and perceived contrast rely on the same mechanism also in more complex images such as the ones used here.

Acknowledgement: MA 5127/3-1 and MA 5127/4-1

53.445 **Visual perception of liquids: insights from deep neural networks** Jan Jaap R Van Assen[1](mail@janjaap.info), Shin'ya Nishida[1], Roland W Fleming[2]; [1]NTT Communication Science Laboratories, Nippon Telegraph and Telephone Corporation, [2]Department of Psychology, Justus-Liebig-University Giessen

Perceiving viscosity is challenging because liquids exhibit incredibly diverse behaviors across scenes. To gain insights into how the visual system estimates viscosity, we developed an artificial network consisting of three convolution layers and one fully-connected layer. We trained it to estimate viscosity in 100,000 computer-generated animations of liquids with 16 different viscosities across 10 scenes with diverse liquid interactions, e.g. stirring or gushing. As expected, with sufficient training, the network predicts physical viscosity nearly perfectly for the training set. Importantly, in the initial training phase, it showed a pattern of errors more similar to human observers for both trained and untrained sets. We analyzed the representations learned by the network using representational similarity analysis. Surprisingly, viscosity (either physical or perceptual) had little explanatory power on the activation pattern of the 4096 units in the final fully-connected (FC) layer. We suspected that the final layer has a rich representational capacity so that it could represent seemingly task-irrelevant stimulus dimensions in addition to the task-relevant one. Indeed, we found it easy to read out scene category from the FC activation patterns. When we reduced the number of units in the FC layer to 40 or less (which had little effect on viscosity prediction performance), viscosity explained the FC activation patterns very well. Inspired by classical psychophysical and neurophysiology experiments, we then probed artificial neural responses with low-level stimuli isolating specific stimulus characteristics. This allowed us to identify nodes sensitive to specific orientations, spatial frequencies, motion types, etc., and to test the extent to which high-level responses can be understood as their weighted combinations. Together, these observations suggest that the nature of the representation depends on the capacity of the network, and this is likely the case for biological networks as well.

Acknowledgement: JSPS KAKENHI (JP15H05915) and an ERC Consolidator Award (ERC-2015-CoG-682859:

53.446 **The colors of three-dimensional transparent objects** Robert J Ennis[1](Robert.Ennis@psychol.uni-giessen.de), Katja Doerschner[1,2,3]; [1]Justus-Liebig University, Giessen, Germany, [2]Bilkent University, Ankara, Turkey, [3]National Magnetic Resonance Research Center (UMRAM), Ankara, Turkey

Studies of perceptual transparency have mostly focused on the generation of the percept, with thin filters floating above a Lambertian background. However, in the natural world transparent objects are not just thin and see-through: they have a 3D shape, often possess specular highlights, and generate caustics, refractions and shadows and - if they absorb parts of the light spectrum - a tinted image of the background. Such objects interact with light very differently from matte, opaque objects and little is known about how the color of such objects – which is a mixture of the object's material color, the illumination and colors of objects in the background – is perceived. Here, we investigate the perceived color of tinted, 3-D glass objects in a complex scene under a blue and a yellow illuminant. We conducted three asymmetric matching experiments in which observers either changed the color of a patch until it had the same color as the object; changed the color of a patch until it looked like the dye that was used to tin the object; and changed the color of a transparent 2-D filter on an achromatic Voronoi background until its color matched the object. Observers' color matches correlated significantly with the mean chromaticity and luminance of

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the object. However, in the first two experiments, the mean luminance of matches was offset by ~40 L* units on average. The mean luminance in experiment 3 did not show a luminance offset and matches corresponded best to a distributed region of patches of mid- to low-luminance across the surface of the object, according to the CIEDE2000 metric. These results suggest that the color of a 3-D transparent object is not determined by a single region. Rather, an integration process presumably takes place, which could help reduce the bias from colors behind the transparency.

Acknowledgement: Funding was provided by the Alexander von Humboldt Foundation in the framework of the Sof'ja Kovalevskaja Award endowed by the German Federal Ministry of Education and Research

53.447 **Motion generated scission of surface color from transparent layer** Zhehao Huang[1](allensholmes@gmail.com), Qasim Zaidi[1]; [1]Graduate Center for Vision Research, State University of New York

If movement is seen in a discrete part of a static background, it is likely to result from physical motion behind an opening, possibly covered by a neutral or colored transparency.In this situation, color transparency is perceived despite the absence of X-junctions.Therefore we tested if motion information alone is sufficient to invoke scission between surface and transparency colors, by using 280 spectrally selective surface reflectances and 6 spectrally selective transparent filters.First we quantitatively compared scission from motion to scission from X-junctions.Perceived colors of the transparent overlay and the opaque overlaid surfaces were similar under motion generated color transparency and transparency from the same filter moving on a static version of the same background, demonstrating the power of motion per se to invoke color scission.Next we found that motion generated color scission was incomplete by comparing overlaid surface colors under motion-generated transparency to exposed background surfaces, and to exposed surfaces of the same chromaticity as the overlaid surface. The perceived color of overlaid surfaces could be modeled as resulting from spectral filtering followed by the counteracting effect of lateral induction from adjacent areas under the filter. As a control, we also compared the two situations when the surround was completely dark.Under this condition, the moving filter is seen as a spotlight, and its perceived color has previously been shown to be a result of spatial integration, not scission.The moving background behind the static filter could also be interpreted as under a static spotlight.Perceived overlays and overlaid surfaces again appeared similar under the two conditions.We conclude that motion alone is sufficient to evoke percepts of color transparency that are indistinguishable from simulations of moving transparent filters.Color transparency perception thus corresponds to multiple physical conditions and does not require the presence of X-junctions.

Acknowledgement: EY07556

53.448 **Effects of the Spatial Spectrum on the Perception of Reflective and Refractive Materials** Flip Phillips[1](flip@skidmore.edu), J Farley Norman[2], James T Todd[3]; [1]Psychology and Neuroscience, Skidmore College, [2]Department of Psychological Sciences, Western Kentucky University, [3]Department of Psychology, The Ohio State University

Highly reflective and refractive materials such as gemstones, polished metals, shimmering water, glazed ceramics and the like, act as touchstones of visual wonder for humans. While this might simply be indicative of a "sparkly good!" mechanism of prehistoric origin, the question remains how the human visual system uses this information to identify materials. Since the 15th century, painters (e.g., van Eyck, Heda, Claesz) have been acutely aware of the depiction of these materials. Even contemporary comic illustrators make it a priority to depict this phenomenology via denotative mechanisms like 'lucaflection' (Mort Walker).It is intuitively tempting to assign the heavy lifting of material perception to the specularity of the material. Indeed, transparency and translucency seem to be special cases of our day-to-day experiences with materials — the vast majority of which that seem relatively opaque. However they are frequently not as opaque as they may seem (grapes, for example) and even those that are completely so still have sub-surface interactions with light that make for complicated depiction.In a series of experiments we show that the spatial composition of the illuminating environment has a strong effect on material perception of non-trivial objects made from ostensibly opaque materials. Broad (i.e., low-frequency dominant) fields of illumination result in fiducially black materials to be perceived as 'metal' while sparse fields (small, isolated high frequency information) biased perception of metal toward 'black plastic.' Preliminary work with transparent and translucent materials suggests the same mechanisms may be at work — The structure of refracted environmental information plays an even more significant role than that of the specular highlights. Finally, multi-scale analysis of the illumination environment shows clustering more consistent with the empirical perceptual impressions of the surface than with the actual surface material.

53.449 **Refractive-index perception of thick transparent materials modulated by object motion and self-motion** Maruta Sugiura[1](maru.sugiura@gmail.com), Michiteru Kitazaki[2]; [1]Graduate School of Engineering, Toyohashi University of Technology, [2]Department of Computer Science and Engineering, Toyohashi University of Technology

When a thick transparent object is located on a textured background, its distortion field is a cue for perceiving index of refraction (Fleming, et al., 2011). Object motion and self-motion enhance the glossiness perception (Tani, et al. 2013). Since it is unknown whether the self-motion or motion parallax improves the perception of refractive index, we aim to investigate effects of object motion and self-motion on the perception of thick transparent materials. One of transparent bumpy objects (test stimulus) in front of a random-texture background was presented on a CRT monitor for 6 s, followed by a similar but different-shape matching stimulus. Twenty participants monocularly observed them, and they were asked to adjust the refractive index of the matching stimulus to make its material identical to the test stimulus. The test stimulus was randomly chosen from stimuli of five refractive indices (1.3-1.7), and either rotated around the vertical axis or remained stationary. The participants observed it with or without head motion rightward and leftward at 0.5Hz. When the object moved with self-motion, the object's retinal image moved synchronously with the head motion by a 3D tracker (valid motion-parallax). The matching stimulus was always stationary without self-motion. We found that the object motion without the head motion decreased the perceived refractive index, but the combination of the object motion and the self-motion significantly improved the perception of the refractive index ($p < .001$, $\eta p2=.585$). These results suggest that the retinal image motions of transparent materials could not be perceived accurately without motion parallax, but rather they might be perceived like as non-rigid objects (cf. Kawabe, et al. 2015). Thus, it might decrease the perceived refractive index. However, the valid motion parallax contributes to perceiving the accurate shape and refractive index of transparent materials.

Acknowledgement: Supported by Grant-in-Aid for Scientific Research (A) #18H04118

53.450 **Online shopping and the visual perception of fabric qualities** Maarten W.A. Wijntjes[1](m.w.a.wijntjes@tudelft.nl), Robert Volcic[2]; [1]Perceptual Intelligence Lab, Industrial Design Engineering, Delft University of Technology, [2]Department of Psychology, New York University Abu Dhabi

Online shopping confronts us with an interesting problem: we first see the representation of something, and only later we see it in reality. If reality disappoints us, we return the product, which is an unsustainable scenario. This motivates the search for optimal (visual) representations that predict reality as good as possible. We investigated how to quantify the quality of apparel photos by measuring a set of perceived material attributes. We used images of 28 fabrics represented in four different styles (draped over ball, flat with wrinkles, 2 zoomed-in versions with different light). We let observers (n=153, distributed over different blocks) rate six attributes: warmth, softness, weight, shininess, elasticity and roughness on a continuous scale in an online experiment. Each setting was repeated 3 times. First, we computed intra-correlations of the 28 ratings for three repetition pairs and we found that they were stable across both attributes and photo styles. This implies that observers' internal consistency did not depend on either attribute or style. Next, we analyzed correlations between observers, a measure of visual ambiguity. We found these to vary for both attributes and photo styles. Zoomed-in pictures were more ambiguous than zoomed-out. Furthermore, 'shininess' was least ambiguous, followed by 'softness', while the most ambiguous was 'warmth'. We also performed a Principle Component Analysis which revealed that low dimensional embeddings had markedly different loadings for each or the four photo styles. Interestingly, the difference between the two zoomed-in picture was larger than between zoomed-out pictures. Moreover, explained variance was higher for first PCA components in the zoomed-out pictures. This results reveal that photographic styles influence perceived material qualities, and that certain styles are less ambiguous than others. Furthermore, this paradigm can easily be used for the ultimate test case of seeing and/or feeling the fabrics in reality.

Acknowledgement: MW was supported by the NWO

53.451 **Lighting effects on the perception of fresh produce** Fan Zhang[1](f.zhang-2@tudelft.nl), Sylvia Pont[1]; [1]Perceptual Intelligence Lab, Delft University of Technology

In previous works we presented a systematic canonical modes approach to testing and predicting lighting effects on material perception. In the current study we test lighting effects on fresh produce using our canonical approach. In several studies related to research into still life painting conventions and perception it is noted that strong highlights will render fruits and vegetables more "appetizing". This implies that more directed lighting will make fresh produce look more "appetizing". Here we wanted to test this hypothesis and the relation between "appetizing" and other attributes. In a real setup we presented a red apple, a green apple, a banana, an orange, a potato, and a pepper under diffused and focused light. In each trial, one object was presented in a box on a neutral grey floor with white walls. In a rating experiment, we asked observers to judge the six objects under the two illuminations on ten qualities, including seven qualities tested by Schifferstein et al. (2016), namely "appetizing", "healthy", "fresh", "natural", "beautiful", "tasty", "attractive", and three qualities that are commonly tested in material perception studies, namely "soft", "smooth", and "glossy". Previously we found that lighting effects were material dependent and stronger for materials with peaked BRDFs. Thus, in the current study, we expected the lighting effects to be stronger for the apple, orange, and pepper than for the more matte banana and potato. In preliminary results with 7 observers, 1) only the separate data for the pepper were confirming the hypothesis that focused light makes fresh produce look more appetizing, 2) for which the ratings were higher for focused than for diffused lighting, except for natural, beautiful, attractive, and soft.

Acknowledgement: DyViTo (Dynamics in Vision and Touch - the looks and feel of stuff) has received funding from the EU's Horizon 2020 research and innovation programme under grant agreement No. 765121

53.452 **The perceptual identification of glass** James Todd[1](todd.44@osu.edu), Farley Norman[2]; [1]Ohio State University, [2]Western Kentucky University

This research was designed to examine a variety of stimulus factors that can influence the perceptual identification of glass. The stimuli included 40 images of solid and hollow glass objects with varying structural complexity and patterns of illumination. They also included another 40 images of objects composed of other non-glass materials to serve as controls. Nine naïve observers rated each stimulus by adjusting four sliders to indicate their confidence that the depicted material was metal, shiny black, glass, or something else, and these adjustments were constrained so that the sum of all four settings was always 100%. The results reveal that confidence ratings for glass categorizations are strongly influenced by the pattern of illumination, and are generally higher for hollow objects than for solid ones. Specular reflections have surprisingly little influence on the identification of glass. When they are presented in isolation, the materials are categorized as shiny black with high confidence. Conversely, when the transmitted light is presented in isolation, the confidence ratings of glass categorizations are comparable to those obtained when reflected and transmitted light are presented in combination. We also included several stimuli that were created by extracting the edges from images of glass and shiny black objects, and we presented them as white lines against a black background. The extracted edges from the glass objects were categorized as glass with much higher confidence than the edges from shiny black objects. This finding suggests that contour structure is an important source of information for the perceptual identification of glass. The informative aspects of that structure include contours that are formed at the interface between hollow and solid regions, and local eddies of light flow that occur in internally concave regions of the surface boundary.

Visual Memory: Neural mechanisms 2

Tuesday, May 21, 8:30 am - 12:30 pm, Pavilion

53.453 **Neural oscillatory processes underlying context binding in visual working memory** Qing Yu[1](qyu55@wisc.edu), Bradley R Postle[1,2]; [1]Department of Psychiatry, University of Wisconsin-Madison, [2]Department of Psychology, University of Wisconsin-Madison

Working memory tasks typically involve the presentation of one or more to-be-remembered items, then retrieval of the item(s) after a short delay. Although not always explicitly noted, success on these tasks often requires not only the retention of the identity of the to-be-remembered items, but also the retention of each item's context, such as the location at which each was presented, and/or their order of presentation. Although working memory for item information has been studied extensively in recent years, the neural implementation of binding to context remains poorly understood. In the current study we recorded the electroencephalogram (EEG) while participants performed three types of working memory tasks, each with different context binding demands. Sample presentation was identical on all three trial types: three sinusoidal gratings presented sequentially (500 ms presentation, 500 ms ISI), each at a different location on the screen. After a 2-s delay, a probe stimulus was presented centrally, and participants made a Yes/No recognition judgment. On location-context trials, an arrow superimposed on the probe indicated the location of the sample item against which the probe was to be compared. On order-context trials, a digit superimposed on the probe ("1", "2", or "3") indicated the ordinal position of the item against which the probe was to be compared. On context-irrelevant trials, no cue accompanied the probe, indicating that it was to be compared against all three sample items. Behavioral performance was superior for order-context and for location-context trials than for context-irrelevant trials. EEG results revealed, for both context-binding conditions, elevated alpha-band (8-13 Hz) power at bilateral parietal electrodes and elevated theta-band (4-7 Hz) power at midline frontal electrodes, relative to context-irrelevant trials. These results suggest a general neural mechanism for context binding across different domains in visual working memory.

Acknowledgement: NIH R01 MH095984

53.454 **Negative impacts of iron deficiency on visual category learning quantified in terms of dopaminergic status and brain energy expenditure** Michael Wenger[1,2](michael.j.wenger@ou.edu), Rachel Sharp[1], Amanda McCollum[1], Lisa De Stefano[1,2], Stephanie Rhoten[1], Tory Worth[3]; [1]Psychology, The University of Oklahoma, [2]Cellular & Behavioral Neurobiology, The University of Oklahoma, [3]Center for Cognitive Neuroscience, Duke University

Of all the nutritional challenges in the world, iron deficiency (ID) is the most prevalent, and can be found at high rates in both developing and developed countries. The negative impacts of ID include changes such as increases in contrast detection thresholds and decreases in attentional control and memory retrieval efficiency, and (in college-aged women) decrements in academic standing. Animal models of ID have consistently indicated effects of ID on dopamine (DA) synthesis and regulation and energy expenditure. The work presented here tests the extent to which the effects of ID in humans can be better quantified by focusing on behavioral measures that have been shown to be directly related to levels of DA, and on measures of energy expenditure. A set of iron sufficient and iron deficient non-anemic women learned two visual categorization tasks while concurrent EEG was acquired. These tasks have been shown to be reliant on declarative and procedural memory systems (Ashby & Crossley, 2010), and to be sensitive to dopaminergic status. Behavioral performance was assessed as inverse efficiency (mean RT / P(C); Townsend & Ashby, 1978), dopaminergic status was assessed by task-related blink rate (Jongkees & Colzato, 2016), and energy expenditure was assessed using a neural efficiency score constructed as the ratio of the cumulative hazard function for the RT distribution and the cumulative global field power of the EEG, which we have shown to be related to metabolic measures of energy expenditure. Results showed that lower iron status was related to higher inverse efficiency, lower neural efficiency, and lower task-related blink rates. All of this suggests that the impact of ID can be better quantified by focusing on measures of DA status and energy expenditure.

Acknowledgement: University of Oklahoma, Vice President for Research

53.455 **Prioritizing relevant information in visual working memory sculpts neural representations in retinotopic cortex to reduce their uncertainty** Thomas C Sprague[1,3](tsprague@nyu.edu), Aspen H Yoo[1], Masih Rahmati[1], Grace E Hallenbeck[1], Wei Ji Ma[1,2], Clayton E Curtis[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University, [3]Department of Psychological and Brain Sciences, University of California, Santa Barbara

Increasing visual working memory (WM) load causes a steep decline in recall precision about specific feature values (Wilken & Ma, 2004; Zhang & Luck, 2008; Bays & Husain, 2008), and causes neural representations in visual, parietal, and frontal cortex to weaken (Buschman et al, 2011; Emrich et al, 2013; Sprague et al, 2014). However, knowledge about the relative importance of different items can enable the flexible allocation of resources to maintain the most relevant items most precisely, mitigating the impact of these bottlenecks (Klyszejko et al, 2014; Emrich et al, 2017; Yoo et al, 2018). We hypothesized that prioritizing a WM representation sculpts its neural population response profile, resulting in a representation that is read out with reduced uncertainty (Ma et al, 2006; van Bergen et al, 2015). We scanned

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participants with fMRI while they performed a multi-item memory-guided saccade task. Participants precisely remembered two positions, each with a different response probability (66.7% vs 33.3%), over a delay, then reported one cued position with a saccade. Participants effectively used the cued probabilities to prioritize items in WM: endpoints of memory-guided saccades were more precise for the high-priority item and responses were faster. To evaluate the impact of prioritization on neural representations, we extended a recently-developed generative model based decoding approach (van Bergen et al, 2015) to estimate likelihood functions over spatial position for each of the two items. This allowed us to quantify the uncertainty with which each item was encoded by the population-level activation pattern. In visual field maps across occipital and parietal cortex, high- compared to low-priority items were decoded with lower neural uncertainty and with lower decoding error. Thus, the strategic allocation of WM resources sculpts the precision and uncertainty with which representations are encoded, revealing a key neural mechanism underlying voluntary control over memory quality.

Acknowledgement: NIH F32-EY028438 (TCS), NIH R01-EY027925 (CEC and WJM), and an NVidia Hardware Grant (TCS)

53.456 **Spatial location does not elicit normalization in visual memory** Luis D Ramirez[1,2](luisdr@bu.edu), Julia Schwartz[1,2], Ilona Bloem[1,2], Sam Ling[1,2], Melissa M Kibbe[1,2]; [1]Department of Psychological and Brain Sciences, Boston University, Boston, Massachusetts, USA, [2]Center for Systems Neuroscience, Boston University, Boston, Massachusetts, USA

Perception and visual memory are fundamental to cognition, and yet the neural correlates that make them unique have yet to be fully understood. Recent work has found that visual memories bypass normalization, a canonical computation that commonly occurs in perception (Bloem et al., 2018). Here, we examined whether having an item tied to a contrast and spatial location elicits normalization in visual memory. Given that spatial location is a fundamental representation in retinotopic space, we reasoned that this task would encourage a high-fidelity representation of the remembered stimulus that would be potentially more prone to normalization. Building off of Bloem et al., 2018, our surround suppression paradigm consisted of a method-of-adjustment task in which participants (n=10) replicated the location and contrast of a central stimulus, which was enveloped by a full contrast surround stimulus presented simultaneously with (perception condition), or sequentially from (visual memory condition), the central stimulus. To quantify normalization strength, these two conditions were compared to an absent surround condition. Participants reported both the location and perceived contrast for stimuli across five contrast levels (10%-75%), at various locations (0-359º) near the boundary of foveal vision (eccentricity=5º). After a delay-period, participants used a dial to replicate the location and contrast held in memory. While the precision of reports for both location and contrast were highly comparable between conditions, results show that normalization-driven suppression only emerged during perception, with only signs of minor facilitation in visual memory. In sum, this experiment further substantiates that visual memory and visual perception are distinct from each other: while visual memory may engage the same cortical areas as visual perception, its representations appear qualitatively distinct from true visual representations.

Acknowledgement: This research was funded by National Institutes of Health Grant EY028163 to S. Ling.

53.457 **The nature of top-down signals during non-spatial working memory** Masih Rahmati[1](masih.rahmati@nyu.edu), Thomas C Sprague[1,2], Kartik K Sreenivasan[3], Clayton E Curtis[1]; [1]New York University, [2]Department of Psychological and Brain Sciences, University of California, Santa Barbara, [3]New York University Abu Dhabi

Theoretical models emphasize the importance of top-down signals in the mechanisms that support working memory (WM; Curtis & D'Esposito, 2003; Sreenivasan et al., 2014). Yet, the nature and mechanisms by which top-down signals support WM functions remain unknown. Previously, we demonstrated that WM representations of an item's spatial position (Rahmati, Saber, & Curtis, 2018) and a non-spatial feature (i.e., orientation; Rahmati, et al., 2018) could be reconstructed from the pattern of activity in visual cortex, even when those representations are remapped to a part of the visual field that was not retinally stimulated. Although these results implicate top-down signals in remapping WM, we could not distinguish among mechanisms by which the top-down signals operated. Here, we test how top-down signals facilitate remapping of WM content to distinguish between models that posit that top-down signals carry precise feature information about WM representations, or they simply enhance the gain of neurons with receptive fields matching prioritized attentional space. Using fMRI and an inverted encoding model (Sprague et al., 2013), we reconstructed the stimulus orientation of a gabor maintained in WM during a retention interval from visual field maps defined in visual and parietal cortex. In order to reveal what information was carried by the top-down signals, participants compared the rotated 90-degree version of the orientation of a sample gabor presented in one quadrant, e.g., upper right, to thethe gabor tested in the quadrant diagonal from the sample, e.g., lower left. In parietal cortex, the delay period activity across voxels with receptive fields that mapped the diagonal probe quadrant contained information about the rotated orientation. In visual cortex, voxels mapping the probe quadrant contained information about both the original and rotated orientation. Therefore, WM representations in parietal and visual cortex are supported by top-down signals carrying spatial and non-spatial features.

Acknowledgement: NYU Global Seed grant for collaborative research (to CC & KS), NIH F32-EY028438 (to TCS) and NVidia Hardware Grant (to TCS)

53.458 **Attention and selection in visual working memory** Matthew F Panichello[1](mfp2@princeton.edu), Timothy J Buschman[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Psychology, Princeton University

Capacity limitations are ubiquitous in cognition; only so much information can be processed simultaneously. Primates compensate for capacity limits by prioritizing information processing based on their goals. For example, visuospatial attention compensates for limits in sensory processing by selecting a subset of stimuli for enhanced representation. Similarly, working memory has a limited capacity, and a 'selection' process akin to visual attention can selectively enhance a subset of items in working memory at the expense of others. However, neither the neural mechanism underlying selection nor its relation to attention is well understood. To explore this question, we trained two macaque monkeys to switch between an 'attention' and a 'selection' task.In both tasks, animals were presented with one or two colored squares (the samples) at different locations on a screen. After a memory delay, the animal reported one of the two items on a continuous scale. Critically, a spatial cue indicating which item was task-relevant appeared either before (prospective) or after (retrospective) the samples. Behavioral analyses indicated that prospective cues encouraged attention and retrospective cues encouraged selection. Report precision decreased with load on retrospective trials but not prospective trials, suggesting that the animals attended only the cued sample on prospective trials. Report accuracy increased when retrospective cues appeared earlier during the delay on two-item trials, suggesting that the animals prevented decay due to interference by selecting the cued sample in memory. To understand the neural mechanisms supporting attention and selection, we recorded neural activity simultaneously in prefrontal and parietal regions associated with attentional control. We identify neurons that encoded the locus of the task-relevant sample on prospective and retrospective trials and examine they extent to which these signals overlap across the brain.

Acknowledgement: MFP was supported by a National Defense Science and Engineering Graduate Fellowship and TJB was supported by a grant from the Office of Naval Research (ONR N00014-16-1-2085).

53.459 **Visual-biased frontal structures are preferentially connected to multisensory working memory regions.** Abigail Noyce[1](anoyce@bu.edu), Ray W. Lefco[2], James A. Brissenden[1], Sean M. Tobyne[2], Barbara G. Shinn-Cunningham[3], David C. Somers[1]; [1]Psychological and Brain Sciences, Boston University, [2]Graduate Program in Neuroscience, Boston University, [3]Carnegie Mellon Neuroscience Institute, Carnegie Mellon University

Lateral frontal cortex contains discrete regions that are recruited for working memory (WM) in sensory-specific ways. We collected block-design fMRI (TE=30 ms, TR = 2000 ms, 1 mm iso) while 15 subjects performed 2-back WM for visual (face photographs)and auditory (cat/dog vocalizations) stimuli. Sensorimotor control blocks were also collected. In addition, we collected 2-3 runs (180 TRs each) of eyes-open resting-state fMRI for each subject. Directly contrasting visual WM task activation with auditory WM revealed 6 bilateral sensory-biased structures along the precentral sulcus and inferior frontal sulcus of individual subjects. Visual-biased structures in the superior and inferior precentral sulcus (sPCS and iPCS) and mid inferior frontal sulcus (midIFS) are interleaved with auditory-biased structures in the transverse gyrus intersecting precentral sulcus (tgPCS), caudal inferior frontal sulcus (cIFS), and frontal operculum (FO). Each individual subject's visual- and auditory-biased frontal regions served as seeds in a seed-to-whole-brain resting-state functional connectivity analysis. After thresholding the resulting

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maps to remove negative correlations, we computed the difference in connectivity to the visual- and auditory-biased regions for each cortical vertex (Tobyne 2017). This differential connectivity analysis revealed subdivisions within areas we had previously identified as candidate multi-sensory WM regions (Noyce 2017). Anterior insula (AIC) contains a caudal portion with preferential connectivity to frontal auditory structures, and a more rostral portion with preferential connectivity to frontal visual structures. Similarly, pre-supplementary motor area (preSMA) contains a region with preferential visual connectivity, flanked above and below by regions with preferential auditory connectivity. Assessing task activation in these regions showed that the visual-connected portions of preSMA and AIC aresignificantly and equally recruited in both WM tasks, while the auditory-connected portions are not recruited in either task. These results provide further evidence that human cortical mechanisms for visual cognition participate flexibly in a wide range of tasks.

53.460 **Time-dependent recovery of retrospectively cued information during working memory storage.** Asal Nouri[1](anouri2015@fau.edu), Edward Ester[1]; [1]Department of Psychology, Graduate Neuroscience Training Program, Florida Atlantic University

Working memory (WM) performance can be facilitated by an informative cue presented during storage. Two recent studies suggest that this effect – termed a retrocue benefit – results from a recovery of information following the presentation of an informative cue. In one study, researchers used multivariate analyses of EEG data to reconstruct time-resolved representations of memoranda while participants performed a retrospectively cued WM task. In the absence of a retrospective cue, the information content of each reconstructed representation gradually decreased during storage. This decrease, however, was partially reversed by a 100% valid retrospective cue presented midway through the delay period. This reversal was interpreted as evidence that in some cases, participants can rely on other memory stores (e.g., long-term memory or "activity silent" memory) to supplement active WM representations. Here, we asked whether the degree of information recovery is contingent on the timing of a retrospective cue. Following earlier work, we recorded EEG while participants performed a retrospectively cued WM task. During neutral trials, participants were required to remember the spatial positions of two discs over a 3000 ms delay period. During valid trials, a 100% predictive cue indicating which disc participants would be probed to report was presented 1000 ms, 1500 ms, or 2000 ms after the onset of the memory array. Using an inverted encoding model, we replicated earlier findings documenting a recovery of location-specific information following a valid retrospective cue. However, the amount of recovery monotonically decreased with the timing of the retrospective cue. Our findings suggest that memory stores used to supplement active WM storage also degrade with time, leading to smaller retrospective cue benefits with longer delays.

53.461 **fMRI encoding model of virtual navigation** Zhengang Lu[1](zhengang@sas.upenn.edu), Joshua B Julian[1,2], Russell A Epstein[1]; [1]Department of Psychology, University of Pennsylvania, Philadelphia, Pennsylvania, USA, [2]Kavli Institute for Systems Neuroscience, Centre for Neural Computation, The Egil and Pauline Braathen and Fred Kavli Centre for Cortical Microcircuits, Norwegian University of Science and Technology, Trondheim, Norway

Neurophysiological recording studies of freely-moving rodents have identified neurons that represent spatial quantities such as location, heading, and distances to environmental boundaries. We explored the possibility that voxel-wise encoding modelling of fMRI data obtained during virtual navigation could be used to identify similar representations in humans. To test this idea, a participant performed a "taxi-cab" task within two large (201 vm * 120 vm) virtual reality cities (city 1A for 144 min and city 1B for 48 min). The cities had identical spatial layouts and buildings, but different surface textures on the buildings and roads. On each trial, the participant searched for a passenger at a random location and took him to an indicated destination. fMRI responses during navigation were regressed against predictor variables generated from a variety of navigation-related feature spaces, corresponding to location within the city, virtual head direction, egocentric distances to boundaries, and allocentric distances to boundaries. Thus, each feature space quantified a specific hypothesis about how navigation-related information might be represented in the brain, and the resulting beta weights revealed how specific feature spaces were represented in each voxel. To validate the encoding models estimated from city 1A data, we examined model predictions using the held-out brain activation during navigation in both city 1A and 1B. The encoding models significantly predicted activity of voxels distributed across a wide range of brain regions, with consistent networks of significant predictive voxels for both cities. These results suggest that these networks encode spatial information that is at least partially invariant to the visual appearance of the environment. More generally, our results suggest that voxel-wise encoding models can be used to investigate the neural basis of spatial coding during unconstrained dynamic navigation.

Acknowledgement: NIH R21 EY022751

53.462 **Neuronal activity in Prefrontal and Posterior Parietal Cortex Mediating Working Memory Judgments** Sihai Li[1](sili@wakehealth.edu), Xuelian Qi[1], Christos Constantinidis [1]; [1]Department of Neurobiology and Anatomy, Wake Forest School of Medicine

The dorsolateral prefrontal cortex (dlPFC) and posterior parietal cortex (PPC) play a critical role in spatial working memory. Activity in these areas has been shown to determine the variability of monkeys' responses (endpoints of eye movements) in a delayed response task. Here we addressed the role of these areas on categorical judgments based on information retained in working memory. We trained two monkeys in a Match / Nonmatch task, which required them to observe two stimuli presented in sequence with an intervening delay period between them. If the two stimuli were different, the monkeys had to saccade to the location of the second stimulus; if they were the same, they held fixation. Neurophysiological recordings were performed in areas 8a and 46 of the dlPFC and 7a and LIP of the PPC. We collected a total of 210 neurons. We selected neurons with activity during the first stimulus and delay period that was significantly elevated relative to the baseline fixation (n=53, paired t-test, $p < 0.05$). We hypothesized that random drifts causing the peak activity of the network to move away from the first stimulus location and towards the location of the second stimulus would result in categorical errors. Indeed, when the first stimulus appeared in a neuron's preferred location, the neuron showed significantly higher firing rates in correct than in error trials (paired t-test, p = 2.2 x 10-4). When the first stimulus appeared at a non-preferred location and the second stimulus at a preferred, activity in error trials was higher than in correct (paired t-test, p = 0.042). The results indicate that the activity of dlPFC and PPC neurons influences categorical judgments of information maintained in working memory, and the magnitude of neuronal firing rate deviations could determine the role of cortical areas in working memory performance.

Acknowledgement: Supported by NIH grant: R01EY016773

53.463 **The P3b ERP component as a function of visibility, accuracy, decision, and confidence** Lara Krisst[1](lckrisst@ucdavis.edu), Steven J. Luck[1]; [1]Center for Mind & Brain and Department of Psychology, University of California, Davis

Previous research has shown that the P3b ERP component is associated in some ways with visual awareness, but researchers have debated whether the P3b is a neural correlate of visual consciousness, whether it can occur outside of awareness, and whether it is associated with post-perceptual processes that are distinct from consciousness (e.g., decision processes, task relevance,metacognition). To address these issues, we manipulated stimulus visibility via backward masking during an oddball task. For each participant, target luminance was adjusted during pretesting to yield 75% correct performance with a mask SOA of 50 ms. SOAs of 0, 17, 33, 50, and 200 ms were used in the main experiment. Participants reported the direction of the stimulus (right/left arrows) and rated the confidence of each response. One stimulus was rare (.10) and the other was frequent (.90). We found that P3b amplitude was modulated by SOA, response accuracy, decision processes, and confidence: P3b amplitude was greater for longer than shorter SOAs, greater for correct than for incorrect responses,greater for 'hits' than for 'false alarms', and larger on high- confidence than low-confidence trials. P3b was absent for missed oddballs, indicating that participants were unable to produce a P3b response unless they were aware of the stimulus, arguing against the idea that P3b can occur outside of visual awareness.

53.464 **Alpha power gating of early visual information inferred using an iconic memory task** Amalia Gomoiu[1](a.gomoiu.1@research.gla.ac.uk), Roberto Cecere[1], Stephanie Morand[1], Monika Harvey[1], Gregor Thut[1]; [1]Institute of Neuroscience & Psychology, University of Glasgow, Glasgow, UK

Amplitude fluctuations of brain oscillations at baseline have repeatedly been shown to affect the perceptual fate of incoming sensory stimuli. Particularly, pre-stimulus power in the alpha-band (8-14Hz) over occipito-parietal areas has been inversely related to visual perception, and is thought to reflect gating of sensory information (Thut et al., 2012). However, despite a comprehensive body of work, there is little consensus on the processing stage at which alpha power affects perception of visual stimuli. One prominent, yet untested interpretation is that alpha oscillations inhibit/gate the information flow at an initial, input stage into sensory cortices (Romei et al., 2010). Alternatively, it has been proposed that this influence comes later, when information is read out from early sensory cortices to higher-order areas (Chaumon et al., 2014). Here, we distinguish between these alternatives by investigating whether pre-stimulus alpha-power influences the initial availability or rather information decay using a classic visual iconic memory task. Specifically, the availability of visual information was sampled at different times between 40 and 300ms after presentation of a multi-item visual display using post-cueing, while concurrently recording multichannel EEG in 27 participants. Logistic regression was then employed to link pre-stimulus oscillations to iconic memory performance across trials within participants, followed by cluster-based statistics across participants and single trial sorting of memory performance. Results revealed a pre-stimulus cluster in the alpha and beta bands over occipito-parietal areas that affected initial availability but not iconic memory decay within participants. A similar, but non-significant trend was observed between participants. Our findings suggest that power is linked to input-gating rather than decay of visual iconic memory trace. This provides first time evidence for very early gating effects of alpha-band amplitude, complementing evidence for alpha-power influence on later processing stages.

Acknowledgement: Economic and Social Research Council

53.465 **Probing the Neurocognitive Architecture of Visual Working Memory by Enhancing Storage vs. Manipulation Abilities** Hrag Pailian[1](pailian@fas.harvard.edu), George A. Alvarez[1]; [1]Department of Psychology, Harvard University

In an ever-changing world, intelligent behavior is shaped by our abilities to store and manipulate representations in visual working memory (VWM). Previous work (Pailian & Alvarez, 2018; Pailian & Halberda, 2015) has demonstrated that memory storage relies on separate resources than memory updating, suggesting separate underlying neural mechanisms. Here, we probe the neural architecture of VWM, using trans-cranial direct current stimulation (tDCS) to upregulate neuronal activity in the right posterior parietal cortex (PPC) and determining its effects on memory storage vs. memory updating. Across two nearly identical sessions (counterbalanced order), we applied 20 minutes of either anodal or sham stimulation over the right PPC. During this period, participants completed a behavioral task, in which they were presented with four colored dots that were subsequently hidden by opaque occluders. On some trials, all occluders remained stationary, requiring participants to simply store color information. On other trials, pairs of occluders swapped positions, requiring participants to update the color-location bindings of the moving objects. Memory for a cued item was subsequently tested. Relative to sham stimulation, anodal-tDCS failed to improve manipulation-related performance ($p=.20$) across all individuals. However, significant improvements were observed for storage, such that accuracy increased by up to ~20%. This dissociation suggests that storage and manipulation rely on separate neural resources, and that factors determining manipulation ability are separate from storage constraints. Moreover, storage improvements were observed in low ($p< .04$) - but not high ($p=.16$)-memory individuals. The magnitude of this neuroenhancement scaled continuously with initial storage capacity ($r=-.76$, $p=.001$), and was driven by a reduction in misbinding errors. Neurostimulation techniques modulating different neural mechanisms may provide an important lens onto understanding how individuals vary in their storage and manipulation capacities, whether these behavioral limits reflect genuine cognitive maxima, and how storage and manipulation substrates/mechanisms interact to dynamically update visual information.

53.466 **Classification of load in visual working memory using single-trial EEG data** Kirsten Adam[1](kadam@ucsd.edu), Edward Awh[2], Edward K. Vogel[2]; [1]Department of Psychology, University of California San Diego, [2]Department of Psychology, University of Chicago

Here, we used data acquired from 4 published studies (combined n = 340 participants) to test whether working memory load can be predicted from the broadband EEG signal across all electrodes, even at the single trial level. In Experiment 1 (Unsworth, Fukuda, Awh, and Vogel, 2015), we first demonstrate that we can classify memory load (2 versus 6 items) using a multivariate classifier across all electrodes. Importantly, the multivariate load signal was independent of the hemifield in which items were stored, such that combining trials across left and right lateralized displays did not impede accurate classification; thus the load signal has a global character. In Experiment 2 (Hakim, Adam, Gunseli, Awh & Vogel 2018), we demonstrate that the multivariate classification signal is specific to working memory task demands, as opposed to a physical stimulus confound or attention demands; we could classify load during the retention interval when participants were remembering the position of 2 versus 4 items, but not when they directed attention to those positions without storing the items themselves. Finally, in Experiments 3 and 4 (Fukuda, Mance & Vogel, 2015; Fukuda, Woodman & Vogel, 2015) we pushed this method further by classifying load across a finer parametric manipulation of load (set sizes 1-8). Intriguingly, the confusion matrix for these analyses revealed higher discriminability between lower loads (1-3) than between higher loads (6-8), suggesting that this multivariate signal respects hypothesized capacity limits and is not simply a measure of overall effort. Combined, these analyses demonstrate that multivariate classification of broadband EEG data can be used to predict visual working memory load in a manner that is (1) independent of where the items were encoded (2) specific to object-based storage demands and (3) precise enough to differentiate item-by-item increments in the number of stored items.

Acknowledgement: NIH grant 5T32-MH020002 (KA). NIH grant 5R01-MH087214 (EV and EA). ONR grant N00014-12-1-0972 (EV)

53.467 **Categorical Target Repetition Reduces Early Contralateral Delay Activity** Ashley M Ercolino[1](ashley.ercolino@knights.ucf.edu), Joseph Schmidt[1]; [1]Psychology, College of Sciences, University of Central Florida

Previous work has shown identical target repetition results in superior search performance (Goldstein & Beck, 2018), a decreased reliance on visual working memory (VWM) as indicated by contralateral delay activity (CDA; Carlisle, et. al., 2011) and possibly, an increased reliance on long-term memory (Woodman, Carlisle, & Reinhart, 2013). However, in the real world, we often have to search for the same category of items rather than the same exact item. For example, an airport security screener needs to repeatedly search for the category of "weapon". This study evaluated the effect of categorical repetition on search performance and target-related VWM utilization. Participants were cued with two possible targets prior to performing a search task containing one target and five non-target category distractors. Target categories consecutively repeated three to nine times; each target category was presented for two non-consecutive runs of trials. Contrary to identical target repetition findings, there was a speed accuracy trade-off in which search slowed but became more accurate with repetition (both, $p< .05$), but eye movement measures of search performance showed little effect of repetition.Interestingly, examining target-related CDA over time and repetition revealed a significant interaction ($p< .01$). Over repetitions, early CDA decreased, whereas late CDA was fairly stable, suggesting that VWM maintenance shortly after preview offset reduced with categorical repetition but later VWM maintenance did not. We speculate that decreased CDA shortly after cue offset may indicate a reduction in feature extraction from the target cue over repetitions. Conversely, the stable presence of CDA in the later time window may be indicative of the maintenance of long-term categorical information in VWM prior to search onset.

53.468 **Neural indices of proactive target templates** Sage EP Boettcher[1](sage.boettcher@psy.ox.ac.uk), Freek van Ede[1], Anna C Nobre[1]; [1]Brain and Cognition Lab, University of Oxford

In perception, representational templates are proposed to be used proactively to anticipate target stimuli and facilitate performance. We designed a novel task and recorded EEG to test for the neural instantiation of representations of anticipated targets. In an associative-cueing task, observers were presented with a cue followed by a target on each trial. One of three possible targets was presented for 30ms followed by a mask and a forced choice discrimination response. Half of the cues were predictive of the target identity for two of the targets (67% validity) while the remaining cues were neutral (33% chance for each of the three potential targets to follow). The remaining target had an occurrence probability of 33%, irrespective of the preceding cue. Importantly, two distinct identity cues predicted the same target, enabling us to tease apart activity associated with cue vs. target representations. Analysis of the event related potentials locked to the onset of the cue indicates an effect of identity cues relative to the neutral cues – despite the fact that all cues predicted the occurrence of a target after the same interval in the same location. Specifically, we see an early posterior positivity followed by a late frontal negativity for identity relative to neutral cues.Additionally, we used multivariate pattern analysis to investigate whether the identity of the predicted target could be decoded during the cue period, independently from cue-related differences. This revealed traces of the upcoming target identity in similar periods as the observed ERP differences.The instantiation of a target template from memory thus appears to unfold dynamically in time, and to be reflected in complementary signatures of the EEG. In sum, we provide evidence for a dynamic predictive perceptual mechanism which can be used to facilitate the processing of incoming visual information.

53.469 **Decoding objects' roughness held in visual working memory** Munendo Fujimichi[1](fujimichi@cv.jinkan.kyoto-u.ac.jp)**,** Hiroyuki Tsuda[1]**,** Hiroki Yamamoto[1]**,** Jun Saiki[1]; [1]Graduate School of Human and Environmental Studies, Kyoto University

Previous studies on visual working memory revealed that both visual and parietal cortex play important roles for the memory of color and shapes. In contrast, prior studies on perception of objects' material properties have shown that the ventral visual pathway supports the material perception. Which regions are responsible for visual working memory for objects' material properties? To test this question, we conducted an fMRI experiment where participants performed a delayed roughness discrimination task (main task) in a 3T scanner. In each trial, two sample objects were sequentially presented. These objects consisted of rough object and smooth object. After these objects were presented, a numerical cue was presented. The cue indicated which sample to memorize. After an 11s delay, a probe object was presented and the participants indicated which one of the probe object and the memorized one had lower roughness. The imaging runs of the main task were followed by two kinds of imaging: localizer runs to identify brain regions processing objects, color, faces, and scenes, and phase-encoded retinotopy measurements to define retinotopic visual areas. We applied multi-voxel pattern analysis (MVPA) to predict the memorized sample's roughness, rough or smooth. The results of MVPA showed above-chance accuracies in the early visual areas, intraparietal sulcus, and ventral object vision pathway. These results suggest that not only the early visual cortex and intraparietal sulcus, but also ventral vision pathway can hold objects' roughness in visual working memory.

Acknowledgement: Japan Society for the Promotion of Science (JSPS), Tokyo

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Objects and Scenes: Cortical category selectivity

Tuesday, May 21, 2:30 - 4:15 pm, Talk Room 1

Moderator: Aude Oliva

54.11, 2:30 pm **An object-topic map in primate inferotemporal cortex** Pinglei Bao[1,2](pbao@caltech.edu), Liang She[1], Doris Y. Tsao[1,2,3]; [1]Division of Biology and Biological Engineering, Caltech,, [2]Howard Hughes Medical Institute, [3]Computation and Neural Systems, Caltech

How is the representation of complex visual objects organized in inferotemporal (IT) cortex, the large brain region responsible for object recognition? Areas selective for a few categories such as faces, bodies, and scenes have been found, but the vast majority of IT is "wild," lacking any known specialization, leading to uncertainty over whether any general principle governs IT organization. We recorded responses of IT cells in macaque monkeys to a set of objects, and built a low dimensional object space to describe these objects using a deep network Alexnet, by performing principal component analysis on the responses of fc6 layer. We found that responses of single IT cells could be well-modeled by projection onto specific axes of this object space. Remarkably, cells were spatially clustered into networks according to their preferred axes, and this clustering was determined by the topography of object space. Furthermore, this topography was replicated across at least three hierarchical stages of increasing view invariance. Finally, pooling cells across this newly identified object-topic map allowed reconstruction of general objects. Taken together, these results provide a unified picture of IT organization in which category-selective regions are part of a topographic continuum.

54.12, 2:45 pm **Ultra-high-resolution fMRI reveals differential representation of categories and domains across lateral and medial ventral temporal cortex** Eshed Margalit[1](eshed.margalit@gmail.com), Keith W Jamison[2,3], Kevin S Weiner[4,5], Luca Vizioli[2], Ruyuan Zhang[2], Kendrick N Kay[2], Kalanit Grill-Spector[1,6]; [1]Neurosciences Graduate Program, Stanford University, [2]Center for Magnetic Resonance Research (CMRR), Department of Radiology, University of Minnesota, [3]Department of Radiology, Weill Cornell Medical College, [4]Department of Psychology, UC Berkeley, [5]Helen Wills Neuroscience Institute, UC Berkeley, [6]Department of Psychology, Stanford University

Introduction: Visual object categories are represented in a reliable topology within ventral temporal cortex (VTC): neural representations in lateral VTC differ from those in medial VTC. Despite this regularity, it is unknown if the two subdivisions (1) represent visual information at the same category-abstraction level and (2) if they differ in the spatial scale of their representations. We hypothesized that visual information at different category-abstraction levels is represented at different spatial scales within VTC. Methods: Seven participants completed a visual category fMRI experiment. Stimuli were drawn from ten categories (e.g., "Corridors", "Houses") grouped into five domains (e.g., "Places"). Data were collected at the ultra-high-resolution of 0.8mm using 7T fMRI, affording dense sampling both parallel to the cortical surface and through cortical depth (Fig S1). In each subject, we computed correlations between distributed responses to different stimuli in each VTC subdivision and each of three cortical depths (Fig S2). We evaluated the capacity of each subdivision to discriminate responses to objects from different categories and domains by computing (1) the difference between within- and between-domain correlations (domain-level discriminability), and (2) the difference between within- and between-category correlations (category-level discriminability). Results: Domain-level discriminability was stronger in lateral than medial VTC, whereas category discriminability was higher in medial than lateral VTC, ($F(1, 24) = 31.0$, $p < .0001$). Analysis by cortical depth revealed that category-level discriminability was stable across cortical depth, while domain-level discriminability decreased from the superficial to the deepest depth, ($F(1, 24) = 78.5$, $p < 10\text{-}8$). Simulated downsampling of our data to 2.4mm eliminated these effects. Conclusions: These results suggest that (1) discovering differences in category representations across VTC requires ultra-high-resolution fMRI, and (2) visual category representations in VTC occur at a variety of abstraction levels, affording downstream regions different perspectives of the visual world.

Acknowledgement: NSF GRFP, NEI 1R01EY02391501A1, NIH Grant P41 EB015894, NIH Grant P30 NS076408, NIH Grant S10 RR026783, NIH Grant S10 OD017974-01, W. M. Keck Foundation

54.13, 3:00 pm **Rapid onset of category-selective biases in human cortex.** Edward Ester[1](eester@fau.edu), Jordan Camp[1], Tayna Latortue[1], Tommy Sprague[2], John Serences[3]; [1]Department of Psychology, Florida Atlantic University, [2]Department of Psychology, University of California Santa Barbara, [3]Department of Psychology, University of California San Diego

Categorization refers to the process of mapping continuous sensory inputs onto discrete concepts. It is a cornerstone of flexible behavior that allows organisms to generalize existing knowledge to novel stimuli and to discriminate between physically similar yet conceptually different stimuli. Humans and other animals can readily learn arbitrary novel categories, and this learning "distorts" perceptual sensitivity such that discrimination performance for categorically distinct exemplars is increased (acquired distinctiveness) and discrimination performance for categorically identical exemplars is reduced (acquired similarity). A recent imaging study reported a possible basis for these distortions by demonstrating that category learning biases neural representations of to-be-categorized stimuli at the earliest stages of the visual system (V1-V3). However, the temporal dynamics of these biases are poorly understood. On the one hand, category biases in reconstructed representations could reflect changes in early sensory processing, in which case they should manifest shortly after the appearance of a to-be-categorized stimulus. On the other hand, these biases could reflect changes in post-sensory processing (e.g., decision making or response selection), in which case they should appear shortly before the onset of a behavioral response. Here, we report data from three experiments designed to evaluate these alternatives. In each experiment, we recorded high-density EEG while participants learned to categorize simple objects (orientations and locations) into discrete groups, then used an inverted encoding model to reconstruct time-resolved representations of these objects on a trial-by-trial basis. In all three experiments, robust category-selective biases emerged within 100-200 ms of stimulus onset and persisted until participants' behavioral report (typically 800-1200 ms after stimulus onset). Our findings indicate that category learning alters relatively early stages of visual processing.

54.14, 3:15 pm **Comparing visual object representational similarity in convolutional neural networks and the human ventral visual regions** Yaoda Xu[1](xucogneuro@gmail.com), Maryam Vaziri-Pashkam[2]; [1]Psychology Department, Yale University, [2]National Institute of Mental Health

Convolutional neural networks (CNNs) have achieved amazing successes in visual object categorization tasks in recent years. Some have considered them to be good working models of the primate visual system, with different CNN layers corresponding to different levels of visual processing in the primate brain. However, much remains unknown about how visual information is processed within a CNN, making it more like a blackbox than a well understood system. Using methods developed in human neuroscience, here we examined information processing in several CNNs using two approaches. In our first approach, we compared the representational similarities of visual object categories from the different CNN layers to those obtained in retinotopically and functionally defined human occipito-temporal regions through fMRI studies. Regardless of the specific CNN examined, when natural object categories were used, the representational similarities of the early CNN layers aligned well with those obtained from early visual areas, presumably because these layers were modeled directly after these brain regions. However, representational similarities of the later CNN layers diverged from those of the higher ventral visual object processing regions. When artificial shape categories were used, both early and late CNN layers diverged from the corresponding human visual regions. In our second approach, we compared visual representations in CNNs and human visual processing regions in terms of their tolerance to changes in image format, position, size, and the spatial frequency content of an image. Again, we observed several differences between CNNs and the human visual regions. Thus despite CNNs' ability to successfully perform visual object categorization, they process visual information somewhat differently from the human brain. As such current CNNs may not be directly applicable to model the details of the human visual system. Nevertheless, such brain and CNN comparisons can be useful to guide the training of more human brain-like CNNs.

54.15, 3:30 pm **Representation of scene layout in human OPA is fast and invariant to surface-texture** Linda Henriksson[1](linda.henriksson@aalto.fi), Marieke Mur[2], Nikolaus Kriegeskorte[2,3]; [1]Department of Neuroscience and Biomedical Engineering, Aalto University, Finland, [2]MRC Cognition and Brain Sciences Unit, University of Cambridge, UK, [3]Zuckerman Mind Brain Behavior Institute, Columbia University, USA

Although the scene-responsive occipital place area (OPA) and parahippocampal place area (PPA) are well-established functional regions in the human brain, their computational roles in scene perception remain incompletely understood. In this study, we investigated how scene layout is encoded in these regions, using both functional magnetic resonance imaging (fMRI) and magnetoencephalography (MEG). We constructed all possible combinations of five scene-bounding elements (left wall, right wall, back wall, ceiling, floor) in three different surface-textures. The resulting 96 scenes were shown to 22 subjects. The regions-of-interest (primary visual cortex, V1; OPA; PPA) were defined based on criteria independent to the main experiment. The representations were characterized by applying Fisher linear discriminant analysis between each pair of scenes and constructing representational distance matrices (RDMs) from the results. In V1 and PPA, the fMRI response-patterns better discriminated the texture of the scenes than the layout, whereas in OPA, the fMRI response-patterns discriminated the layout better than the texture. Moreover, only in OPA, the layout discrimination generalized across surface-textures. Already the early MEG representations were similar to the fMRI OPA representation, suggesting that the scene layout is rapidly extracted from the retinal input. Finally, the representations were also characterized using a set of models. The fMRI- and MEG-RDMs were fitted by a linear combination of low-level image feature (GIST) and scene-element based models. Whereas the representation in V1 was well captured by the GIST model, the OPA representation was better captured by models based on the presence of the scene-elements. Correspondingly, the dynamic representation captured by MEG was better explained by including the presence of the scene-elements than by the GIST model alone. Taken together, our results suggest that the layout of a scene is encoded rapidly in human OPA and that this representation is invariant to the identity of the scene.

Acknowledgement: Academy of Finland grant number 278957

54.16, 3:45 pm **Spatial schemata determine cortical representations of the environment** Daniel Kaiser[1](danielkaiser.net@gmail.com), Jacopo Turini[2], Radoslaw M Cichy[1,3,4]; [1]Freie Universität Berlin, [2]Goethe-Universität Frankfurt, [3]Berlin School of Mind and Brain, [4]Bernstein Center for Computational Neuroscience Berlin

For understanding complex natural environments, the brain must efficiently extract information from a rich, ongoing stream of sensory input. Here we characterize how spatial schemata (i.e., our knowledge about the structure of the world) help the visual system to make sense of these inputs. Specifically, we elucidate how schemata contribute to rapidly emerging perceptual representations of the environment. In separate EEG and fMRI experiments, we showed participants fragments of natural scene images, presented at central fixation, while they performed an orthogonal categorization task. Using multivariate analyses, we then investigated where and when neural representations of these fragments were explained by their position within the scene. We observed a sorting of incoming information according to its place in the schema in scene-selective occipital cortex and within the first 200ms of vision. This neural sorting operates flexibly across visual features (as measured by a deep neural network model) and different types of environments (indoor and outdoor scenes). This flexibility highlights the mechanism's ability to efficiently organize incoming information under dynamic real-world conditions. The resulting organization allows for rapid inferences about the current scene context and its behavioral affordances and can thereby support efficient real-life behaviors.

Acknowledgement: The research was supported by DFG grants awarded to D.K. (KA4683/2-1) and R.M.C. (CI241/1-1).

54.17, 4:00 pm **Reliability-Based Voxel Selection for Condition-Rich Designs** Leyla Tarhan[1](ltarhan@g.harvard.edu), Talia Konkle[1]; [1]Department of Psychology, Harvard University

In most neuroimaging studies, responses are measured across the whole brain, though not all regions are necessarily informative. To consider relevant regions, current practices range from selecting voxels with high overall activity to restricting all analyses to a few independently-defined regions of interest. However, these methods tend to rely on arbitrary activity thresholds and voxel counts, and often presume particular regional boundaries. Here, we introduce an alternative method – reliability-based voxel selection. This method first computes split-half reliability for each voxel by correlating response profiles over conditions in odd and even halves of the dataset. Next, a voxel-reliability cutoff is derived that optimizes both coverage and multi-voxel pattern reliability across conditions. We employed this method on an example dataset consisting of whole-brain responses to 60 short action videos. A voxel-wise split-half reliability threshold of $r>0.3$ selected a set of voxels over which the multi-voxel patterns for the 60 conditions reached an average reliability of $r=0.88$ in group data ($sd=0.03$). We next considered an alternative subset of voxels selected based on overall activity (all>rest $t>2.0$). The reliable voxel method yielded a higher condition pattern reliability (mean r across items and subjects =0.65 for reliable voxels, 0.47 for active voxels, $t(12) = 15.8$, $p < 0.001$), and this relationship held over a range of possible thresholds defining active voxels. These results replicated in a separate dataset of whole-brain responses to 72 objects ($t(10) = 21.65$, $p < 0.001$). Simulations indicate this method is suitable for designs with 15 or more conditions. The key advantages of this voxel-selection method are (1) that it leverages the structure of the data itself, without any a priori hypotheses about regions of interest or the relationships among the conditions, and (2) it emphasizes data reliability as the first step when analyzing condition-rich neuroimaging data.

Acknowledgement: Funding for this project was provided by NIH grant S10OD020039 to Harvard University Center for Brain Science, NSF grant DGE1144152 to L.T., and the Star Family Challenge Grant to T.K.

Color and Light

Tuesday, May 21, 2:30 - 4:15 pm, Talk Room 2

Moderator: Angela Brown

54.21, 2:30 pm **A neural correlate of heterochromatic brightness** Jing Chen[1](chenjingps@gmail.com), Karl Gegenfurtner[2]; [1]Department of Sport Psychology, School of Kinesiology, Shanghai University of Sport, Shanghai, China, [2]Department of General Psychology, Justus-Liebig-University Giessen, Germany

The standard luminance function, V(λ), is mainly defined by heterochromatic flicker photometry (CIE, 1924). It is, however, often in disagreement with heterochromatic brightness judgments. While luminance is firmly grounded physiologically in the retino-geniculo-cortical M-pathway, no such correlate is known for heterochromatic brightness. Here, we wanted to explore whether steady-state visually evoked potentials (SSVEP) at low temporal frequencies could serve as such a neural correlate in humans (Regan, 2009, Vision Research). We recorded SSVEPs to chromatic stimuli flickering at 3Hz or at 15Hz against a black background. In each trial, the stimulus had one of the "principle" colors on the RGB display (i.e., R, G, B, RG, RB, GB, RGB), and its linearized intensities were swept from 12.5%, 25%, 37.5% to 50%, each step lasting 1 second. At a flicker frequency of 15Hz, which is often used in flicker photometry, the SSVEP amplitudes could be well predicted by stimulus luminance ($r2 = .81$). However, when the frequency was 3Hz, SSVEP amplitudes were barely related to luminance ($r2 = 0.13$). They were much better accounted for by stimulus max[r,g,b] values ($r2 = 0.65$). This max rule (1) weights the red, green, and blue channels equally, (2) combines them non-linearly with a maximum rule, and (3) agrees quite well with recent psychophysical findings on color-weight photometry by Koenderink et al (Vision Research, 2018). Our results provide a consistent, reliable and easy to measure neural correlate of heterochromatic brightness.

Tuesday PM

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54.22, 2:45 pm **What is halfway between a starfish and a locomotive? Studies of the intrinsic geometric structure of Hering color-opponency.** Lindsey N Hutchinson[1](hutchinson.297@osu.edu), Angela M Brown[1], Delwin T Lindsey[1,2]; [1]College of Optometry, The Ohio State University, [2]Department of Psychology, The Ohio State University, Mansfield

Color scientists have long tried to use geometry to represent human color perception. While color space is not generally Euclidean, Ennis&Zaidi, 2013 ("E&Z") suggested that perceptual color space may be affine under a Hering color-opponent mental representation ("HCOR"). Consider the following construction: First, bisect the four edges of any quadrilateral within a vector space. Then, bisect the opposite-edge bisection intervals. By Varignon's theorem ("VT"), if the space is at least affine, these bisection midpoints (BSMs) will coincide (Todd, 2001). Twelve subjects viewed equiluminant colors pairwise, and adjusted a third color in hue and saturation to bisect the perceived interval between each pair, following the VT paradigm. Like E&Z, we found that uninstructed BSMs were far from coincident, but subjects did better for small quadrilaterals than for large quadrilaterals (LQ). However, unlike E&Z, we found little effect of HCOR instructions. To further test HCOR, we manipulated the choice of LQ colors. We chose one LQ enclosing white (as in E&Z) and two LQs shifted in redness/greenness. We predicted that if subjects were truly bisecting colors in a metrical HCOR space, the chosen BSMs should move with the LQ colors. Four subjects received extensive practice and a tutorial on the geometric representation of colors in Hering color-opponent space. Subjects' BSMs were more nearly coincident than before instruction, but there was no shift in red/green locations of the BSMs across LQs (ChiSq=2.92,p=0.232). This suggests that E&Z's LQ centered on white was a special case for which categorical and metrical judgments happen to give the same result. Our subjects did not judge colors in a metrical, color-opponent space, but rather sought colors that were categorically distinct from the endpoints. Halfway between two categorically different items (like red and green, or a starfish and a locomotive) is not defined within any continuous, affine space.

Acknowledgement: T35-EY007151

54.23, 3:00 pm **Material property space analysis for depicted materials** Mitchell van van Zuijlen[1](m.j.p.vanzuijlen@tudelft.nl), Paul Upchurch[2], Sylvia Pont[1], Maarten Wijntjes[1]; [1]Perceptual Intelligence lab, Industrial Design Engineering, Delft University of Technology, [2]Cornell University

The ability to estimate material properties enables us to visually differentiate between fresh and rotting food and warns us that red-glowing metal might be hot, for example. From our experiences interacting with materials, we have semantic knowledge which tells us for example, that steel is usually harder than silk, which implies the existence of a specific distribution of material properties per material. In the first experiment in the study by Fleming et al. (JoV 13(8) 2013) participants rated 10 photographed materials for 9 material properties. In the second experiment, they collected ratings for 42 material properties for 6 material names - i.e. only semantic information. They performed a principal component analysis (PCA) for both experiments, and found that photographic and semantic materials have a very similar representation in material feature spaces. In our study we had 316 participants estimate 10 material properties for 1350 stimuli (15 classes containing 90 exemplars) depicted in paintings. As expected, these materials show striking similarities with Flemings' photographic and semantic materials on the distribution of materials upon the first two PCA dimensions. These first two primary components in a PCA visualize the majority of variability between the different materials, in other words these two components allow for differentiating between materials. This raises the question if the majority of variability within different materials is similar – i.e. do we use the same material properties to differentiate between and within materials?We applied a PCA on each individual material to examine the purely visual contributions on the material feature space and noted striking differences in the structure of these material feature spaces. This implies that we use both a general, robust material feature space to distinguish between materials, but defer to a specific material feature space for the differentiation within a material.

Acknowledgement: This work is part of a VIDI program with project number 276-54-001, which is financed by the Netherlands Organization for Scientific Research (NWO).

54.24, 3:15 pm **Effects of ipRGCs and rods on color matching between object and luminous colors** Akari Kagimoto[1](kagimoto-akari-wx@ynu.jp), Katsunori Okajima[2]; [1]Graduate School of Environment and Information Sciences, Yokohama National University, JAPAN, [2]Faculty of Environment and Information Sciences, Yokohama National University, JAPAN

It has been reported that object and luminous colors cannot be matched in many situations even though their tristimulus values are identical. To clarify whether ipRGCs and/or rods affect such color matching between different color modes, participants compared color appearances of a color patch and a color on an LCD monitor using their central vision. They responded whether the appearances of two colors are the same or not. When the answer was "different", participants responded the color appearances using an elementary color scaling method. The visual size of each stimulus was 2-deg, the xy-chromaticity values were (0.347, 0.358) and the luminance value was 100 cd/m2. We used a multispectral light source (OL490) for illuminating the color patch which enables to generate an isometric color pair. We prepared 5 conditions: (1) Isometric color match where two spectral distributions were identical, (2) Metameric color match including ipRGCs and rods, (3) Metameric color match including ipRGCs response but not rods response, (4) Metameric color match including rods response but not ipRGCs response, and (5) Metameric color match with different ipRGCs and rods responses. The results under the condition (1) showed that all participants responded that color appearances of the object and luminous colors were perfectly identical, indicating that there exists no color-mode problem when both spectral distributions are identical. On the other hand, the results under the condition (2) showed that some participants responded that color appearances of the object and luminous colors were different, suggesting that there are individual differences on sensitivities of photo-receptors. Compared results of the elementary color scaling under the conditions (2)-(5) revealed that ipRGCs and rods contribute to color appearance. We concluded that the color-mode problem is caused by the individual differences on sensitivities of photo-receptors as well as the contributions of ipRGCs and rods to color appearance.

Acknowledgement: This work was supported by JSPS KAKENHI Grant Numbers 15H05926 and 18H04111.

54.25, 3:30 pm **Sensitivity to gloss** Jacob R. Cheeseman[1](jacob.cheeseman@psychol.uni-giessen.de), Roland W. Fleming[1]; [1]Department of General Psychology, Justus Liebig University Giessen

Despite the prevalence of well-validated colorimetric standards, predicting the perceived gloss of surfaces from physical measurements remains challenging. The complex interactions between distal scene parameters and proximal image data make it difficult to determine mappings between physical reflectance properties and perceived gloss. Indeed, degenerate scene conditions can be constructed in which slight variations in the BRDF can drastically alter the appearance of rendered images, while in other conditions, large changes in the BRDF have hardly any visible effect. Yet, for many practical purposes (e.g., quality control), it would be extremely useful to characterize our sensitivity to changes in reflectance parameters. Here, we sought to define conditions for measuring sensitivity to reflectance changes, paving the way for standards that could serve both industry and vision researchers. Stimuli consisted of renderings of glossy objects under HDR light probe illumination. Using MLDS, we created a perceptually-uniform parameterization of the specular reflectance parameter (A) of the ABC reflectance model (Löw et al., 2012). Then, in a 2AFC task, we measured psychometric functions for gloss discrimination across a range of reflectance values when all other scene variables were held constant. JNDs increased with specular reflectance, suggesting that gloss sensitivity depends on the change in the image produced by different parameter values, even if these steps are made perceptually-uniform. To identify conditions that maximize or minimize gloss discrimination, we performed a large-scale statistical image analysis, in which we measured the magnitude of image change as a function of specular reflectance across varying distal scene variables, including shape, viewpoint, and illumination. We then measured visual gloss sensitivity for important test cases drawn from this analysis. We find that, although sensitivity varies systematically as a function of scene variables other than specular reflectance, optimal conditions for measuring and interpreting sensitivity to gloss can be determined.

Acknowledgement: EU H2020 MSC ITN No 765121 "DyViTo" and ERC Consolidator award "SHAPE" (ERC-CoG-2015- 682859)

54.26, 3:45 pm **Chocolate, chrome, or cloth? The appearance of specular highlights determines perceived material category**
Alexandra C Schmid[1](alexandra.schmid@psychol.uni-giessen.de), Katja Doerschner[1,2]; [1]Justus Liebig University Giessen, [2]Bilkent University

The past decade has seen a surge in studies investigating how we perceive material properties of objects, with the majority focusing on the perception of gloss. This research has shown that how glossy an object or surface looks is determined by the appearance of specular highlights (their shape, contrast, sharpness, size, alignment), which in turn is determined by complex interactions between physical factors (surface properties, shape, illumination), and viewpoint. Although previous research acknowledges that highlight properties and appearance are multidimensional, very few studies have explored the dimensionality of gloss perception, that is, that a change in physical properties or appearance of the surface may not just affect the level of gloss but the quality/material of the surface altogether. We addressed this directly by investigating how properties of specular highlights affect perceived material category. We rendered complex glossy objects under natural illumination fields, manipulating five gloss parameters (specular strength, roughness, anisotropy, anisotropic rotation, specular tint), and two diffuse shading parameters (saturation, lightness). Observers judged what material each object was made from, with no restrictions. After processing for duplicates and similar terminology, over 200 words were used to describe the materials. Cluster analysis revealed that the stimuli fell into strikingly distinct perceptual categories such as plastic, glazed porcelain/ceramic, metals (e.g. gold, bronze, chrome), fabric (e.g. velvet, silk), wax/soap, and even chocolate, yet there was no simple mapping of rendering parameters onto categories. We implemented an image-based model of gloss appearance that predicted perceived material category and generalised to different objects and lighting conditions. Our results demonstrate that the appearance of specular highlights yield a much richer experience of glossy objects than suggested by previous studies. These findings are in line with the idea that the perception and neural processing of qualities like glossiness should be considered in the context of material recognition.

Acknowledgement: This research was supported by a Sofja Kovalevskaja Award from the Alexander von Humboldt Foundation, sponsored by the German Federal Ministry for Education and Research

54.27, 4:00 pm **Investigating the influence of surface properties on reaching movements**
Martin Giesel[1](martin.giesel@abdn.ac.uk), Karina Kangur[1], Julie M. Harris[2], Constanze Hesse[1]; [1]School of Psychology, University of Aberdeen, [2]School of Psychology and Neuroscience, University of St Andrews

We used an obstacle-avoidance paradigm to investigate how surface properties of obstacles affect hand movements in a reaching task. The obstacles' surfaces were made from five different materials (wood, sandpaper, sugar granules, rock salt, Astro Turf). All obstacles had the same shape, size and colour, but their surface textures differed in granularity, density and height. An auditory cue signalled participants to reach in-between two obstacles either to the upper or lower half of a target area that was located 40 cm away from the start position of the movement. Obstacles were placed midway between start position and target area to the left and right of the movement path. In each trial, one of the obstacles was always the smoothest obstacle (baseline obstacle, i.e., wood) while the other was one of the five obstacle types. Obstacle types, obstacle positions, and cued end location were presented interleaved and in pseudo-randomised order. Vision between trials was occluded using shutter glasses and hand movements were recorded using an electromagnetic motion tracking system. After the reaching task, participants rated the roughness, smoothness and pleasantness-to-touch of each obstacle. We analysed the differences between movement trajectories depending on the position of the baseline obstacle (left or right) using three parameters: the area under the trajectory, the lateral position of the hand between the obstacles and at the end of the movement. All parameters were computed relative to the baseline condition, in which the baseline obstacle was presented on both sides. We found a significant position shift for all three parameters indicating that participants moved their hands closer to the baseline obstacle (i.e., away from other obstacles). The strength of this shift was positively correlated with the roughness ratings of the obstacles. These findings provide proof-of-concept for the use of behavioural measures of material properties.

Acknowledgement: Supported by Leverhulme grant RPG-2017-232 to CH & JH

Eye Movements: Models, neural mechanisms

Tuesday, May 21, 5:15 - 7:15 pm, Talk Room 1

Moderator: Jude Mitchell

55.11, 5:15 pm **Saccade adaptation alters smooth pursuit velocity of small, but not large objects**
Scott Watamaniuk[1,2](scott.watamaniuk@wright.edu), Jeremy B Badler[2], Stephen J Heinen[2]; [1]Dept of Psychology, Wright State University, [2]The Smith-Kettlewell Eye Research Institute

Spot pursuit is thought to require attention, yet pursuit of larger targets does not. Interestingly, catch-up saccades are also more frequent during spot pursuit. Thus it is possible that the saccadic system, which itself is attentive, might confer the attentive properties to pursuit, while small-object pursuit itself is also inattentive. Alternatively, spot pursuit may require attention because the saccadic system is contributing to pursuit velocity in addition to triggering catch-up saccades. Here we test this by adapting the saccadic system and seeing if the adaptation transfers to pursuit. During adaptation, observers fixated a central spot and generated saccades to a flashed 10° eccentric target. While the saccade was in progress, the target was displaced 3° towards the fixation point. An EyeLink 1000 recorded eye movements at 1000 Hz, and provided gaze contingent target displacement. Saccade adaptation proceeded for 100 trials, following which saccade amplitude was significantly shortened. Following adaptation, observers pursued a spot stimulus (0.5°) or a large concentric ring of 8 spots (6° diameter) that moved from the center of the screen at a constant velocity of 10°/sec. We found that steady-state eye velocity in the adapted saccade direction was significantly reduced following saccade adaptation but only for spot pursuit – eye velocity during pursuit of the large target was not affected. The results are evidence that saccadic adaptation transfers to spot but not large object pursuit, and suggest that sub-saccadic signals contribute to smooth eye velocity during pursuit of a small spot.

55.12, 5:30 pm **Pupil size, locus coeruleus, emotional intensity, and eye movements during unconstrained movie viewing**
Sebastiaan Mathôt[1](s.mathot@cogsci.nl), Adina Wagner[2], Michael Hanke[2]; [1]Department of Psychology, University of Groningen, The Netherlands, [2]Institute of Psychology, Otto-von-Guericke-Universität Magdeburg, Germany

The adaptive-gain theory states that high Locus Coeruleus (LC) activity is associated with exploration (behavior characterized by distractibility and frequent task switching), whereas intermediate LC activity is associated with exploitation (focus on a single task). Because studies have reported a correlation between pupil size and LC activity, pupil size is often used as a convenient proxy for LC activity when testing the theory's predictions. Here we take a data-driven approach to explore the relationships between LC activity, pupil size, emotional intensity (of movie scenes), and frequency of eye movements in an unconstrained setting. We analyzed data of participants watching the movie Forrest Gump during combined fMRI recording and eye tracking. We analyzed correlations in different frequency bands, in order to isolate whether correlations exist primarily in rapid (seconds) or slow (minutes) fluctuations. We found a positive correlation between LC activity and pupil size, confirming previous reports. But this correlation was limited to high frequencies; notably, the very slow decrease in pupil size over time, which is often seen in experiments and presumably reflects increased drowsiness, was not accompanied by a decrease in LC activity. We further found that the emotional intensity of the movie scenes affects pupil size, but not LC activity. Finally, we found that pupil size, but not LC activity, correlates with frequency of eye movements; specifically, large pupils were associated with fewer eye movements, suggesting exploitation-like, rather than exploration-like, behavior. Taken together, our results suggest that, in an unconstrained setting, there is a correlation between pupil size and LC activity, but that neither pupil size nor LC activity predicts eye-movement behavior in a way that is consistent with the adaptive-gain theory.

Acknowledgement: Netherlands Organization for Scientific Research

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55.13, 5:45 pm **Selective peri-saccadic suppression of low spatial frequencies is a visual phenomenon**

Matthias Ph Baumann[1,2](matthias-philipp.baumann@student.uni-tuebingen.de), Saad Idrees[1], Thomas Münch[1], Ziad Hafed[1,2]; [1]Werner Reichardt Centre for Integrative Neuroscience, Tübingen University, Tübingen, Germany, [2]Hertie Institute for Clinical Brain Research, Tübingen University, Tübingen, Germany

Visual sensitivity is strongly impaired around saccades, a phenomenon known as saccadic suppression. This robust phenomenon does not constitute a mere global suppression, but instead shows selectivity for low spatial frequencies, which has been used to suggest selective motor-driven suppression of magnocellular visual pathways (e.g. Burr et al., 1994). However, neural studies failed to reveal selective magnocellular pathway suppression. Moreover, Idrees et al. (VSS, 2018) recently described a surprisingly far-reaching contribution of visual image processing mechanisms to saccadic suppression, without the need to invoke explicit motor-based suppression commands. Here we show that this is also true for selective suppression of low spatial frequencies. Six participants localized a brief (~12 ms) vertical Gabor grating flashed at one of four locations (4-AFC paradigm). The gratings had one of 6 spatial frequencies (0.41-6.83 cycles/deg), and they were presented over a uniform gray background in a dark room. At a radius >10 deg from display center, the gray background was replaced by either a coarse or fine band-passed random texture (as in Idrees et al., VSS, 2018), in order to simulate a "virtual monitor" edge. In one condition, gratings were presented peri-saccadically with saccades directed towards display center; in another, gratings appeared during fixation after the "virtual monitor" and surrounding texture were translated in a saccade-like manner, again towards display center. With a coarse peripheral context, selective suppression of low spatial frequencies occurred with or without saccades, therefore due to saccade-like image translations. Even more surprisingly, when the surround was fine, both real and "simulated" saccades exhibited suppression that was not selective for spatial frequency, violating (Burr et al., 1994). Thus, selective or unselective suppression happens with or without saccades, as a function of saccade-induced image translations and peripheral visual contexts. Our results support the view that saccadic suppression is a primarily visual phenomenon.

55.14, 6:00 pm **Visual space generated by saccade motor plans**

Eckart Zimmermann[1](eckartzi@gmail.com), Marta Ghio[1], Giulio Pergola[2], Benno Koch[3], Michael Schwarz[3], Christian Bellebaum[1]; [1]Institute for Experimental Psychology, Heinrich Heine University Düsseldorf, Düsseldorf, Germany, [2]Department of Basic Medical Sciences, Neuroscience and Sense Organs, University of Bari Aldo Moro, Bari, Italy, [3]Department of Neurology, Klinikum Dortmund, Dortmund, Germany,

How the perception of space is generated from the multiple maps in the brain is still an unsolved mystery in neuroscience. We investigated whether space perception in general is constituted by information contained in efference copy signals. A neural pathway ascending from the superior colliculus through the medio-dorsal (MD) nucleus of thalamus to the frontal eye field has been identified in monkeys to convey efference copy information about the metrics of upcoming eye movements. Information sent through this pathway stabilizes vision across saccades. We wondered whether this motor plan information might also shape spatial perception even when no saccades are performed. We studied patients with lesions in different parts of the thalamus. Patients performed a double-step task testing motor updating, a trans-saccadic localization task testing visual updating and a localization task during fixation testing a general role of motor signals for visual space in the absence of eye movements. Single patients with medial and lateral thalamic lesions (affecting the MD and VL nuclei) showed deficits in the double-step task, reflecting insufficient transfer of efference copy. However, a patient with an MD lesions was impaired in trans-saccadic localization, suggesting that different types of efference copies contribute to motor and visual updating. Interestingly, the MD patient also mislocalized objects during fixation. The size and the spatial location of the deficit was consistent with the under-representation of the saccade vectors in first two experiments. These data suggest that motor plans are not consulted only as the final output stage for generating actions but play a primary role in constituting the perceptual experience that leads to the generation of behavior.

Acknowledgement: ERC grant moreSense (757184)

55.15, 6:15 pm **Consideration of eye movements reconciles behavioral and neuronal measures of contrast sensitivity**

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The contrast sensitivity function (CSF), how sensitivity varies with the frequency of the stimulus, is a fundamental assessment of visual function. Elucidation of its mechanisms is instrumental to understand how the visual system works in both health and disease. Under photopic conditions, the CSF measured with stationary gratings exhibits a well-known band-pass shape that typically peaks around 3-5 cycles and gradually transitions to a low-pass shape when gratings are temporally modulated. It is generally assumed that the CSF is largely shaped by the response characteristics of retinal neurons. However, the sensitivities of these neurons, as measured in experiments with immobilized eyes, considerably deviate from the CSF, especially at low spatial frequencies, where they exhibit much stronger responses than expected from the CSF. Under natural viewing conditions, humans incessantly move their eyes, even when looking at a fixed point. These fixational eye movements transform the visual scene into a spatiotemporal flow of luminance on the retina and are not present in neurophysiological characterizations of cell responses, when the eyes are normally immobilized. We used neuronal models to quantitatively examine the impact of eye drift on neural activity and compare the responses of retinal ganglion cells to the CSF of primates. We show that consideration of the retinal consequences of incessant eye drifts, coupled with the known spatiotemporal response characteristics of retinal ganglion cells, accounts for the band-pass shape of the CSF as well as for its transition to low-pass with temporally modulated gratings. Consideration of residual retinal motion with imperfect retinal stabilization also provides an explanation for the puzzling finding that visual sensitivity shifts to higher spatial frequencies under retinal stabilization. These findings make specific predictions both at the behavioral and neuronal levels and suggest a fundamental integration between perception and action beginning at the retina.

Acknowledgement: Michele Rucci: NIH EY018363 - NSF BCS-1457238, 1420212. Jonathan D. Victor: NIH EY07977

55.16, 6:30 pm **Meaning maps and deep neural networks are insensitive to meaning when predicting human fixations**

Marek A. Pedziwiatr[1](pedziwiatrma@cardiff.ac.uk), Thomas S.A. Wallis[2,3], Matthias Kümmerer[2], Christoph Teufel[1]; [1]Cardiff University Brain Research Imaging Centre, School of Psychology, Cardiff University, [2]Werner Reichardt Centre for Integrative Neuroscience, University of Tübingen, [3]Wilhelm-Schickard Institute for Computer Science (Informatik), University of Tübingen

An important aspect of vision – control of eye-movements in scene viewing – is intensely debated, with many studies suggesting that people look at scene regions rich in meaning. A recent proposal suggests that the distribution of meaning can be quantified by 'Meaning Maps' (MMs). To create MMs, images are segmented into partially overlapping patches, which are rated for their meaningfulness by multiple observers. These ratings are combined into a smooth distribution over the image. If MMs capture the distribution of meaning, and if the deployment of eye-movements in humans is guided by meaning, two predictions arise: first, MMs should be better predictors of gaze position than saliency models, which use image features rather than meaning to predict fixations; second, differences in eye movements that result from changes in meaning should be reflected in equivalent differences in MMs. Here, we tested these predictions. Results show that MMs performed better than the simplest saliency model (GBVS), were similar to a more advanced model (AWS), and were outperformed by DeepGaze II – a model using features from a deep neural network. These data suggest that, similar to saliency models, MMs might not measure meaning but index the distribution of features. Using the SCEGRAM database, we tested this notion directly by comparing scenes containing consistent object-context relationships with identical images, in which one object was contextually inconsistent, thus changing its meaning (e.g., a kitchen with a mug swapped for a toilet roll). Replicating previous studies, regions containing inconsistencies attracted more fixations from observers than the same regions in consistent scenes. Crucially, however, MMs of the modified scenes did not attribute

more 'meaning' to these regions. DeepGaze II exhibited the same insensitivity to meaning. Both methods are thus unable to capture changes in the deployment of eye-movements induced by changes of an image's meaning.

55.17, 6:45 pm **Multiplexed allocentric and egocentric signals in the primate frontal eye fields during a cue-conflict saccade task** J Douglas Crawford[1,2,3,4](jdc@yorku.ca), Vishal Bharmauria[1,2], Amir Sajad[1,4,5], Xiaogang Yan[1,2], Hongying Wang[1,2]; [1]Centre for Vision research, York University, Toronto, Canada., [2]Vision: Science to Applications Program, York University, Toronto, Canada, [3]Department of Psychology, York University, Toronto, Canada, [4]Department of Biology, York University, Toronto, Canada, [5]Vanderbilt Vision Research Centre, Vanderbilt University, USA

Allocentric (landmark-centered) and egocentric spatial cues are optimally integrated for visuomotor behavior (Byrne et al. J. Neurophysiol. 2010; Fiehler et al. Front. Hum. Neurosci. 2014), but the neural underpinnings of such integration are unknown. We hypothesized that this occurs at an early cortical level, such that frontal cortex output would code an integrated, multiplexed motor command. To test this, we recorded 173 frontal eye field (FEF) neurons in two Rhesus macaques trained on a cue-conflict saccade task, where a visual landmark shifted during the memory interval between seeing and acquiring a target. Visual and motor response fields preferentially coded target position (T) and future gaze (G) in eye coordinates, respectively (Sajad et al. Cereb. Cortex 2015), but gaze shifted 37 % toward a virtual target (T') fixed to the landmark (Li et al. J. Vis. 2010). To test how the FEF coded this shift, we determined the best fits of spatially tuned response fields along an allocentric spatial continuum (T-T') and plotted these as a function of their best fits along an egocentric (T-G) continuum. A slope/bias of zero (found in control visual responses) would suggest no allocentric influence, an upward bias would indicate uncorrelated multiplexing, and a positive slope would indicate integrated multiplexing. The population of neurons with motor responses ($n = 116$) had a significant slope (0.35 ± 0.08, $R2 = 0.13$) and no significant bias. Segregated visuomotor cells and motor-only cells had significant slopes (0.34 ± 0.13, $R2 = 0.1$; 0.45 ± 0.13, $R2 = 0.22$ respectively), and significantly opposed biases (0.13 ± 0.12 and -0.18 ± 0.13 respectively). These results suggest that allocentric and egocentric signals balance and converge at the level of frontal cortex output, such that the FEF motor burst provides an integrated estimate of optimal behavior to the subcortical structures for gaze control.

Acknowledgement: Canadian Institutes for Health Research, Canada Research Chair Program, Canada First Research Excellence Fund

55.18, 7:00 pm **V1 neurons tuned for high spatial frequencies show pre-saccadic enhancement** Jacob L Yates[1,2](jyates7@ur.rochester.edu), Shanna H Coop[1,2], Jude F Mitchell[1,2]; [1]Brain and Cognitive Science, University of Rochester, [2]Center for Visual Science, University of Rochester

During natural vision, visual input arrives to the brain in the context of ongoing oculomotor behavior. Saccadic eye movements, in particular, occur 3-5 times a second and have profound perceptual consequences, not limited to saccadic suppression and spatiotemporal warping, but also attention-like enhancements preceding eye movements. While previous studies have identified signatures of saccadic suppression in early visual cortex, none have identified pre-saccadic enhancements. Here, we studied the representation of visual information in V1 immediately preceding and following saccadic eye movements. Unlike previous studies that used repetitive planned saccades, we used a full-field foraging paradigm that enabled very high saccade counts under more realistic viewing conditions. Awake, head-fixed marmosets freely viewed full-field sinewave gratings to identify small targets embedded in the scene while we recorded from populations of V1 neurons using linear electrode arrays. The spatial frequency and orientation of the full-field gratings were updated randomly on each frame to support subspace reverse correlation (Ringach et al., 1997). Saccades produced substantial pre- and post-saccadic firing rate modulations in almost all neurons. Post-saccadic modulations followed a biphasic form with suppressive firing rate changes preceding enhancements whereas pre-saccadic modulations were largely explained by gradual decreases in firing rate starting 100ms before saccade onset. Using a linear-nonlinear-Poisson model fit to spiking data, we decomposed these firing rate modulations into a stimulus-driven linear component and a monotonic nonlinearity that maps the output of the linear stage into spike rate. Although firing rates decreased preceding saccades, the slope of the spiking nonlinearity became steeper, enhancing selectivity for preferred stimuli immediately preceding the saccade onset. This enhancement occurred most frequently in neurons with high preferred spatial frequencies in agreement with the human psychophysical phenomena. These results show that pre-saccadic activity is enhanced for V1 neurons carrying higher spatial frequency information during free-viewing.

Acknowledgement: NIH U01-NS094330, U of R SPIN grant to JFM T32EY007125 to SHC JLY is an Open Philanthropy Fellow of the Life Sciences Research Foundation

Visual Search: Space, time

Tuesday, May 21, 5:15 - 7:15 pm, Talk Room 2

Moderator: Anna Kosovicheva

55.21, 5:15 pm **Visual search for categorical targets is biased toward recently viewed exemplars** Brett Bahle[1](brett-bahle@uiowa.edu), Andrew Hollingworth[1]; [1]University of Iowa

The guidance of attention toward task-relevant objects during visual search often relies on a target template representation. In addition, many searches are categorical, where the goal of search is to find any item belonging to a category (Yang & Zelinsky, 2009). In the present study, we investigated the extent to which these categorical template representations are biased toward recently viewed category exemplars. Participants first completed an exposure task in which they viewed pictures of objects from common categories and classified them as natural or artifact. Critically, each exemplar from a given category always appeared in one color (e.g., all cars were blue). After completing the categorization task, participants performed four blocks of visual search. They saw a label specifying the target category and searched for the target picture within an array of objects. The target picture matched (e.g., a different blue car) or mismatched (e.g., a red car) the color of the previously viewed exemplars. Searches were more efficient for matching compared with mismatching color exemplars, and this effect reliably diminished across search blocks, as participants accrued more trials of search with exemplars of both colors. Moreover, eye-tracking results demonstrated that this effect was due to more efficient guidance to the target, as evidenced by faster first fixations on the target object when it matched compared with when it mismatched the previously viewed exemplar color. These results suggest that well-established category representations guiding visual search are constantly updated to reflect recent visual regularities within a category. The relationship between these findings and general theories of category structure will be discussed.

55.22, 5:30 pm **Reliance on central vs. peripheral vision for visual search in younger and older adults** Anne-Sophie Laurin[1](anne-sophie.laurin@umontreal.ca), Julie Ouerfelli-Éthier[2], Laure Pisella[3], Aarlenne Zein Khan[2]; [1]Department of Psychology, University of Montreal, [2]School of Optomerty, University of Montreal, [3]ImpAct, INSERM UM1028, CNRS UMR 5292, Bron, France

It has been suggested that older adults rely more on their central vision at the expense of peripheral vision, compared to younger adults. To test this, we examined how older and younger participants performed two visual search tasks: pop-out and serial, in the presence of artificial central scotomata. Pop-out search relies on processing of the entire visual scene (i.e. global processing) whereas serial search requires processing of each feature serially (i.e. local processing). 13 healthy younger ($M = 21.8$, $SD = 1.5$) and 15 older adults ($M = 69.1$ years, $SD = 7.3$) performed a pop-out and a serial version of a visual search task in the presence of different sized gaze-contingent artificial central scotomata (no scotoma, 3° diameter, 5° and 7°). Participants were asked to indicate as quickly as possible whether a target was present or not among distractors whose number varied (16, 32 or 64 objects). We found evidence for a greater decline in peripheral processing in older adults compared to younger in pop-out but not in serial search. For the pop-out condition with no scotoma, we found that the further the target in the periphery, the longer the search time, and that this increase was proportionally greater for older adults compared to younger adults. Further, increases in scotoma size were associated with a greater increase in reaction times for older adults compared to younger participants. For the serial condition, both groups showed similar increases in reaction times with target distance from center and scotoma size. We surmise that this may be due to task difficulty in serial search; central vision is necessary for both groups. In conclusion, these findings suggest that, in global processing, older adults distribute more resources towards central vision compared to younger adults.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC), Fonds de recherche du Québec, Nature et technologies (FRQNT)

Tuesday PM

See page 3 for Abstract Numbering System

55.23, 5:45 pm **A novel learning-based paradigm to investigate the visual-cognitive bases of lung nodule detection**Frank Tong[1,2](frank.tong@vanderbilt.edu), Malerie G. McDowell[1], William R. Winter[3], Edwin F. Donnelly[3]; [1]Psychology Department, Vanderbilt University, [2]Vanderbilt Vision Research Center, [3]Department of Radiology, Vanderbilt University Medical Center

Even expert radiologists will sometimes fail to detect the presence of a pulmonary nodule in a chest X-ray image, with estimated rates of missed detection of 20-30%. The challenging nature of this real-world search task lies not only in the visual contrast or the size of the nodule, but also in the heterogeneity of nodule appearance and the variability of the local anatomical background. For this study, we developed image processing software to create hundreds of visually realistic simulated nodules to investigate the visual-cognitive bases of nodule detection and the impact of extended training. First, we tested radiologist participants (n=10) with both real and computer-simulated nodules at a challenging nodule localization task. Performance accuracy was significantly better for real nodules than for the subtle simulated nodules that were created (70.5% vs. 59.0% accuracy, $p < 0.005$). Of greater interest, radiologists performed no greater than chance level at discriminating whether nodules were real or computer-simulated (mean accuracy, 52.9%). Next, we evaluated the impact of training naive undergraduate participants at a localization task involving simulated nodules. After 3-4 training sessions with 600 simulated cases, we observed significant improvements in performance for both simulated nodules (30.3% accuracy pre-test, 78.2% accuracy post-test, $p < 0.00001$) and real nodules (37.5% pre-test, 62.5% accuracy post-test, $p < 0.0005$.). In a final study, we found that undergraduates who had extended training with either light or dark polarity nodules showed much better subsequent performance at localizing nodules of the corresponding trained polarity. Our results demonstrate that marked improvements in nodule detection can be achieved by implementing a training regimen with numerous realistic examples; moreover, such training leads to learning of a polarity-specific perceptual template of nodule appearance. These findings suggest promising avenues for the development of a learning-based paradigm to facilitate the training of future radiologists.

Acknowledgement: R01EY029278

55.24, 6:00 pm **Accurately Quantifying the Subsequent Search Miss Effect in Multiple-Target Visual Search** Stephen Adamo[1](sadamo13@gmail.com), Patrick H Cox[2], Dwight J Kravitz[2], Stephen R Mitroff[2]; [1]University of Central Florida, [2]The George Washington University

Subsequent search miss (SSM) errors, wherein observers are prone to miss a second target if a first was already detected, are well documented in academic radiology and cognitive psychology. This phenomenon (originally called satisfaction of search) has critical implications as radiologists are more likely to miss an abnormality if a prior abnormality was detected. Cognitive psychologists have replicated the SSM effect with simplified and randomly-generated search displays in attempts to inform its underlying cause(s). Within these experiments, a SSM effect is typically taken as the difference between the hit rate for a second target on dual-target trials and the hit rate on single-target trials. However, this approach may artifactually inflate estimates of SSM errors. In dual-target displays, the easier target is likely to be found first, implying that the second target is more difficult. Consequently, second-target data are more likely to come from the harder portion of the distribution of trials, whereas single-target data include the full range of target difficulty. The current study demonstrates that this participant-driven circularity inflates empirical estimates of the SSM effect, but nowhere near enough to explain the entire effect. Further, the circularity can be avoided with matched single and dual-target displays, so that whichever target is detected second, a matched single-target trial is available for comparison. This "matched-display" design, already widely used in radiology, equates many confounds that make a target harder to find (e.g., clutter). While previous SSM studies in cognitive psychology are still informative, they likely overestimated the absolute SSM effect. This study argues for a course correction to unbiased methods and designs, which will ultimately improve the sensitivity of SSM experiments by removing an artifactual inflation. Moreover, it is important to consider other psychology paradigms that might include similar participant-driven circularities as this issue is not isolated to SSM studies.

Acknowledgement: Postdoctoral Ford Foundation Fellowship

55.25, 6:15 pm **Right time, right place: implicit learning of target onsets in a visual search task** Nir Shalev[1,2](nir.shalev@wolfson.ox.ac.uk), Sage E.P. Boettcher[1,2], Anna C. Nobre[1,2]; [1]Department of Experimental Psychology, University of Oxford, United Kingdom, [2]Oxford Centre for Human Brain Activity, Department of Psychiatry, Wellcome Centre for Integrative Neuroimaging, University of Oxford

The brain constitutes a predictive system that is constantly learning about regularities in the environment and utilizing these regularities to anticipate events. Studies have shown that expectations improve performance by altering perception and allowing motor preparation. However, behaviour also benefits from temporal predictions by guiding spatial attention to specific locations at specific times. For example, we can effectively divert our spatial attention from the road while waiting for a traffic light to turn green; predictions in time allow us to estimate when is a good time to re-engage. We investigated the guidance of spatial attention based on the online formation of temporal predictions. To this end, we designed a novel variation of a visual search task. On each trial (lasting approximately 10 seconds) individuals searched for eight targets among distractors in a dynamic display in which the items faded in and out at different locations and times. The screen was split into four distinct quadrants. On each trial, four of the eight targets were spatially and temporally predictable in that they always appeared in the same quadrant at the same time (e.g. predictive target 1 always appeared in quadrant 3 after 2 seconds; Figure#1a). Crucially, the other four targets were distributed randomly in time and space, making it impossible to use sequential information to find targets. We showed that subjects found predictable targets more often and faster than random targets (Figure#1b). Additionally, we showed a large drop off in the hit rate of random targets which immediately follow predictable targets, suggesting that observers inhibit predicted spatial locations in the time following the prediction (Figure#1c). We support our behavioural data with eye-tracking, to identify how temporal predictions modulate search trajectories. These results provide important insight into the interactions between spatial and temporal predictions in a natural task such as visual search.

Acknowledgement: Wellcome Trust Senior Investigator Award (ACN) 104571/Z/14/Z, and the NIHR Oxford Health Biomedical Research Centre. The Wellcome Centre for Integrative Neuroimaging is supported by core funding from the Wellcome Trust (203139/Z/16/Z).

55.26, 6:30 pm **Pick up your bricks! Interactive visual search in a familiar real-world environment** Marian Sauter[1](sauter.marian@gmail.com), Wolfgang Mack[1]; [1]Institute of Psychology, General Psychology, Bundeswehr University Munich

Research on visual search is overwhelmingly limited to participants sitting in front of a computer screen pressing buttons. But how well do these effects transfer to real-life situations? In this series of experiments, we gradually investigated the feasibility of using an interactive environment to learn about how people search. We used a real-world search task that almost everybody has been familiar with since childhood: Finding specific LEGO bricks among many distractors. In the first experiments, the bricks were mounted on gray plates to mirror classic computerized visual search tasks. A specific target brick was contained on each plate multiple times. As expected, the results indicate that participants performed worse when they had to search for a feature conjunction and when the target was less discriminable from the distractors. In the next experiments, the to-be-picked-up target bricks (and up to 200 distractors) were poured onto trays. The results show that the size of the target brick was the major indicator for search difficulty. Target shape and color had only limited influence on performance. In the final set of experiments, participants were instructed to assemble four similar objects out of multiple different bricks. This included a search for multiple different target bricks simultaneously. First results indicate that participants first looked for multiple target bricks at once and picked up all they could find. Then, they specifically looked for missing pieces to assembled one object after the other. Overall, this setup proved to be valuable to learn about participants' every-day search strategies. We are convinced that using the LEGO environment will prove to be an important method in future visual search research as it offers the applicability and generalizability of familiar real-world environments while also providing a standardized search space.

55.27, 6:45 pm **Automatic pre-saccadic selection of stimuli perceptually grouped with saccade targets** Olga Shurygina[1](olghenitta@gmail.com), Arezoo Pooresmaeili[2], Martin Rolfs[4,5]; [1]Berlin School of Mind and Brain, Humboldt-Universität zu Berlin, Germany, [2]Perception and Cognition Group European Neuroscience Institute, Göttingen, Germany, [3]Department of Psychology, Humboldt-Universität zu Berlin, Germany, [4]Bernstein Center for Computational Neuroscience Berlin, Germany

Before the onset of a saccadic eye movement, visual performance increases at the saccade target. This pre-saccadic attention shift is obligatory and spatially confined. In natural vision, movement targets are often part of extended objects. Electrophysiological studies revealed an automatic spread of attention to objects grouped with an attended stimulus by Gestalt criteria (Wannig et al., 2011). Here, we assessed if this automatic spread of attention is reflected in enhanced visual sensitivity to perceptually-grouped stimuli before saccadic eye movements. We presented four gratings at the vertices of an imaginary diamond that was itself positioned in one of four locations of the screen. In each trial, the two stimuli closest to the central fixation point were potential saccade targets. A central cue indicated the current saccade target and provided the go-signal for the eye movement. Shortly after cue onset (25–225 ms), we probed sensitivity at one of the four stimuli by briefly changing the orientation of the grating at that location. Observers were required to report the direction of orientation change irrespective of its location. Performance in this task served as a direct measurement of attentional deployment. Crucially, in each trial, one of the two distant stimuli was grouped with the saccade target as they shared the same color and pattern of Brownian motion about their location (grouping by similarity and common fate). We observed a substantive pre-saccadic attention shift: performance was highest at the saccade target and steadily increased towards movement onset. Moreover, performance at the distant locations was better if that location was perceptually grouped with the saccade target. The time course for the involuntary selection of distant, grouped locations did not follow the pre-saccadic attention shift but remained constant across relative to movement onset. We conclude that grouping-based attentional selection occurs involuntarily and independently from movement execution.

55.28, 7:00 pm **Memory for distractors during hybrid search: The effect of target template specificity** Stephanie M Saltzmann[1](ssaltz2@lsu.edu), Melissa R Beck[1]; [1]Louisiana State University

Previous research has demonstrated that individuals are capable of remembering some identity information about task irrelevant distractors during visual search, although performance is not at ceiling even when the distractor was fixated just before the memory test. Memory for distractors may be improved in hybrid search because, individuals look at distractors longer when the target memory set size is large. Additionally, memory for distractors may be improved when they are semantically related to the target because items that are semantically related to target may also be processed more. Participants in Experiment 1 encoded 1 or 32 target items for 3s each, followed by a search task. On a subset of trials, search ceased after the 4th, 5th, or 6th fixation and was replaced with a two-alternative forced choice (2AFC) test for the identity of distractors that had been previously fixated during the previous search array. In Experiment 2 participants encoded either 6 target items from distinct categories or 30 items with 5 items from 6 categories (i.e., 5 dogs, 5 bikes, etc.) and the search arrays could include distractors that were from the same or different categories as the target items. Eye movement data in Experiment 1 revealed evidence for more processing of distractors (i.e., longer dwell time, more revisits) with a higher target memory set size but explicit memory for distractors did not differ between target memory set sizes. In Experiment 2, there was evidence for more processing of distractors with a higher target memory set size and for semantically related arrays. However, explicit memory for distractors was best when target memory set size was high and the arrays were semantically distinct. Overall these results suggest that hybrid search can improve memory for distractors if the distractors and targets are not semantically related.

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Faces: Models, neural mechanisms

Tuesday, May 21, 2:45 - 6:45 pm, Banyan Breezeway

56.301 **Intersubject multivariate connectivity reveals optimal denoising strategies for visual category-specific regions**
Yichen Li[1,2,3](yl3506@nyu.edu), Rebecca Saxe[3], Stefano Anzellotti[4]; [1]Courant Institute of Mathematical Sciences, College of Arts and Science, New York University, [2]Department of Computer Science, College of Arts and Science, New York University, [3]Department of Brain and Cognitive Sciences, School of Science, Massachusetts Institute of Technology, [4]Department of Psychology, Morrissey College of Arts and Sciences, Boston College

Recognizing face and scene images recruits distinct networks of brain regions. Investigating how information is processed and transformed from region to region within these networks is a critical challenge for visual neuroscience. Recent work has introduced techniques that move towards this direction by studying the multivariate statistical dependence between patterns of response (Coutanche and Thompson-Schill 2013, Anzellotti et al. 2017, Anzellotti and Coutanche 2018). As researchers develop increasingly sophisticated tools to model statistical dependence between the fMRI signal there is a risk that models may increasingly capture artifactual relationships between regions. Choosing optimal denoising methods is a crucial step to maximize the accuracy of connectivity models. A common approach to compare denoising methods uses simulated fMRI data, but it is unknown to what extent conclusions drawn using simulated data generalize to real data. To overcome this limitation, we introduce intersubject multivariate pattern dependence (iMVPD) which computes the statistical dependence between a brain region in one participant, and another brain region in a different participant. IMVPD is multivariate, it trains and tests models on independent partitions of the real fMRI data, and it generates predictions that are both between subjects and between regions. Since whole-brain sources of noise are more strongly correlated within subject than between, we can use the difference between standard MVPD and iMVPD as a 'discrepancy metric' to evaluate denoising techniques, where more effective techniques should yield smaller differences. As a sanity check, the 'discrepancy metric' is the greatest with no denoising. Furthermore, a combination of CompCorr and removal of the global signal optimizes denoising in face- and scene-selective regions (among all denoising options tested on selected regions). In future work, iMVPD can be used for applications like studying individual differences and analyzing types of data where only one region is measured in each participant (i.e. electrophysiology).

56.302 **Connectivity at the origins of domain specificity: the case of the cortical face network**
Frederik S Kamps[1](fkamps@emory.edu), Cassandra L Hendrix[1], Patricia A Brennan[1], Daniel D Dilks[1]; [1]Department of Psychology, Emory University

It is well documented that the adult brain contains a mosaic of domain-specific networks (or sets of cortical regions). But how do these domain-specific networks emerge? One hypothesis is that the brain comes prewired with connections that ensure the development of particular domain-specific networks. Here we addressed this hypothesis by considering the test case of the cortical face processing network, a network of face-selective regions in ventral visual cortex that is perhaps the most extensively studied domain-specific network in adults. Using resting-state fMRI in the youngest human sample tested to date, we found that two cortical regions that will later develop face selectivity similar to adults – the "proto" occipital face area (OFA) and fusiform face area (FFA) – already show adult-like functional connectivity in as little as 24 days after birth. Importantly, while this connection may serve to ensure that these regions go on to develop similar functions later in life, it cannot explain why this network always develops selectivity for faces in particular, and not other domains (e.g., scenes). Addressing this question, one proposal is that the ultimate function of the network depends on inputs from regions earlier in the visual hierarchy. For example, given that neonates receive extensive experience with faces at the fovea, face selectivity may develop in regions that receive biased foveal input. Consistent with this proposal, we found that the proto cortical face network shows stronger connectivity with foveal than peripheral V1. Taken together, these results suggest that connectivity of regions that will later develop strong face selectivity in adulthood is strikingly early developing, if not innate, and likely scaffolds subsequent functional development of these regions, providing novel evidence for what may be a general mechanism of the origins of domain-specific networks.

Acknowledgement: The work was supported by Emory College, Emory University (DDD), National Eye Institute grant T32EY7092 (FSK), the National Science Foundation Graduate Research Fellowship Program grant DGE-1444932 (CLH), a NARSAD Young Investigator Award (CLH), and an Emory University HERCULES Center grant NIEHS P30 ES019776 (DDD).

56.303 **Electrophysiological responses to the own-face differ in magnitude and scalp topography compared to personally familiar faces and unfamiliar faces**
Alison C. Campbell[1](campbel1@uvic.ca), James W. Tanaka[1]; [1]University of Victoria, B.C., Canada

There is likely no face that is more familiar to us than our own. Yet, it is unclear whether own-face effects reflect this great familiarity or whether processing for the own-face is distinct from that of all other familiar faces. Using a Fast Periodic Visual Stimulation paradigm (Liu-Shuang et al., 2014), we compared electrophysiological responses spontaneously elicited by brief presentations of an unfamiliar identity, a familiar friend-face (e.g., roommate or good friend), and the participant's own face. Experimental stimuli consisted of natural photographs of participant and non-participant faces which varied in expression and viewpoint. EEG was recorded while participants viewed 70s image sequences with a presentation rate of 6 Hz (F1). In each condition, photos of the same unfamiliar identity, their friend's face, or the participant's own face were presented as every 7th image (F2 = 0.86 Hz) embedded within a stream of unfamiliar faces. At 6Hz, strong brain responses were observed over both central occipital and occipito-temporal sites corresponding to the rate of visual stimulation of identity change. Responses at the 0.86 Hz frequency displayed right occipito-temporal topographies, reflecting an identity-specific response to either the repeated unfamiliar identity, the friend-face, or the own-face. The magnitude of the response to the own-face exceeded that of the friend-face, and response to the friend-face exceeded that of the unfamiliar identity. Additionally, the scalp topography of the 0.86 Hz response in the own-face condition was distinguished by a strong fronto-central component. Our results suggest that response magnitude observed over occipito-temporal sites reflect a face familiarity for both own- and other-faces, whereas fronto-central responses reflect a process that is unique to own-face perception.

Acknowledgement: Natural Sciences and Engineering Research Council

56.304 **The spatiotemporal characteristics of brain signals in race perception: Insights from a magnetoencephalography study**
Sarina Hui-Lin Chien[1,2](sarinachien@mail.cmu.edu.tw), Chun-Man Chen[1], Chien-Hui Tancy Kao[3], En-Yun Hsiung[1]; [1]Graduate Institute of Biomedical Sciences, China Medical University, Taichung, Taiwan, [2]Graduate Institute of Neural & Cognitive Sciences, China Medical University, Taichung, Taiwan, [3]Woolcock Institute of Medical Research, University of Sydney, Sydney, Australia

Introduction. Race is a perceptual and social category. People automatically encode the race of indivduals and often categorize them by which. Many studies examined the behavioral effects of race on face recognition and categorization; very few investigated the neural underpinnings of race perception. Here we explore the spatiotemporal characteristics of brain signals responding to face race with magnetoencephalography (MEG). Methods. Thirteen Asian participants (mean age: 24.27 ± 2.13) joined the study. We used five morphing face stimuli, averaged between an Asian female and a Caucasian female (A0/C100, A25/C75, A50/C50, A75/C25, and A100/C0), to manipulate the strength of "race typicality." In the MEG (Elekta Neuromag TRIUX MEG), the participants passively viewed the stimuli in random order. They also completed a 2AFC race categorization task separately. The Principal Component Analysis (PCA) for time series between -50 and 450 ms, Time-Frequency Representations (TFRs), and the group differences of Event-Related Fields (ERFs) at M170 and M250 were performed. Results. Three major components (48% of total variance) captured the main differences between seeing Asian (A100/C0) and Caucasian (A0/C100) faces: PCA1 shows strong Caucasian preference at M170 (MEG1721, left temporal lobe); PCA2 shows strong Asian preference at M170 and strong Caucasian preference at M250 (MEG2641, right temporal lobe); PCA3 component shows strong Caucasian preference at both M170 and M250 (MEG1723, left temporal lobe). The TFRs between 150-200 ms revealed a stronger power for Asian faces in the left prefrontal lobe and Caucasian faces in the right temporal lobe. The ERFs of Asian and Caucasian faces were significantly different in prefrontal lobes and right temporal lobe at M170, and in prefrontal and temporal lobes at M250. Conclusion. Our analyses revealed that both M170 and M250 components are correlated with race categorization temporally, while bilateral temporal lobes and a portion of prefrontal lobe might be involved spatially.

Acknowledgement: Taiwanese Ministry of Science and Technology MOST 105-2420-H-039-001-MY3, to Dr. Sarina H.L. Chien

56.305 **ERP responses to race and implicit bias in children and adults** Eli Fennell[1](efennel3@fau.edu), Melissa Mildort[1], Elizabeth Soethe[1], Arushi Sachdeva[1], Gizelle Anzures[1,2,3]; [1]Department of Psychology, Florida Atlantic University, [2]Brain Institute, Florida Atlantic University, [3]Center for Complex Systems and Brain Sciences, Florida Atlantic University

Prior research has demonstrated own-race recognition and implicit racial biases in adults and children (Baron & Banaji, 2006; Lee, Anzures, Quinn, Pascalis, & Slater, 2011). Some studies have found differences in event-related potentials (ERPs), whereas other studies have found similar ERPs, to own- and other-race faces in adults (Wiese, 2013). Event-related potentials to face race and their relation to implicit biases in children have yet to be investigated. We therefore examined ERPs to own- and other-race faces in a simple viewing task, and their relation to implicit racial biases in children and adults.Caucasian young adults and 5- to 10-year-olds viewed Caucasian and East Asian faces, and houses while their electroencephalographic waveforms were recorded. To ensure participants were attentive, they were instructed to press a button whenever they viewed infrequently-occurring images on a gray rather than a white background. Trials requiring button presses were excluded from analyses. Prior to the EEG task, participants completed a computerized child-friendly implicit association task measuring racial biases. Preliminary results indicated larger P100 and N170 and delayed P100 responses in children compared to adults (p values < .001). Neither children nor adults showed modulation of the N170 in response to race, but adults showed larger P100 responses to other- compared to own-race faces ($p < .02$). There were also trends towards greater implicit own-race biases associated with longer N170 latencies to other- compared to own-race faces in the left hemisphere in adults ($p = .05$), and larger N170 responses to own- compared to other-race faces in the right hemisphere in children and adults ($p = .08$). Overall, preliminary results suggest that race is more salient to adults than children in a task that did not require explicit attention to race. However, trends suggest that implicit racial biases are associated with ERPs in children and adults.

Acknowledgement: NICHD

56.306 **Category-selective response to periodic face stimulations in natural-image sequence degrades nonlinearly with face omissions** Charles C.-F. Or[1](charlesor@ntu.edu.sg), Bruno Rossion[2]; [1]Division of Psychology, School of Social Sciences, Nanyang Technological University, Singapore, [2]Université de Lorraine, CNRS, CRAN, & CHRU-Nancy, Service de Neurologie, Nancy, France

Periodic presentations of variable natural face images in a rapid sequence of variable images of nonface objects elicit sensitive category-selective neural response captured in the human electroencephalogram (EEG) objectively at the periodic face frequency (Rossion et al., 2015, J Vis). Here, we test the resistance to degradation of the face-selective response by systematically varying the proportion of periodic face occurrence in the nonface object stream. High-density EEG was recorded from 16 observers during presentations of 54-s sequences of random object images sinusoidally contrast-modulated at F = 12 Hz (i.e., 12 images/s; 83-ms stimulus-onset asynchrony). Observers performed an orthogonal task by responding to random colour changes of a central fixation cross. There were 9 conditions. In the 100% condition, natural face images were embedded in the sequence always at a fixed interval of F/9 (1.33 Hz; every 9th image). In other conditions, a proportion of periodic face events was omitted, replaced by nonface object images. The percentages of periodic face events tested in the 9 separate conditions were 0% (i.e., no face presented), 12.5%, 25%, 37.5%, 50%, 62.5%, 75%, 87.5%, and 100%. Selective responses to faces recorded at 1.33 Hz and harmonics (2.67 Hz, etc.) mainly over occipito-temporal areas emerged significantly only at 25% of face images and followed a nonlinear power-function relationship (coefficient: 1.54, sum of scalp-averaged responses over significant harmonics) with the percentage of periodic face events. Removing half of the periodic face events reduced the response by 66%. The results reveal that a face-selective neural response results from complex, nonlinear comparisons between face exemplars and nonface objects.

Acknowledgement: This work was supported by Singapore MOE AcRF Tier 1 Grant 2018-T1-001-069 to C.O. & B.R., NTU HASS-SUG to C.O., and ERC Grant facessvep 284025 to B.R.

56.307 **An EEG-based investigation of the contribution of shape and surface properties in ensemble face processing** Marco A Sama[1](marco.sama@mail.utoronto.ca), Jonathan S Cant[1], Adrian Nestor[1]; [1]Department of Psychology, University of Toronto Scarborough

The visual system encodes summary face information (e.g., an average identity) from groups of simultaneously presented faces (i.e., an ensemble), which can be decoded and visualized from EEG data (Roberts et al., VSS 2018). However, the interplay between the processing of an ensemble and specific target faces within the set remains to be clarified. Moreover, the relative contribution of different facial attributes, such as shape and surface properties, to ensemble encoding remains to be explored. To investigate these issues, we conducted an EEG study in which face ensembles could vary in shape properties, surface properties, or both. Each ensemble contained six faces surrounding a seventh central face which was either the average identity of that ensemble (consistent face; CF), or the average identity of a different ensemble (inconsistent face; IF). Importantly, facial ensemble variability in shape and surface properties was matched across the two attributes. Pattern analysis of EEG data revealed, first, that the central face within an ensemble could be decoded regardless of whether it was embedded in CF or IF ensembles. Second, CF and IF ensembles could be discriminated above chance, which was driven primarily by surface information in the proximity of the N170 ERP component. Third, overall decoding was more successful for ensembles varying in surface properties or in both properties relative to shape properties only. These results resonate with the finding that texture and ensemble perception rely on shared neuroanatomical substrates (Cant & Xu, 2012). Further, they are consistent with the dominant role of surface information in single-face representations as revealed by neural and behavioral data (Nemrodov et al., 2019). More generally, these findings further our understanding of the factors mediating face ensemble processing, and suggest that shape and surface properties both contribute, in differing degrees, to the representation of identity in crowds of faces.

Acknowledgement: NSERC

56.308 **Population receptive field measurements of stimulus-driven effects in face-selective areas** Sonia Poltoratski[1](sonia09@stanford.edu), Kendrick Kay[2], Kalanit Grill-Spector[1,3]; [1]Department of Psychology, Stanford University, [2]Center for Magnetic Resonance Research, University of Minnesota, [3]Wu Tsai Neuroscience Institute, Stanford University

Classic theories suggest that high-level visual recognition is largely invariant to the item's position and size, but this is challenged by consistent reports of spatial biases and position information in high-level visual regions. Recent work in our lab (Kay, Weiner, and Grill-Spector, 2015; Gomez et al. 2018) has used population receptive field (pRF) models to computationally quantify spatial representations in face selective areas. However, it remains unknown how these spatial representations may contribute to face recognition behavior. Spatial integration of information is critical to two behavioral hallmarks of face processing: holistic processing, and competition between multiple items. In two experiments (Fig 1), we used 3T fMRI to map pRFs in 6 participants with stimuli thought to disrupt spatial processing enroute to face recognition: inverted faces (Experiment 1), and face pairs (Experiment 2), and compared these pRF properties to those measured with single, upright faces. To ensure fixation, participants performed a 1-back task on rapidly presented letters. Compared to upright faces, inverted faces yielded (1) a shift in the location of pRFs centers to the lower visual field, (2) lower variance explained by the pRF model, and (3) lower response amplitude (Fig 2). Further, these differences increased in magnitude from IOG-, to pFus-, to mFus-faces. Meanwhile, compared to a single upright face, presenting a face pair reduced pRF size and coverage across manipulations of the size of the single face, as predicted by classic theories of visual competition (Fig 3). In both experiments, we did not observe differences in pRFs or visual field coverage in V1 across varying mapping stimuli. Together, these results show for the first time that not only top-down attention, but also bottom-up

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stimulus driven properties can shift pRFs in face-selective regions. These data suggest that pRFs in high-level regions have complex properties that may constrain recognition behavior.

Acknowledgement: NSF Grant #1756035 to Kalanit Grill-Spector

56.309 **A Dynamic Representation of Orientation and Identity in Human Ventral Face Processing Areas as Revealed by Intracranial Electroencephalography** Arish Alreja[1](aalreja@andrew.cmu.edu), Michael J. Ward[2], R. Mark Richardson[1,2], Avniel S. Ghuman[1,2,3,4]; [1]Center for Neural Basis of Cognition, Carnegie Mellon University, [2]Department of Neurological Surgery, University of Pittsburgh, [3]Department of Neurobiology, University of Pittsburgh, [4]Department of Psychology, University of Pittsburgh

Faces can be recognized across a remarkable degree of transformations, including viewpoint, which greatly shifts the position and orientation of facial features. Face identity processing is thought to involve a distributed network of several brain areas including the occipital face area (OFA) and fusiform face area (FFA). FMRI studies in humans and parallel studies in non-human primates, have suggested a hierarchical organization of face viewpoint coding, from orientation dependence through mirror invariance culminating in viewpoint invariance. Here we present data from 12 subjects with a total of 35 face sensitive intracranial electroencephalography (iEEG) electrodes implanted in face sensitive patches of the human ventral visual stream showing that single regions dynamically change their representation over time, in contrast to traditional hierarchical models. Specifically, multivariate classification and representational analyses showed that the early representation (80-180 ms after viewing a face) reflected a mirror symmetric code, with a relatively strong representation for forward facing and away facing faces (90 degree profiles). In the same regions, the representation then shifted to where intermediate face viewpoints (45 degree profiles) were represented strongly from approximately 200-240 ms. Viewpoint dependent/invariant identity coding for faces was then examined by training a classifier to predict identity using one set of face viewpoints and testing it on identities from other viewpoints. The early representation for identity (80-200 ms) was viewpoint dependent and showed some suggestion of mirror invariant identity coding. A viewpoint invariant identity code emerged later (400-600 ms) in many of the same regions that showed viewpoint dependence earlier. Taken together, these results provide support for a model wherein the representation for face viewpoint, and identity as it relates to viewpoint, changes over time with single regions supporting the computation for multiple aspects of face coding over time, likely through network-level interactions with the extended face processing system.

Acknowledgement: NSF 1734907, NIH R01MH107797

56.310 **Typical unfamiliar face discrimination ability in anterior temporal lobe epilepsy** Angelique Volfart[1,2,3](angelique.volfart@gmail.com), Jacques Jonas[1,2,4], Louis Maillard[1,2,4], Bruno Rossion[1,2,3], Hélène Brissart[2,4]; [1]Université de Lorraine, [2]CRAN, UMR 7039, Université de Lorraine, CNRS, [3]Institute of Psychological Research and Institute of Neurosciences, Université Catholique de Louvain, [4]Neurology Department, Regional University Hospital of Nancy

Compared to patients with prosopagnosia, other animal species, infants or children, neurotypical human adults are experts at individuating pictures of unfamiliar faces, but the neural basis of this function remains largely unknown. Since an increasing number of studies rely on intracranial recordings in anterior temporal epileptic patients (aTLE) to investigate the neural mechanisms of face recognition, it is important to assess aTLE patients' ability to discriminate and match unfamiliar individual faces. Here, we tested 42 patients with left (n=17) or right (n=25) aTLE, and 42 healthy matched controls. Seven computerized neuropsychological tests were administered: the Benton Face Recognition Test (BFRT), the Cambridge Face Memory Test (CFMT), delayed matching of upright pictures of faces and objects, the Mooney Face Test, famous face recognition and naming, unfamiliar face and object learning. Relative to controls, we found that (1) both left and right aTLE patients were impaired (-10.5% and -8.2% in accuracy, respectively) in learning unfamiliar faces, but without any specificity (i.e. impairment also for nonface objects); (2) on average, right aTLE patients had significantly slower response times at all tasks, but this included the WAIS' Code subtest assessing processing speed, showing that this effect is not specific to visual tasks and (3) importantly, there was no difference between aTLE patients and matched controls on all the tasks assessing individual face discrimination (mean BFRT scores at 42.3/54 and 42.6/54 and CFMT scores at 47.2/72 and 47.1/72 for left and right aTLE respectively, significant inversion effect for matching individual faces but not cars). Overall, our study shows that left and right aTLE patients do not differ quantitatively and qualitatively at unfamiliar face discrimination tasks relative to healthy controls.

56.311 **Local image features dominate responses of AM and AF face patch neurons** Elena Waidmann[1](elena.waidmann@nih.gov), Kenji W Koyano[1], Julie J Hong[1], Brian E Russ[1,2], David A Leopold[1]; [1]Section on Cognitive Neurophysiology and Imaging, National Institute of Mental Health, Bethesda, MD, [2]Nathan Kline Institute, Orangeburg, NY

The fMRI-defined face patches of the macaque inferotemporal cortex contain neurons that are known to respond more strongly for faces than for other images. Previous studies have measured the tuning of such neurons to parametrized internal facial features. Here we investigated the relative contribution of internal and contextual head, body, and background information in the anterior medial (AM) and anterior fundus (AF) face patches. We developed a stimulus paradigm in which we systematically swapped image elements to investigate the relative influence of internal facial features (eyes, mouth), external facial features, attached bodies, and background scenes. Each test stimulus was a photorealistic composite image containing a combination of the image parts, presented to each of three monkeys briefly during a passive viewing task requiring strict fixation. We recorded local populations of single neurons from AM in one monkey and from AF in two other monkeys, using chronically-implanted microwire bundles. We found that most AM neurons were strongly modulated by either internal or external facial features, but few were modulated by both. For those sensitive to internal features, variation of the upper face (eyes), but not the lower face (nose-mouth) was most important. Although no AM neurons were selective for body parts, AF neurons tended to be weakly modulated by variation in bodies. AF neurons at one recording site were predominantly sensitive to details of the external hair, but not to inner facial features. At the second AF site, neurons were primarily modulated by the lower face, with many selectively firing for an open mouth. None of the neurons in either area were strongly modulated by background scene. In sum, the parts-swapping paradigm demonstrates that face patch neurons exhibit idiosyncratic specialization for internal and contextual facial features that is to a large extent shared within a 1mm3 volume of tissue.

56.312 **The neurons that mistook Stuart's hat for his face** Michael J Arcaro[1](Michael_Arcaro@hms.harvard.edu), Carlos R Ponce[2], Margaret S Livingstone[1]; [1]Harvard Medical School, [2]Washington University School of Medicine in St. Louis

Inferotemporal cortex contains neurons that respond selectively to complex visual images such as faces, hands, and bodies. Such neural tuning is typically probed in highly controlled experiments where stimuli are presented in isolation. However, our typical visual experience is more complex. Here, we explored tuning properties of IT neurons under naturalistic conditions. We recorded from microelectrode arrays implanted in the middle and posterior face patches in two adult monkeys. Tuning was first characterized with a rapid serial visual presentation of 3,000 images. Consistent with prior studies, neurons in these face patches responded more strongly to human and monkey faces than to any other image category. We then probed tuning to large natural scene images. To identify scene components that modulated these neurons, we presented each image centered at different positions relative to each neuron's receptive field, such that neural responses were probed to all parts of each scene across the experiment. Consistent with our initial results, we found that neurons responded most strongly when faces were centered within their receptive fields. However, neurons also typically responded to non-face images, such as cookies, that contained features typical to faces: dark round things in a tan background. Strikingly, neurons also responded when occluded faces were presented within their receptive fields. For example, neurons did not respond to a picture of Stuart Anstis's hat held in his hand, but did respond when the same hat occluded his face. Together, our results demonstrate that face-selective neurons are sensitive not only to features common to faces but also to contextual cues. We propose that visual features are the building blocks for face-selective neurons, and context-dependent responses arise from learning statistical regularities in the environment. In support of this, visual features that co-occur with faces, such as bodies, appear to be critical for these contextual responses.

Acknowledgement: NIH

56.313 **How does the macaque brain characterize face pareidolia?** Jessica Taubert[1](jesstaubert@gmail.com), Susan G Wardle[1], Susheel Kumar[1], Clarissa James[1], Elissa Koele[1], Adam Messinger[1], Leslie G Ungerledier[1]; [1]The National Institute of Mental Health

The common misperception of faces in inanimate objects, known as face pareidolia, can be considered an error of face detection. Examination of these errors has the potential to reveal new insight into the functional organization of category-selective cortex in primates. Previously we showed that rhesus monkeys (Macaca mulatta) perceive illusory faces in the same images (e.g. eggplant, bell pepper, coffee) that humans do (Taubert et al., 2017, Current Biology; Taubert et al., 2018, PNAS), demonstrating that this experience is not unique to humans. Here we examined the macaque brain's response to face pareidolia by directly adapting a fMRI paradigm previously used in humans (Wardle et al., 2017, bioRxiv). The brain's response to face pareidolia is particularly interesting in terms of understanding category-selective areas in visual cortex, as these stimuli are simultaneously perceived as both objects and faces. We used contrast agent enhanced functional imaging in awake macaques (N=4) in a 4.7T Bruker vertical MRI scanner. The on-off block design used the same paired stimuli as the human experiment: examples of face pareidolia and matched objects belonging to the same category. We categorized regions-of-interest in the superior temporal sulcus as place-selective, object-selective or face-selective, based on independent data from functional localizer runs. Interestingly, the data revealed several differences in the response to these stimuli compared to the human brain. For example, the only face-selective area that reliably responded more to examples of face pariedolia than to matched objects in the macaque brain was located in the prefrontal cortex. This region has been implicated in behavior towards socially relevant information. Overall, our results indicate that objects that belong to more than one semantic category may be processed differently by the macaque and human brain; these differences inform our understanding of high-level perception in both species.

Acknowledgement: The NIMH intramural Research Program

56.314 **Neural circuitry for conscious and unconscious face processing in typical subjects** Daylín Góngora[1,2](daylin.gongora@gmail.com), Ana M Castro-Laguardia[1], Agustín Lage-Castellanos[3,4], Mitchell Valdés-Sosa[2], Maria A Bobes[1,2]; [1]The Clinical Hospital of Chengdu Brain Science Institute, MOE Key Lab for Neuroinformation, University of Electronic Science and Technology of China UESTC, Chengdu, China, [2]Department of Cognitive Neurosciences, Cuban Neuroscience Center, Cuba, [3]Department of Neurostatistics, Cuban Neuroscience Center, Cuba, [4]Department of Cognitive Neuroscience, Faculty of Psychology and Neuroscience, Maastricht University, The Netherlands

Cognitive models about face recognition postulate two independent streams of processing, one conscious involved in processing personal semantic information and another unconscious related to the affective reaction to this identity. These two streams of processing could be supported either by two parallel neural circuitries or by one single route operating in sequence.One strategy to disentangle this matter is to reveal face information gradually in order to potentially disclose relative timing differences between different brain areas while using a very short sampling rate of BOLD acquisition. Here we adapted a paradigm from Gentile et al. (2016) to explore the timing of conscious and unconscious (subliminal presentation) of familiar face processing in typical subjects in three regions: amygdala (Amyg), face fusiform area (FFA) and occipital face area (OFA). The sample was composed of 13 young healthy subjects (five females). The stimuli were unfamiliar and familiar faces (tailored to each subject, consisting of family members or close acquaintances) of ten identities each. Face visibility was varied parametrically by creating a graded sequence of 20 images from each stimulus with decreasing degrees of phase-scrambling. The recognition threshold was determined individually as the sooner picture at which the subject was able to give the name of any person. Subliminal presentation threshold was defined as two-phase step backward of the identity's recognition threshold. We found that response latency for the conscious presentation was shorter in comparison for unconscious one for familiar and unfamiliar faces. Besides, the familiar stimuli elicited a sooner response than the unfamiliar kind. We also found a temporal gradient from OFA to FFA to Amyg when the BOLD response is compared with the baseline, but without significant difference among Amyg with the other regions. This fact supports the existence of two different streams operating in parallel for familiar face processing.

56.315 **Spatial organization of face part representations within face-selective areas revealed by 7T fMRI** Jiedong Zhang[1](zhangjiedong@gmail.com), Peng Zhang[1], Sheng He[1,2]; [1]Institute of Biophysics, Chinese Academy of Sciences, [2]Department of Psychology, University of Minnesota

In the early visual cortex, neurons sensitive to different visual features tend to be spatially organized at fine scales, such as ocular dominance columns and orientation pinwheels in V1. In high-level visual category-selective regions in the ventral pathway, neurons are found to be sensitive to different visual features such as object parts, but whether there is generally fine-scale spatial organization of these neurons within each region remains unclear. Here we used high-field 7T fMRI to examine the spatial organization of neural tuning to different face parts within each face-selective region. Five kinds of face parts (i.e., eyes, nose, mouth, hair, and chin) were presented to participants while they were scanned in the MRI. In the right pFFA, contrasting the neural responses to eyes and mouth revealed consistent spatial patterns in all six participants. Aligned with the orientation of mid-fusiform sulcus, the posterior part of right pFFA was biased to eyes, while the anterior part was biased to mouth stimuli. Similar spatial tuning patterns were observed in the right OFA, but no obvious spatial pattern was found in the right aFFA, left OFA, or left FFA. Among other face parts, chin generated similar (but less robust) spatial response patterns as mouth, while no clear spatial pattern was observed in responses to nose and hair stimuli. Our results demonstrate that within some face processing regions, there exist systematic spatial organizations of neural tuning to different face parts. Such fine-scale spatial patterns may reflect the distribution of neurons sensitive to different dimensions in face feature space.

Acknowledgement: CAS Pioneer Hundred Talents Program, NSFC grant (No. 31322025), NSFC grant (No. 31540078)

56.316 **Neural Encoding and Decoding with Convolutional Autoencoder for Predicting Emotional Judgment of Facial Expressions** Gary C.W. Shyi[1,2](cwshyi@gmail.com), Wan-Ting Hsieh[3], Felix F.-S. Tsai[3], Jeremy C.-C. Lee[3], Shih-Tseng Tina Huang[1,2], Joshua O. S. Goh[4], Ya-Yun Chen[2], Chi-Chuan Chen[4], Yu Song Haw[2]; [1]Department of Psychology, National Chung Cheng University, Taiwan, [2]Center for Research in Cognitive Science, National Chung Cheng University, Taiwan, [3]Department of Electrical Engineering, National Tsing Hua University, Taiwa, [4]Graduate Institute of Brain and Mind Sciences, National Taiwan University, Taiwa

Convolutional Autoencoder (CAE) has become a popular approach to building artificial systems endowed with the capability of automatic emotion recognition under unsupervised learning. Here, we explored the viability of using CAE to unravel the neural encoding and decoding for predicting emotional judgment of facial expressions among human observers. Specifically, 25 young adults were asked to discriminate faces of varying degree of emotional expression with the neutral faces. The mean difference threshold for discriminating emotional expressions was then derived from averaging across the difference threshold for each of the six basic emotions (i.e., happiness, anger, sadness, surprise, fear, and disgust), and participants were then divided into high- versus low-thresholders based on the median split. They were then asked to explicitly judge the emotional intensity of displayed faces while their brains undertook fMRI scanning. The BOLD signals of 47,636 voxels based on the 90 ROIs specified according to the Automated Anatomical Labelling (AAL) were fed to a one-dimensional CAE model with three encoding layers and three decoding layers. The results of reconstructed brain activities based on the learned voxel weights were then remapped onto the AAL-defined ROIs to locate brain regions that may contribute differentially to the emotional judgments of facial expression among high- and low-thresholders. For low-thresholders who actually required smaller image differences to discriminate facial expressions, the results of the CAE suggests that brain regions that are involved in basic visual processing appear to play a greater role. In contrast, for high-thresholders who required greater image differences to discriminate facial expressions, brain regions responsible for emotion processing and those that are involved in top-down emotional regulations appear to play a greater role. Taken together, these findings highlight the utility of using the CAE, in conjunction with neuroimaging data, to unravel brain mechanisms underpinning emotional processing of facial expressions.

Acknowledgement: The Ministry of Science and Technology, Taiwan, ROC

56.317 **fMRI responses by face-like objects: the effect of task modulation revealed by ROI time courses, MVPA searchlight mapping, and Granger Causality.** Hsiao-Hsin Wang[1](d0932770321@gmail.com), Chun-Chia Kung[1]; [1]Department of Psychology, National Cheng Kung University, Tainan, Taiwan

Using fMRI to investigate visual processing of facelike objects is intriguing in two aspects: first, its name implies the interplay between several category-related (e.g., face and object-selective) regions-of-interest (ROIs); second, since fMRI is relatively slow in temporal resolution, whether it is possible to show the transient face-related signatures (as N170 in ERP or M170 in MEG) in fMRI, and under what task context and temporal resolution, will also reveal the strength (and limitations) of different methodologies. Previously, we have found that under two different task contexts: face/object classification (FOC), or facelikenss judgment (FLJ), face-like objects (or FLO) showed two different patterns of time courses in face- (e.g., FFA) and object- (e.g., LOC) selective areas: in FOC condition, FLO drove the LOC, but flat FFA responses; whereas in FLJ condition, FLO drove the FFA in earlier times (< 6s), but LOC increased later (after 6s). To further mitigate the FFA and LOC interaction (and also with other brain regions), Granger Causality Mapping (GCM) was applied to assess relative dGCM by either FFA or LOC. We found that (a) under both FOC and FLJ tasks, LOC Granger-caused many related areas: inferior temporal areas, primary visual cortex, anterior cingulate, dlPFC, and r-Precuneus; whereas the rFFA was more influenced by surround IT areas, especially more so in FLJ context. In addition, MVPA searchlight analyses on FLO under two tasks revealed that the only significant region to reliably classify was thalamus, a region implicated in input-output mapping contingencies. Taken together, these results suggested that FLO was flexibly modulated by the task instruction, and the effective connectivity between FFA and LOC, revealed by GCM, showed not only the distributed nature of LOC and FFA under different contexts, but also the influencing and being influenced to upstream and by downstream areas, via the gating control in thalamus.

56.318 **fMRI mapping of retinotopy using face and object stimuli in rhesus monkeys** Adam Messinger[1](messinga@mail.nih.gov), Benjamin Jung[1], Caleb Sponheim[2], Leslie G Ungerleider[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, [2]University of Chicago

Visual processing in the primate brain consists of a ventral visual stream that primarily processes the shape of visual stimuli (the “what” stream) and a dorsal visual stream that primarily processes the location of those stimuli (the “where” stream). Early visual areas have been shown to be retinotopically organized, with different portions of the visual field spatially mapped to the cortex. Such retinotopy becomes less apparent in later stages of the ventral visual stream, where many neurons have large receptive fields. These later ventral stream areas have been shown using fMRI to contain category-selective regions (e.g. face patches). It is unclear the extent to which these later stages of the ventral visual stream and category-selective regions retain information about stimulus location. Using a block design, we measured fMRI responses in rhesus macaques to images of monkey faces and objects presented in each of four quadrants of the visual field during a central fixation task. Stimuli were 7x7 degrees of visual angle and presented at 6 degrees of eccentricity. We evaluated responses in anatomically-defined ventral visual stream areas. Early visual areas (V1-V4) responded retinotopically, generally preferring the contralateral visual field, with more inferior regions preferring the upper visual field and more superior regions preferring the lower visual field. Later stages of the ventral visual stream retained a contralateral preference and voxels responding significantly more to stimuli in the lower quadrants than the upper quadrants were more common than the reverse. This result indicates that some information about stimulus location is retained even in the later stages of the ventral stream, where complex shapes such as faces and objects are processed. The bias for lower-field stimuli suggests that face and object recognition may be more accurate or efficient in the lower relative to the upper visual field.

Acknowledgement: NIMH IRP

56.319 **Causal evidence for expectancy effects in body selective cortex** Marco Gandolfo[1](m.gandolfo@bangor.ac.uk), Paul E. Downing[1]; [1]School of Psychology, Bangor University

With a glimpse, we infer others’ traits based on their visual appearance, and these inferences shape our social behavior. Sex and weight are two key traits strongly cued by body shape. We found in previous work that advance knowledge of the sex of a body, provided by a verbal prime, influences the selection of visual features useful for judging body weight, and improves performance on that task. Such findings inform us about the organization of body shape representations. Moreover, they are an example of how prior knowledge about a stimulus attribute can influence perceptual performance. A current open question relates to the neural underpinnings of such expectancy effects. Specifically, how and where does prior information influence cortical processes relevant to perception? We addressed this question for the case of body perception, by asking whether activity in a body selective cortical region is causally involved in forming expectations about an incoming body visual stimulus. Participants judged body images as either slim or heavy. Each body was preceded by a verbal cue to its sex (80% valid, 20% invalid). Participants received online rTMS (4 pulses, 10 Hz) over functionally localized extrastriate body area (EBA) or occipital place area (OPA), starting at prime onset and ending 100 ms before image onset. Stimulation over EBA, but not OPA, significantly decreased the benefit of valid cues on body size judgements. These findings elaborate the causal role of body selective EBA in processing socially relevant body shape cues. Crucially, they show that verbally-driven, content-specific expectancy effects are expressed as selective pre-activation in the occipitotemporal cortex, before stimulus onset. In this respect, they shed light on the neural basis of expectancy effects on perception in general.

56.320 **Deaf individuals show enhanced face processing in the periphery** Kassandra R Lee[1](kassandral@nevada.unr.edu), Elizabeth Groesbeck[2], O. Scott Gwinn[3], Fang Jiang [1]; [1]Department of Psychology, University of Nevada, Reno, [2]School of Medicine, University of Nevada, Las Vegas, [3]College of Education, Psychology, and Social Work, Flinders University, Adelaide, Australia

Deaf individuals often display enhanced visual processing abilities, particularly for peripheral motion. Deaf individuals are also more accurate at face discrimination, however this has only been examined in the central visual field. Our aim is to determine whether these face processing enhancements extend to the periphery, and whether they are also reflected in the neurophysiological responses. Face stimuli were created by morphing between original faces and their anti-face in 1% steps. In a face matching task, subjects were presented with a ‘target’ face and after a delay were required to identify which of two ‘test’ faces matched the target. Test faces appeared either centrally (3.4° from fixation) or peripherally (10°). In an EEG task, a steady-state visual evoked potential (SSVEP) oddball paradigm was used, in which facial images were presented at a base frequency (6 Hz) and within the sequence a different ‘oddball’ face was presented at a lower frequency (1.2 Hz). The similarity between base and oddball images was varied, and were again presented either centrally or peripherally. Behaviorally, there was no difference between subject groups in the central field, however in the periphery, deaf subjects performed significantly better than hearing subjects. This difference was not reflected in the EEG results, with both groups showing similar reductions in oddball amplitudes for faces that were more similar. Furthermore, deaf subjects showed larger decreases in overall amplitudes when images were presented in the periphery. Our behavioral results show that deaf individuals’ enhanced face processing abilities may be more pronounced in the periphery. The discrepancy between the behavioral and EEG results suggest that the face discrimination task and SSVEP oddball reflect different aspects of face processing, with the former perhaps involving more feature-based processing and the latter being more holistic.

Acknowledgement: This work was supported by grants from the National Institutes of Health (EY-023268 to FJ, EY-10834 to MW), with further support for core facilities provided by COBRE P20 GM103650

56.321 **Density of Top-Layer Codes in Deep Convolutional Neural Networks Trained for Face Identification** Connor J Parde[1](connor.parde@utdallas.edu), Y. Ivette Colon[1], Matthew Q Hill[1], Rajeev Ranjan[2], Carlos Castillo[2], Alice J O’Toole[1]; [1]School of Behavioral and Brain Sciences, The University of Texas at Dallas, [2]University of Maryland Institute for Advanced Computer Studies, University of Maryland

Deep convolutional neural networks (DCNNs) are the state-of-the-art in automatic face recognition and currently outperform humans on some tasks. These networks perform tens of millions of neuron-like computations to produce a “top-layer” face representation that is highly compact. This representation supports robust face identification, while retaining information about face gender and viewpoint. We tested the density of information encoded in the top-layer face representation by sub-sampling feature units and measuring the cost to identification accuracy as the number of units decreased. Using a 101-layer ResNet-based DCNN trained for face recognition (Ranjan et al., 2017), subsets of features (N = 512, 256, 128, 64,

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32, 16, 8, 4, 2) were selected randomly without replacement from the full 512-dimensional top-layer feature set. Identification accuracy was tested using the IJB-C dataset (141,332 unconstrained images, 3,532 identities) and measured by the area under the ROC curve (AUC). Face identification performance declined at a remarkably slow rate as the subset size decreased (AUCs: 512, 256, 128, 64 features=0.98, 32 features=0.97, 16 features=0.95, 8 features=0.91, 4 features=0.85, 2 features=0.75). Next, we used the subsamples to predict the viewpoint and gender of the input faces. Viewpoint prediction error (in degrees) and gender prediction accuracy (percent correct) were measured as a function of decreasing subset size. Performance declined more rapidly for viewpoint and gender than for identity. Viewpoint prediction error increased from 7.87°, with the full feature set, to chance (~16°), with subsamples of 64 features or fewer. Gender prediction accuracy decreased from 95.0%, with the full feature set, to near chance (~70%) with subsamples of 32 features or fewer. This indicates that DCNN face representations require input from only a small number of features for successful identification, but require coordinated responses from the full complement of top-layer features to predict image information.

Acknowledgement: This research is based upon work supported by the Office of the Director of National Intelligence (ODNI), Intelligence Advanced Research Projects Activity (IARPA), via IARPA R&D Contract No. 2014-14071600012. The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of the ODNI, IARPA, or the U.S. Government. The U.S. Government is authorized to reproduce and distribute reprints for Governmental purposes notwithstanding any copyright annotation thereon. We thank NVIDIA for donating of the K40 GPU used in this work.

56.322 **Deep networks trained to recognize facial expressions spontaneously develop representations of face identity**
Kathryn C O'Nell[1](kco@mit.edu), Rebecca Saxe[1], Stefano Anzellotti[2]; [1]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, [2]Department of Psychology, Boston College

According to the dominant account of face processing, recognition of emotional expressions is implemented by the superior temporal sulcus (STS), while recognition of face identity is implemented by inferior temporal cortex (IT) (Haxby et al., 2000). However, recent patient and imaging studies (Fox et al., 2011, Anzellotti et al. 2017) found that the STS also encodes information about identity. Jointly representing expression and identity might be computationally advantageous: learning to recognize expressions could lead to the emergence of representations that support identity recognition. To test this hypothesis, we trained a deep densely connected convolutional network (DenseNet, Huang et al., 2017) to classify face images from the fer2013 dataset as either angry, disgusted, afraid, happy, sad, surprised, or neutral. We then froze the weights of the DenseNet and trained linear layers attached to progressively deeper layers of this net to classify either emotion or identity using a subset of the Karolinska (KDEF) dataset. Finally, we tested emotion and identity classification in left out images in the KDEF dataset that were not used for training. Classification accuracy for emotions in the KDEF dataset increased from early to late layers of the DenseNet, indicating successful transfer across datasets. Critically, classification accuracy for identity also increased from early to late layers of this DenseNet, despite the fact that it had not been trained to classify identity. A linear layer trained on the DenseNet features vastly outperformed a linear layer trained on pixels (98.8% vs 68.7%), demonstrating that the high accuracy obtained with the DenseNet features cannot be explained by low-level confounds. These results show that learning to recognize facial expressions can lead to the spontaneous emergence of representations that support the recognition of identity, thus offering a principled computational account for the discovery of expression and identity representations within the same portion of STS.

Binocular Vision: Stereopsis

Tuesday, May 21, 2:45 - 6:45 pm, Banyan Breezeway

56.323 **The neural basis of the high degree of stereoanomaly present in the normal population**
Sara Alarcon Carrillo[1](sara.alarconcarrillo@mail.mcgill.ca), Alex S. Baldwin[1], Robert F. Hess[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

The human visual system calculates depth from binocular disparity. This study explored the variability in stereoacuity (minimum discriminable disparity) and in the relative sensitivity to crossed (near) and uncrossed (far) disparity in adults. The task measured thresholds for identifying the location of a depth-defined shape in a field of dots. The surface appeared to be either in front of (crossed) or behind the screen (uncrossed disparity). Performance for each direction was measured separately. We measured thresholds for 53 adults (28 males) with normal vision. Thresholds ranged from 24 to 275 arc second. This range did not display a bimodal distribution (contrary to previous reports). We then used an equivalent noise approach to determine if elevation in thresholds can be attributed to larger internal input noise or reduced processing efficiency. We measured thresholds with different levels of disparity noise (affecting the disparity of each dot) in 18 subjects. Performance was unaffected at low levels of added noise, however beyond a critical value, thresholds increased with the standard deviation of the noise. This transition point indicated when the effect of the stimulus disparity noise was equivalent to the internal noise of the visual system. Thresholds calculated at high external noise levels indicate the efficiency of the system when processing the noisy input. We found differences in processing efficiency largely explained individual differences in performance. Enhanced efficiency for one direction also explained significant within-subject differences in sensitivity between crossed and uncrossed disparities. For subjects lacking a bias in either disparity direction, there was a tendency for increased equivalent internal noise to be balanced out by increased efficiency for the same direction. Our results show it is variations in the quality of processing and not in the quality of the input into disparity-processing mechanisms that explain individual differences in stereoacuity.

Acknowledgement: CIHR 2RFH

56.324 **The prevalence and diagnosis of "stereoblindness": A best evidence synthesis**
Adrien Chopin[1,2](adrien.chopin@gmail.com), Daphne Bavelier[1,2], Dennis M Levi[3]; [1]Faculte de Psychology et Sciences de l'Education, University of Geneva, Geneva, Switzerland, [2]Campus Biotech, Geneva, Switzerland, [3]School of Optometry, University of California, Berkeley, USA

Stereoscopic vision is the ability to perceive depth from the difference of the two eyes' viewpoints. Some people are totally deprived of this ability. Surprisingly, there is no consensus on the prevalence of total stereoblindness. The value strongly depends on how it is measured, and some stereoblind participants can deceive stereotests. This study aims at determining the prevalence of stereoblindness, clarifying the concept and standardizing the measure. First, we studied the dependence between reported prevalence in young healthy adults and tested presentation times and disparity magnitudes. Second, we identified four approaches to bracket the likely stereoblindness prevalence from the literature. We can take the median of (1) all studies, (2) studies with presentation times < 200ms, (3) and, in addition, with a minimal disparity < 900" and a maximal >900", and (4) studies controlling for eye movements with afterimages. Finally, we propose an ecological definition of stereoblindness as the inability to detect everyday life disparities and propose a quick way to test for it by modifying a common clinical stereotest. It is well-known that stereo-impairment rates decrease with longer presentations. Surprisingly, we did not confirm this data for total stereoblindness rates. We bracketed the stereoblindness prevalence between 6.1% and 7.7%. Ninety percent of everyday disparities are smaller than 1314". Therefore, we define ecological stereoblindness as the inability to perceive disparities < 1300". To test for stereoblindness, we recommend modifying the Random Dot Butterfly stereotest as follows: (1) test at 62 cm (1300"), (2) randomly pick a set of glasses among two, one having the left and right filters exchanged, (3) ask whether the butterfly appears as floating or as a hole, (4) score as pass for 10 out of 11 correct responses, (5) repeat the procedure twice after two errors, and score as stereoblind if the repeat is also failed.

Acknowledgement: This work was supported by grant number RO1EY020976 from the National Eye Institute.

56.325 **Abnormal Sensory Eye Dominance in Stereoanomalous**
Philip R. Cooper[1](philip.cooper2@mail.mcgill.ca), Janine D. Mendola[1]; [1]Department of Ophthalmology, McGill Vision Research, McGill University

Introduction:Stereoanomalous (SA) subjects have normal visual acuity but reduced stereopsis, and may have a prevalence of up to 30%. It has been suggested that in SA subjects an imbalance in interocular inhibition might underlie an asymmetry in sensory eye dominance (SED). Our study expands upon previous findings by examining binocular rivalry (BR) mean dominations durations, dichoptic masking (DM) thresholds and sensory eye dominance (SED) for a group of SA subjects compared to naïve controls. Method: We examined BR dominance durations and DM thresholds for 15 stereonormal (SN) subjects and 10 SA subjects with normal or corrected-to-normal visual acuity. Individuals who scored >6/9 on the Randot stereo test and < 100 arcmin on the PacMan Stereo Acuity test were considered SN. The criterion for SN was visual acuity of 20/40 or better, and less than two-lines

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difference between eyes. We compared near-vertical and near-horizontal oriented sine-wave gratings for BR and DM, in order to dissociate stereo-related mechanisms that rely on horizontal disparities from other eye-based integration mechanisms. Results: Randot scores for SN subjects were 8.53/9 with a PacMan stereoacuity of 32.5 arcmin, while SA subjects scored 2.5/9 and 3380 arcmin respectively. The difference in SED was 0.19 for SN and 0.48 for SA when measured with a neutral density filter bar. The SA group showed an interocular difference in BR durations that was significantly greater than normal ($p = 0.004$). Moreover, the interocular difference for DM was similarly greater for SA subjects ($p = 0.04$). We also found that both SN and SA subjects presented higher DM thresholds for vertical than horizontal orientations. Conclusions: SA subjects show a bias towards their dominant eye for both BR and DM, while SN subjects do not. These data may ultimately provide a practical link to better understand the heterogeneity of stereopsis in the population.

56.326 **Contrast suppression and stereoblind zones in amblyopia** Saeideh Ghahghaei[1](saeideh@ski.org), Preeti Verghese[1]; [1]The Smith-Kettlewell Eye Research Institute

Last year we used a novel stereoperimetry technique to demonstrate that amblyopic observers with measurable stereopsis were functionally stereoblind at the fovea (Ghahghaei & Verghese, 2018). Here we set out to determine whether the size of the central stereo-blind zone is related to the depth of amblyopia as indexed by contrast suppression. Specifically, we measured contrast suppression locally using a dichoptic contrast-matching task and compared it with our map for stereopsis in the same individual. Participants included 5 controls, 3 with anisometropic amblyopia and 2 with micro-strabismus. In the contrast-matching task, observers viewed a full-field horizontal sinusoidal grating (0.5 cycle/deg, contrast 30%) presented to both eyes and a test patch with higher contrast presented to one eye. Observers used the method of adjustment to match the test contrast to the background. The test patch was presented at 0, 1.25, 2.5, 5 and 10° eccentricity along the horizontal and vertical meridians. The patch measured 1° in the fovea and its size was m-scaled with eccentricity. Eccentricity, meridian and the eye in which the test was presented were randomized. For each tested location, we measured the logarithm of the ratio of matching contrasts (RMC) for the amblyopic (non-dominant) to the fellow (dominant) eye. Overall, the amblyopic/deviating eye required greater contrast than the fellow eye, but the spatial mapping between zones with elevated RMC and impaired stereopsis differed between the two clinical groups. For anisometropic amblyopes, a within-subject comparison showed elevated RMC at the stereo-blind fovea. However, outside the fovea, there was no clear mapping between para-foveal locations with impaired stereopsis and contrast suppression. For microstrabs, there was no systematic mapping between the central stereo-deficient zone and elevated RMC. Our results suggest that contrast suppression might contribute to stereo-deficiency but is insufficient to account for the spatial pattern of stereo loss.

Acknowledgement: R01EY27390

56.327 **A comprehensive depth perception model with filter/cross-correlation/filter (F-CC-F) structure** Jian Ding[1](jian.ding@berkeley.edu), Dennis M. Levi[1]; [1]School of Optometry, UC Berkeley

We have developed a new depth perception model with a filter/cross-correlation/filter (F-CC-F) structure, and validated it over a broad range of spatiotemporal conditions. The two eyes' images pass through first-stage spatiotemporal filters to compute the normalized cross-correlation (CC), which goes through a maximum (MAX) operator for solving the correspondence problem, then goes through a disparity window to compute local depth quantities, and finally through a second-stage of spatiotemporal filtering to give the perceived depth. Previous work (Ding & Levi VSS 2016) revealed two normalization mechanisms: (1) an energy model (cross-correlation is normalized by monocular contrast energies) to predict Dmin and (2) a gain-control model (interocular contrast gain-controls before cross-correlation) to predict Dmax. Here, we have developed a full model with multiple pathways to explain both Dmin and Dmax simultaneously. To test the model, we performed rating-scale experiments to measure disparity sensitivities over the whole range of binocular disparities. Stimuli were random-Gabor-patch (RGP) stereograms, consisting of vertical Gabor patches with random positions and phases, but with a fixed spatial frequency (3.0 cpd). We tested five stereogram profiles (circles and annuli of 1.76 – 7.04 arcdeg radius) and eight durations (13 – 2013 ms), revealing the complex spatiotemporal properties of depth perception. We found that disparity sensitivity depends on the stereogram size, which can be explained by a band-pass DOG (Difference of Gaussian) filter as the second-stage filter. The model has four pathways, two for crossed- and two for uncrossed-disparities. Each pathway has its own normalization mechanism (either Energy or Gain-control model), its own disparity window (a disparity sensitivity function, the product of disparity power and exponential decay functions, which increases with stimulus disparity at small disparities but decreases at large disparities), and its own second-stage filter. These second-stage filters were validated experimentally. This comprehensive new F-CC-F model successfully predicts the entire data-set.

Acknowledgement: National Eye Institute grant R01EY020976

56.328 **A model that recovers depth from stereo without using any oculomotor information** Tadamasa Sawada[1](tada.masa.sawada@gmail.com); [1]National Research University Higher School of Economics, School of Psychology

The stereo pair of a human's eyes is spatially separated and their retinal images of a 3D scene are slightly different from one another. This difference is referred to as binocular disparity. Humans can perceive depth within a scene by using binocular disparity. Many believe that the perception of depth requires oculomotor information about the relative orientation of the two eyes. The visual system can obtain such oculomotor information from the efference copy of the oculomotor signal, or from the spatial distribution of the vertical disparity, specifically, the vertical component of the binocular disparity. Note, however, that the oculomotor information provided by these two sources is too restricted or unreliable to explain the reliable depth perception humans have under natural viewing conditions. In this paper, I will describe a computational model that can recover depth from a stereo-pair of retinal images without making any use of oculomotor information or a pirori constraints. This depth recovery model is based entirely on the geometry of the optics of the eyes, which means that I am treating this as a Direct rather than an Inverse problem, according to Inverse Problem Theory. The input to this model is the stereo-pair of retinal images represented as two sets of visual angles between pairs of points in the individual retinal images. The recovered depth is represented in a head-centered coordinate system. Both the representations of the retinal images and of the recovered depth do not change when the eyes rotate. Oculomotor information can be recovered after depth is recovered if it is needed. Note that the model proposed in this study can explain many psychophysical results better than the conventional formulation, which assumes that the visual system requires oculomotor information to use binocular disparity to perceive depth.

56.329 **A Computational Model for Local Stereo Occlusion Boundary Detection** Jialiang Wang[1](jialiangwang@g.harvard.edu), Todd Zickler[1]; [1]John A. Paulson School of Engineering and Applied Sciences, Harvard University

Stereo occlusion boundaries separate foreground surfaces that are visible to both eyes from background surfaces that are visible to only one eye. Anderson and Nakayama (1994) hypothesize the existence of local units in early vision that are specialized to detect these boundaries. They observe that these units could sense where regions with binocular correlation are adjacent to regions without correlation, and they suggest that the units should cover a variety of boundary orientations and a variety of disparity changes across the boundary. In this work, we propose a computational implementation for these units. We introduce a taxonomy of local response patterns that can occur within a population of spatially-distributed, disparity-tuned neurons near an occlusion event. The items in the taxonomy are differentiated by the textures that exist on the surfaces adjacent to the occlusion boundary. We observe that there are distinctive local patterns that make stereo occlusion boundaries uniquely detectable in most cases, but that they can be confused with occlusion-less texture boundaries when the background surface has uniform intensity. This implies that any neurological or computational local detector of one must also detect the other. We argue that the local units should detect both types of boundaries since both cases occur at the correct spatial locations and disparities. We design a computational local detector, using a multi-scale feedforward neural network, that exploits the patterns of our taxonomy while also providing enough capacity to account for natural textural and orientation variations of boundaries. We find that our detector provides accurate boundaries for a variety of stereo images, including many well-known perceptual stimuli, realistically rendered images, and captured photographs. In many cases, it outperforms state-of-the-art computer vision stereo algorithms in finding stereo occlusion boundaries.

Acknowledgement: National Science Foundation Award IIS-1618227

56.330 **The information value of stereotopsis determines its contribution to shape constancy** Marie-Audrey Lavoie[1,2](marieaudreylavoie@hotmail.com), Mercédès Aubin[1,2], Martin Arguin[1,2]; [1]Centre de recherche en neurpsychologie et cognition, [2]Département de psychologie université de Montreal

Bent paperclips with variable depth rotations were displayed either with normal stereopsis, reversed-stereopsis, or without binocular disparity in a sequential matching task. In Exp. 1, where display mode was manipulated as a within-subject factor, the results from the first half of the experiment (trials 1-600) replicated previous findings by Burke (2005), with a weaker depth rotation cost on behavioral performance on "same" trials with normal stereoscopic displays than with reversed stereopsis or null binocular disparity. However, this benefit from normal stereopsis turned to a handicap in the second half of the experiment (trials 601-1200). In Exp. 2, display mode was again manipulated in a within-subject manner but the first (trials 1-600) and second (trials 601-1200) halves of the experiment used distinct sets of stimuli. The negative impact of the depth rotation of stimuli on "same" trials remained weaker with normal stereo than with reversed stereo or null binocular disparity through the first and second halves of the experiment. The same findings occurred in Exp. 3, where display mode was manipulated as a between-subjects factor. The present results suggest that by default, stereoscopic information contributes to visual shape perception and to shape constancy. However, when stereo has a poor information value for specific stimuli, such as in Exp. 1, this contribution may be cancelled, turning potentially useful and valid binocular disparity signals into a source of distraction that impairs performance. In this regard, we note that almost all the literature on shape constancy rests on studies using flat computer screens to display stimuli that participants are supposed to interpret that as 3-D despite a lack of binocular disparity. This may constitute a significant artifact altering the validity of these past studies.

56.331 **The Effect of Depth on Divided Attention in a Stereoscopic Useful Field of View Test** Jake Ellis[1](jdellis1@shockers.wichita.edu), John P. Plummer[1], Ryan V. Ringer[1,2], Shivani Nagrecha[1], Rui Ni[1]; [1]Department of Psychology, College of Liberal Arts and Sciences, Wichita State University, [2]Department of Psychological Sciences, College of Arts and Sciences, Kansas State University

Spatial layout is an important aspect of how humans interact with the environment, including how attention is allocated in space. Prior research has found that that attention mediates the effect of distractors in flanker tasks (Anderson, 1990) and invalid cues (Atchley et al, 1997). However, it is not clear whether and how stereoscopic depth information affects divided attention, as measured by the Useful Field of View (UFOV) test. In the present study, a stereoscopic 3D UFOV test was developed to assess the effect of divided attention between central and peripheral targets which appear at different depths. Peripheral Gabor patches were displayed at one of two retinal eccentricities (5 or 15 degrees) and at one of three depths (20, 0, or -20 arc min) relative to a central (foveal) target. The threshold of display duration was derived using the best PEST procedure for each eccentricity at each depth. The results showed a significant main effect of both eccentricity and depth. For eccentricity, display duration thresholds increased with greater peripheral target eccentricity, which is consistent with previous research (Plummer & Ni, 2014). For depth, display duration thresholds were lower when the peripheral target was displayed at the same depth as the central target, and significantly longer when central and peripheral target depth differed. The results suggest that there is an effect of depth on the divided attention task of the UFOV. Understanding this effect of depth is particularly important when relating the UFOV to everyday tasks such as driving, where depth and spatial layout of a scene play an important role in hazard perception and object recognition.

Acknowledgment: Research reported in this abstract was partially supported by the Cognitive and Neurobiological Approaches to Plasticity (CNAP) Center of Biomedical Research Excellence (COBRE) of the National Institutes of Health under grant number P20GM113109.

Attention: Cues, individual differences, inattentional blindness

Tuesday, May 21, 2:45 - 6:45 pm, Banyan Breezeway

56.332 **The role of color preference under interocular suppression** Albert J Zhai[1](a.jianqiao.zhai@gmail.com), Shao-Min (Sean) Hung[2, 3], Shinsuke Shimojo[2]; [1]Computing and Mathematical Sciences, California Institute of Technology, [2]Biology and Biological Engineering, California Institute of Technology, [3]Huntington Medical Research Institutes

Continuous flash suppression has been widely used to study unconscious processing due to its sustained and strong suppressive power. However, whether high-level cognitive processing can penetrate such strong suppression remains a matter of debate. Here we addressed this issue by asking whether individual color preference plays a role in color processing under suppression. In the first experiment, across six colors matched for physical luminance, we measured the time taken for each color to break through suppression and reach conscious awareness. We showed an increase of suppression time from the most preferred color to the least preferred color, suggesting that preference plays a role in how a color reaches conscious awareness. In the second experiment, we selected the most and least preferred colors of each individual participant and matched their perceptual luminance with the minimum motion paradigm. Each round color patch was later interocularly suppressed and presented as an exogenous distractor in the same or different location where a subsequent Gabor patch was presented. Participants were instructed to indicate visibility of the color patch. If no color patch was detected, subsequently, they were instructed to judge the orientation of the Gabor patch. The location of the suppressed distractor was not indicative of the Gabor patch, and its invisibility was later confirmed by chance performance on a location task in every trial. We found a same-location subliminal color distractor significantly slowed down the response time on the subsequent orientation judgment. However, this distracting effect occurred regardless of which color distractor was presented, suggesting that color preference did not exert an additional effect. Overall, these results showed attentional modulation from an unconscious distractor but inconclusive color preference effect under interocular suppression.

56.333 **Exogenous Covert Orientation of Attention to the Center of Mass** Max K Smith[1](maxsmith2022@u.northwestern.edu), Satoru Suzuki[1], Marcia F Grabowecky[1]; [1]Brain, Behavior and Cognition, Northwestern University

Fast eye movements (saccades) play an essential role in the rapid sampling of our visual environment by bringing objects of interest onto the fovea, increasing visual acuity and thus enhancing visual processing. Prior to the onset of these ballistic, overt eye movements, a center of mass (CoM) calculation occurs (Coren & Hoenig, 1972; Findlay, 1982; Kowler, 2011, Van der Stigchel & Nijboer, 2011). Does a CoM calculation occur for covert attention in the absence of eye movements? In two experiments, participants searched for either a target Q in 6 Os or an O in 6 Qs displayed for 150 ms on a 126° arc of an invisible 5º-radius circle. On target present trials, the target was located either at the center of the arc or displaced laterally. If the CoM is important for orienting attention, we hypothesized that targets at the center of the arc would be detected more quickly and accurately than targets off the CoM, but that this effect would be observed only for the attentionally-demanding feature-absent search for an O in Qs. In both experiments, participants were instructed to fixate a central cross for the duration of the trial, and the trial duration was kept short. For the second experiment, we replicated the first experiment and used an eye tracker to verify maintenance of fixation during each trial. As predicted, in both experiments, a search benefit was observed for the feature-absent search condition when the target letter appeared at the center of the search array compared to when it was laterally displaced. No CoM search benefit was observed for the feature-present condition. These results suggest that the CoM calculation is a process that contributes to the orientation of covert attention in addition to contributing to saccadic programming.

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56.334 **Exogenous attention and anticipatory fixational stability**
Mariel S Roberts[1](mariel.roberts@nyu.edu), Marisa Carrasco[1,2]; [1]Dept. of Psychology, New York University, [2]Center for Neural Science, New York University

Goal: Microsaccades (MS, fixational eye movements < 1°) enhance perception by preventing retinal adaptation and increase resolution, but for briefly presented stimuli, they can blur the image and impair performance. Here, we investigated the timecourse of MS frequency during a visual discrimination task with exogenous (involuntary) attention cueing; specifically, how MS rates would vary across the trial sequence according to task events in both the attention and neutral conditions. Methods: Observers performed a 2AFC orientation discrimination task, following a neutral or an attention cue. Four Gabor patches appeared simultaneously at 4 isoeccentric locations (6.4° eccentricity) and observers discriminated the orientation of the target, indicated by a response cue. Task difficulty was equated by adjusting stimulus contrast. Fixation was monitored: right eye position was monitored with an Eyelink 1000 eye-tracker; if observers made a >1° saccade away from central fixation the trial was cancelled and repeated. A standard velocity-based detection algorithm was used to detect microsaccades (Engbert & Kliegl, 2003). Results: Covert attention increased accuracy and shortened reaction time. MS kinematics followed the main sequence, the higher the peak velocity the greater the amplitude. MS rates systematically varied across the trial; they were highest during the intertrial period, monotonically decreased from fixation through the (neutral or 100% valid attention) cue until stimulus onset, and rebounded in the response interval. The MS main sequence, rate and temporal dynamics were similar in both the attention and neutral conditions. In both cases, saccades were very scarce between cue onset and stimulus offset. Conclusions: During a temporally predictable visual discrimination task, in both neutral and attention conditions, observers systematically exhibited MS suppression in anticipation of an upcoming stimulus, likely because greater fixation stability benefits perception of brief stimuli. These results provide further support for the tightly linked relation between oculomotor behavior and perception across time.

Acknowledgement: NIH NEI R01-EY027401

56.335 **The Role of Attention in Amblyopic Global Form Perception**
Priyanka V Ramesh[1](pvr218@nyu.edu), Cindy Forestal[1], Mark A Steele[2], Lynne Kiorpes[1]; [1]Center for Neural Science, New York University, [2]Pediatric Ophthalmic Consultants

Amblyopia is a cortical visual disorder caused by unequal visual input from the two eyes during development. Amblyopes show reduced visual acuity as well as more "global" perceptual losses, such as figure-ground segregation and global form integration. We tested the hypothesis that these losses are due to deficiencies in attentional processing, such that attentional selection favors the better eye. We conducted two studies with amblyopic and visually-typical, 5-10 year old children. First, we used a classical endogenous spatial cueing paradigm to test the children on a shape discrimination task. We found that amblyopic children have intact attentional capacity; there were no significant differences between the performance of visually-typical and amblyopic children, or between the fellow and amblyopic eye of amblyopes. A valid cue improved accuracy and decreased reaction time in all cases, compared with a neutral cue condition. Since attentional capacity was normal in amblyopic children, we then asked whether cueing attention could negate amblyopic deficits in global form perception. Again, using a classical spatial cueing paradigm, we asked whether an attentional cue could improve children's performance on a contour integration task. The task was to discriminate the orientation of an embedded Gabor contour in one of four stimulus patches filled with randomly-oriented Gabors. The child had to select the contour orientation that matched what had appeared at the patch location indicated by a post-stimulus-presentation cue. We found that all children, despite visual condition, benefitted from attentional cueing: they performed significantly better on trials with a valid cue than with a neutral, uninformative cue. Response latency and accuracy both improved as a result of the valid cue. The results show that attentional cueing improves task performance in amblyopic as well as typical children and may be useful in improving higher-order global form perception in amblyopia.

Acknowledgement: Research to Prevent Blindness

56.336 **Does endogenous attention compensate for spatial performance fields?**
Simran Purokayastha[1](simranpurokayastha@nyu.edu), Mariel S Roberts[1], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Purpose: Performance on visual discrimination tasks is better along the horizontal than vertical meridian (Horizontal-Vertical Anisotropy, HVA), and along the lower than upper vertical meridian (Vertical Meridian Asymmetry, VMA). Exogenous (involuntary) attention improves performance to a similar extent across isoeccentric locations. Here we tested whether endogenous (voluntary) attention, known to be more flexible, would perform a compensatory role, with the greatest benefit at the worst location. Further, we predicted that endogenous attention would improve performance at threshold levels. Methods: Observers performed a 2AFC orientation discrimination task, contingent upon contrast sensitivity, while maintaining fixation. The target could appear at any one of 4 isoeccentric locations along the cardinals. Participants were either cued towards a single location (Valid cue) or to all four locations (Neutral cue). On every trial, 4 Gabors briefly appeared simultaneously at all stimulus locations. A response cue indicated the target, for which participants reported the tilt (left or right). In Experiment 1, contrast was constant across locations. In Experiment 2, we obtained contrast thresholds for the 4 locations separately, which were independently adjusted between the main blocks to maintain 80% accuracy at each location. In both experiments, we measured accuracy and RTs for each location during both attention conditions. Results: Observers reliably demonstrated canonical performance fields. In Experiment 1, the effect of attention was more pronounced in the upper vertical meridian, compensating for poor performance at that location. In Experiment 2, observers required the lowest contrast along the horizontal, and the most at the upper vertical meridian, to attain ~80% accuracy in the neutral condition across all locations. Performance in the valid cue condition was similarly effective across locations. Conclusions: Endogenous attention alleviated PF asymmetries when stimulus contrast was constant at all locations, but not when contrast was adjusted to equate performance across locations.

Acknowledgement: NIH NEI R01-EY027401

56.337 **Truly independent? Stimulus- and goal-driven orienting interact at the level of sensory processing**
Mathieu Landry[1](mathieu.landry2@mail.mcgill.ca), Jason Da Silva Castanheira[1], Amir Raz[1,2]; [1]Montreal Neurological Institute, McGill University, [2]Institute for Interdisciplinary Brain and Behavioral Sciences, Chapman University

Prevailing views on attention consider it to be dichotomous, as either stimulus-driven or goal-driven. Previous research suggests that both forms correspond to distinct, independent functional systems. Notably, findings highlight how these systems combine in an additive manner for task performance. At the neural level, however, the independence of stimulus- and goal-driven orienting systems remains unclear. The current study tested whether we would observe an additive or interactive pattern for the combined influence of stimulus- and goal-driven attention across neural markers of attentional processing. Participants (N=24) completed stimulus-driven, goal-driven, and combined attention spatial cueing tasks while we recorded 64 channels electroencephalography (EEG). We evaluated the isolated and combined influence of these attention systems over the P1, a positive, posterior deflection of the EEG signal that peaks around 100-130ms post-target, and the N2pc, a posterior component occurring 200-300ms post-target with a larger negative contralateral deflection compared to the ipsilateral side. Ample research supports the prominent influence of attention on the P1 and N2pc, making them ideal candidates to evaluate the interaction of stimulus- and goal-driven attention at the level of sensory processing. We analyzed behavioral and EEG data via hierarchical regression models and tested the model comprising the interaction between attention systems (alternate hypothesis) against the model solely comprising their main effects (null hypothesis). Behaviourally, we replicated previous findings supporting an additive pattern between stimulus- and goal-driven attention, as their interaction was not reliable. Bayes factor analysis conveyed strong support in favor of the null hypothesis. Conversely, at the neural level, we saw a reliable interaction between stimulus- and goal-driven attention across both the P1 and N2Pc. Hence, while both systems influence early sensory processing in an interactive manner, this particular effect does not emerge behaviourally. These results highlight the nuanced dynamics of attentional processing at the level of brain and behaviour.

Acknowledgement: NSERC and FQRNT

56.338 **Endogenous and exogenous control of visuospatial attention in freely behaving mice.** Wen-Kai You[1](wenkai.you@gmail.com), Shreesh P Mysore[2]; [1]Solomon H Snyder Department of Neuroscience, School of Medicine, Johns Hopkins University, [2]Department of Psychology and Brain Sciences, Krieger School of Arts and Sciences, Johns Hopkins University

Spatial attention, the ability to select and preferentially process the most important stimulus location in the environment at any instant, is critical for adaptive behavior. To uncover neural circuit mechanisms underlying spatial attention control, the use of a genetically tractable system is critical. As a first step in this endeavor, here, we develop in freely behaving mice, parameterized paradigms for visuospatial attention. Using a touchscreen-based operant set-up, we study, explicitly, endogenous as well as exogenous control of visuospatial attention in mice using, respectively, a spatial expectation task and a flanker task. In the spatial expectation task, a single grating stimulus was presented at one of two possible locations for mice to discriminate its orientation. We manipulated the probability of stimulus occurrence of each location, and found that, compared to blocks in which the stimulus was presented with equal probability at two locations, in blocks when the stimulus was presented with 90% probability at one of the locations, mice exhibited better discrimination sensitivity (d') and faster reaction time (RT) at that location. We found opposite effects at the low-probability location. In the flanker task, two grating stimuli were presented simultaneously. The target was always at the same location, and mice were rewarded based on their responses to target orientation. The second stimulus (i.e. flanker), was also a grating whose orientation was either congruent (same) or incongruent (orthogonal) to that of the target. We systemically manipulated the contrast of the flanker, and found that mice exhibited deteriorated d' and slower RT for high-contrast incongruent flankers. Our results reveal systematic changes in d' as well as RT driven either by learned expectation (endogenous influence) or stimulus salience (exogenous influence), consistent with results from similar human studies. Taken together, we demonstrate that mice exhibit behavioral signatures of visuospatial attention similar to that of humans.

Acknowledgement: JHU Catalyst Award and NIH R03HD093995

56.339 **Does a history of involuntary selection generate attentional biases?** Michael A Grubb[1](michael.grubb@trincoll.edu), John Albanese[1], Gabriela Christensen[1]; [1]Psychology, Trinity College

Voluntarily allocating attention to task-relevant features engenders attentional biases for frequently attended stimuli, even when they become irrelevant (ie., selection history). Little is known, however, to what extent effortful, voluntary attention is a necessary component in the formation of such selection biases. Do task-irrelevant, abrupt onsets, which reflexively draw attention to a particular location, engender attentional selection biases for involuntarily attended locations, biases that persist in the absence of explicit exogenous cues?Using a preregistered data collection and analysis plan (accepted, Psychonomic Bulletin & Review, final manuscript in preparation), we manipulated spatial attention during an orientation discrimination task: two Gabor patches (randomly and independently rotated clockwise or counterclockwise of vertical) were simultaneously presented (8º left/right of fixation); a postcue indicated which was the target. To generate different selection histories for left/right locations, we delivered precues more often to one location (2:1 ratio) during the first half of the study (most-cued side counterbalanced across observers, equal numbers valid and invalid trials at each location). In the second half, no precues were presented, and observers continued the orientation discrimination task. If exogenous attentional selection generates persistent biases, performance should be better on the previously most-cued side, relative to least-cued side. As expected, abrupt onsets reflexively modulated visual processing in the first half: task accuracy increased, and RTs decreased, when the precue appeared near the forthcoming target (valid trials), relative to the distractor (invalid trials). When precues were removed in the second half, however, we found no evidence that exogenous selection history modulated task performance: task accuracy and RTs at previously most/least cued sides were statistically indistinguishable; precue-free follow-up sessions (one day and one week later) also showed indistinguishable performance at left/right locations.Thus, unlike voluntarily directed attention, reflexively allocating attention may not be sufficient to engender historically-contingent selection biases.

56.340 **Pedestrians on our campus use "safe enough" crossing behaviors** Bonnie Angelone[1](angelone@rowan.edu); [1]Rowan University, College of Science and Math, Rowan University

Within the past decade there has been an increase in pedestrian deaths and reports of injuries that result in an emergency room visit.Distractions can take away from the cognitive effort needed to focus on safely crossing roadways as a pedestrian.Pedestrians using cell phones significantly presented more unsafe behaviors than iPod users and non-users.Last year at VSS we showed that there were few differences in safety behaviors when comparing pedestrians using their phones and using their headphones to non-users. Only a small number of people were distracted when crossing (24%).We extended this work to examine the number of safety behaviors demonstrated for different crossing locations, gender and phone use.Pedestrians (N=265) were observed as they crossed at three different locations on our campus. Experimenters recorded gender, phone use and particular safety behaviors: pressing the signal button, looking both ways before crossing, waiting for traffic to stop, looking at traffic during the walk and staying within the zebra stripes. After examining the average number of safety behaviors each person exhibited, there was a trend for females (M=3.19, SD=1.12) to use more safety behaviors compared to males (M=2.93, SD=1.18; t(263)=1.78, p=.076) but no differences between phone users (M=3.16, SD=1.03) and non-phone users (M=2.99, SD=1.20; t(263)=.97, p=.33).Each location contained a different kind of crosswalk signal; two contained an immediate press-to-walk signal (one within a traffic circle (M=2.93, SD=1.24) and one on a straight road (M=3.20, SD=1.03)), the third was a typical delayed press-to-walk signal where traffic will get a red light (M=2.94, SD=1.20).Again, each group displayed similar average number of safety behaviors while crossing (F(2,262)=1.68, p=.188. The pedestrian observed were using "safe enough" behaviors as they crossed the road and did not show signs of distractions detrimentally affecting their safety while crossing on a college campus.

56.341 **Mind-Controlled Motion Pareidolia** Allison K. Allen[1](alkallen@ucsc.edu), Matthew T. Jacobs[1], Rupsha Panda[1], Jocelyn Carroll[1], Kathleen Spears[2], Stephanie Chen[3], Nicolas Davidenko[1]; [1]University of California, Santa Cruz, [2]Leland High School, [3]Basis Independent Silicon Valley

Ambiguous motion stimuli can be disambiguated in accord with one's intentional control (e.g., Kohler, Haddad, Singer, & Muckli, 2008). However, past studies have relied on simple ambiguous test stimuli in which motion could be disambiguated in a limited number of directions (e.g., vertical or horizontal). Recently, Davidenko and colleagues (Davidenko, Heller, Cheong, & Smith, 2017) reported illusory apparent motion (IAM), in which random pixel textures refreshing between 1-3Hz elicit percepts of globally coherent motion that can be perceived as moving in any number of directions (diagonal, rotating, contracting, etc.). The current study investigates intentional control of ambiguous motion within the context of IAM. Stimuli consisted of 15 frames of randomized 140 x 140 pixel textures refreshing at 1.5 Hz. In each 10-second trial, participants (n=49) were instructed to intentionally hold horizontal or vertical motion, or change between vertical and horizontal motion as fast as possible, while reporting any vertical or horizontal motion percepts as they occurred by holding down one of two buttons. To account for experimental demand, we confirmed in catch trials that participants correctly reported motion when it was present, regardless of instruction. Results showed a robust effect of instructions on reported percepts, with participants reporting much more vertical (M: 6.2 s) than horizontal (0.3 s) motion during vertical hold trials (t(48)=11.6, p< 0.00001), and much more horizontal (4.7 s) than vertical (0.8 s) motion during horizontal hold trials (t(48)=5.88, p< 0.00001). In contrast, during change trials, participants reported horizontal (2.0 s) and vertical (3.3 s) motion at more comparable rates (although there was a significant vertical bias, t(48)=3.64, p=0.0007). Our results demonstrate that intentional control is possible within the context of IAM.

56.342 **Subtle social cues: Does another person's body orientation direct our attention?** Carmela Gottesman[1](cvgottesman@sc.edu); [1]University of South Carolina- Salkehatchie

The effectiveness of gaze as a directional cue has been demonstrated in many studies but is the body orientation of people in scenes influencing the viewer's distribution of attention? Four pictures of each of 24 scenes were created. A person was always in the middle of the picture and his/her body was oriented either towards the right or the left of the scene. In half the pictures the person was looking in the same direction as their body orientation (profile view). In the other, they were looking at the camera (frontal view). Six versions of each picture were created by adding a small colored cross in different locations in the scene. Participants were asked to locate the cross as quickly as possible. When the person in the scene was turned toward the part of the scene where the cross was, reaction times (RTs) were faster than when the person was turned the other way. This effect was found for both profile and frontal views. There was also an overall effect of view, where RTs for the profile views were faster than for the frontal views. This general effect was likely due to the inhibitory effect of the direct gaze in the frontal view, as the effect was not larger when the person in the picture was looking toward the area of the scene where the cross was compared to the other direction.

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However, when only the crosses in the direct path of the person's gaze in the profile view were compared, participants were faster when the person was looking in the cross's direction. Therefore, we found evidence that while gaze helped when targets were roughly in the line of sight, the bodily orientation of people in the scenes significantly cued larger areas of the scene, influencing viewers' attention distribution.

56.343 **Does everyone see the forest before the trees? An order-constrained analysis of precedence and interference effects in a hierarchical letters task.** Pieter Moors[1](pieter.moors@kuleuven.be), Johan Wagemans[1]; [1]Department of Brain and Cognition, KU Leuven

Inter-individual variability in global/local processing is often quantified through performance on the well-known hierarchical letters task (Navon, 1977). Here, a global letter stimulus is composed of local letters and participants perform a task (e.g., identification) on the global or local letter(s) in global and local attention conditions, respectively. Congruency between levels (e.g., same or different letter) is manipulated. Global precedence refers to faster average response times in the global versus local attention condition, whereas global/local interference refers to slower response times in local/global attention conditions for incongruent versus congruent stimuli. The size of these reaction time differences is used as a quantification of the ease with which individuals can identify the global letter (precedence) or are hampered by incongruency at the other level (interference). However, a quantification of the statistical evidence for or against individual differences in either measure rarely occurs. In this study, we applied order-constrained modelling (Haaf & Rouder, 2017) to three different data sets (N = 275, N = 116, and N = 40) from three different labs. This technique allows researchers to quantify the evidence for inter-individual differences in precedence and interference and, if present, whether these effects vary are in the same direction for everyone. In our two large-N data sets (with only 50-80 trials per condition), we observed that everyone shows precedence, with unconstrained variability (local and global precedence). Furthermore, everyone shows global and local interference, without inter-individual variability. This implies that precedence is not global for everyone and that interference does not vary between individuals, calling into question its usefulness as an individual difference characteristic. However, the data set with 40 observers and 320 trials per condition showed variability for global interference, and zero local interference. A proper quantification of variability in interference thus seems to require many more trials per observer than standard practice.

Acknowledgement: Research Foundation Flanders

56.344 **Influences of Depression on Sustained Attention and Cognitive Control** Max J Owens[1](mjowens@mail.usf.edu); [1]Psychology, Arts and Sciences, University of South Florida Saint Petersburg

Depression is often associated with cognitive control deficits, particularly difficulties inhibiting unintended cognitive and behavioral responses. However, it's unclear how these difficulties contribute to the basic concentration symptoms associated with the disorder, where the ability to focus attention is disrupted. To fill this gap in the literature, this study explored the behavioral and neural characteristics of sustained attention in depression using the well-validated Sustained Attention to Response Task (SART). In the SART participants are presented with a series of digits from 1 to 9, and are instructed to respond as soon as possible with a button press to every digit except 3, in which case no response is made. The requirement to continuously respond to a majority of stimuli elicits automatic responding, which can lead to slips of attention and unintended responses if cognitive control over behavior is not monitored within the task. The current study used temporal principal component analysis, which parametrically separates overlapping event-related potential (ERP) components, to examine 3 ERP components that may be related to concentration difficulties in depression. Two standard components are related to inhibition, the N2 and P3 were observed to be increased during NoGo digit 3 trials, and are considered to reflect conflict monitoring and resource allocation for cognitive control, respectively. An additional late positivity component was also observed that is hypothesized to reflect cortical deactivation of active stimulus processing. Results showed increased levels of depression were associated with increased P3 amplitudes and reduced late positivity amplitudes during the SART. In addition, depression was unassociated with reaction time or error rate decrements. Together results suggest that depression may require increased and sustained effortful task processing to maintain performance. The results support previous evidence that inefficient cognitive control underlies depression and provides important information for describing the mechanisms of concentration difficulties in the disorder.

Acknowledgement: The current study is funded by a University of South Florida, Saint Petersburg New Researcher Award

56.345 **Comorbidity in Anxiety and Depression Influence Neural Responses to Errors: An ERP Study** Catherine L Reed[1](clreed@cmc.edu), Madison Lodge[1], Audrey Siqi-Liu[1], Morgan Berlin[2], Emilia Hagen[3], Adrienne Jo[1], Anthony Burre[1], Jackson Zeladon[1], Abraham Saikley[1], Jessica Kim[1], Cindy M Bukach[4], Jane W Couperus[5]; [1]Psychology and Neuroscience, Claremont McKenna College, [2]Neuroscience, Pomona College, [3]Neuroscience, Scripps College, [4]Psychology and Neuroscience, University of Richmond, [5]Cognitive Sciences, Hampshire College

Mistakes occur daily, but individual's reactions to error are variable. Some individuals are more sensitive to error, their reaction based on perceived negative consequences and a motivation to perform at a high level. A neural index of response monitoring processes, and specifically error responses to visual inputs, is the error-related negativity (ERN). Previous studies have shown that negative affect produces a larger ERN to errors. Despite a high rate of clinical co-occurrences of anxiety and depression, most studies examine anxiety or depression alone and little work has investigated whether the disorders have separate or interacting influences on error processing. This study investigates whether individual differences in anxiety, depression, and their comorbidity are predictive of ERN amplitudes. Participants completed anxiety (BAI: Beck Anxiety Inventory) and depression (BDI: Beck Depression Inventory) inventories and then performed an error-inducing flanker task while EEG was measured: participants determined if a central arrow faced right or left surrounded by arrows facing the same (congruent) or different directions (incongruent). Based on inventory criteria, participants were classified into Healthy, Anxiety, Depression, and Comorbid groups; mean amplitudes for the ERN and CRN (correct response negativity) were calculated. Our results indicate anxiety and depression disrupt visual error processing, but they exert different effects. Compared to the Healthy and Depressed groups who showed greater amplitudes for error over correct responses, the Comorbid group produced strong error responses but did not distinguish neurally between correct and error responses (CRN vs. ERN amplitudes). It is important to account for comorbidity as it is inclusion may explain the literature's mixed results. Further, anxiety and its comorbidity may more debilitating than depression alone for error processing, which has important implications for targeting learning and coping interventions.

Acknowledgement: NSF DUE 1626554, 1625521, and 1625610

56.346 **Has Social Media Altered Our Ability to Determine If Pictures Have Been Photoshopped?** Nicole A Thomas[1](nicole.thomas3@jcu.edu.au), Ellie Aniulis[1], Alessia Mattia[1], Elizabeth Matthews[1]; [1]College of Healthcare Sciences, James Cook University (Cairns)

The prevalence of social media is undeniable; indeed, the majority of people check social media every day. Furthermore, it is increasingly simple to modify photographs prior to posting them on social media, such as Instagram. Given that higher level cognitive factors influence our perception, does repeated exposure to unrealistically thin, idealised pictures of women influence our ability to detect digitally altered images? Across 3 experiments (total N=378), female participants viewed an unaltered image, followed by a noise mask, then an image of the same female model that had been modified (in increments of 5%) to be either larger or smaller than the original. Body shape dissatisfaction, ideal body size, Instagram usage, self-esteem and BMI were also measured. In Experiments 1 and 2, participants indicated, via visual analogue scale, perceived change between images (-30% to +30%). In Experiment 3, participants made a same/different judgment, which allowed for psychophysical curve fitting. Participants underestimated change levels for thin models (Experiment 1: $t(105)=3.737$, $p< .001$, $d=.729$; Experiment 2: $t(137)=8.474$, $p< .001$, $d=1.448$), and overestimated change levels for plus-size models ($t(137)=6.129$, $p< .001$, $d=1.047$). Although participants were accurate in determining whether two images of plus-size models were the same or different ($t(133)=1.784$, $p=.077$, $d=.309$), the second image of thin models had to be significantly smaller than the first for participants to report they were the same ($t(133)=4.408$, $p< .001$, $d=.764$). Overall, participants believed photographs had been modified to a lesser degree than they actually had been, particularly for thin models. We suggest that regular exposure to unrealistically thin, idealised images on social media has changed our perception

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of "normal", leading to the belief that the average body is larger than it truly is. These findings have implications for our understanding of the roles of social media and social comparisons in relation to body image dissatisfaction.

Attention: Features and objects 2

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56.347 **Attentional dynamics during physical prediction** Li Guo[1](lguo15@jhu.edu), Jason Fischer[1]; [1]Psychological and Brain Sciences, Krieger School of Arts & Sciences, The Johns Hopkins University

The ability to anticipate the physical behavior of objects is crucial in daily life. Recent work has shown that in many scenarios, people can generate rapid and accurate predictions of how the physical dynamics of object interactions will unfold. What elements of a scene do people attend to when making such judgments? Here, we used an eye tracking paradigm to characterize how observers moved their attention through computer-generated 3D scenes when predicting their physical dynamics. Participants (n=23) played a "plinko" game which required them to predict the path that a puck would take as it slid down a board and traversed a number of barriers, ultimately landing in one of four bins. Participants decided which bin the puck would land in, and we ran computer simulations of the puck's behavior in each scene to characterize the possible paths that it could take. In line with previous work, we found that observers' predictions were consistent with a noisy Newtonian model – their successes and failures closely matched those of the computer simulation under a small amount of perceptual uncertainty. Moreover, participants' looking behavior revealed that they precisely tracked the anticipated path of the puck, traversing the scene with their attention and anticipating collision points with high precision. The best-fitting model of observers' looking behavior was one in which they tracked the full path of the puck but also spent a disproportionate amount of time analyzing points at which it would collide with the barriers. Critically, this looking strategy was consistent across scenes of varying complexity, while accuracy and reaction times varied and were correlated with the number of barriers present.
Our findings reveal how observers deploy their attention when predicting physical dynamics, and the results highlight the key elements of a scene that observers analyze to make such predictions.

56.348 **Contrasting Relational and Optimal Tuning Accounts in Attentional and Perceptual Selection**Zachary Hamblin-Frohman[1](z.hamblinfrohman@uq.edu.au), Stefanie Becker[2]; [1]University of Queensland

Recent work in attention suggests that selection doesn't simply highlight a single feature value but takes into consideration the visual context. The current study provides a comparison between two theories which account for relationships between targets and non-targets items. The relational theory proposes that instead of tuning to a specific feature value attention is directed towards the relationship between the target and its environment; leading attention to be directed to the relationally strongest items, e.g. the 'reddest' or the 'largest'. In contrast, optimal tuning accounts suggest that this non-veridical tuning arises through shifting of the attentional template. This theory poses that when targets and non-targets are similar the visual system shifts criteria to an exaggerated target feature allowing for more efficient selection. Probe trials show that shifted-feature items are more likely to be recognised as target items. It is, however, unclear if these results represent early selection or perceptual decision making (and associated memory representations). In the current study, participants performed a visual search in a high similarity (between target and non-targets) or low similarity condition, with the target always the reddest orange amongst orange non-target. On some trials singleton distractors were presented ranging from red to yellow. Saccades directed to these distractors allowed for inferences on which feature values captured attention. Masked probe trials were also displayed requiring identification of the search target; measuring perceptual and memory representations. The visual search results showed that saccades were driven solely by relational context, i.e. all redder distractors reliably attracted gaze. In probe trials the shifting effects were replicated, in the high-similarity context shifted distractors were selected more frequently than the target. This suggests that optimal tuning is not an attentional effect effecting early selection, but is instead related to memory and perceptual representations of the target item.

56.349 **Attribute Amnesia Reveals a Dependency on Conceptual Activation for Memory Consolidation** Michael G Allen[1](mgallen@ucsd.edu), Timothy F Brady[2]; [1]Dept. of Cognitive Science, University of California, San Diego, [2]Dept. of Psychology, University of California, San Diego

Recent work has revealed that participants can frequently fail to remember information (e.g., the identity of a letter) even immediately after processing it (finding the letter in a set of numbers to report its color). This 'attribute amnesia' effect (Chen & Wyble, 2015) poses a problem for our intuitions about conscious awareness; how can we not know the identity of a target we just consciously processed and correctly identified as a letter? Chen and Wyble argue that the target identity is perceptually encoded, but not consolidated into memory unless subjects are required to hold it in mind for a few hundred milliseconds. An alternative to this distinction between perceptual encoding and consolidation is to consider whether participants ever consciously process the identity of the letter at all. That is, the connection between a visual stimulus and the concepts activated in its apprehension may not be straightforward; depending on context and task demands, different levels of relevant concepts may be activated. Thus, when searching for a letter amongst a set of non-letter distractors, it may be that only the well-learned concept 'letter' is ever consciously activated, rather than the specific letter identity. To test this, we compared well-established target categories, such as 'letter' and 'number', with less well-established categories, such as 'letter from the second half of the alphabet', using the paradigms of Chen and Wyble (2015). We found that the attribute amnesia effect for target identity disappeared when the target category was not well-established – that is, reporting the color of the 'letter from the second half of the alphabet' reliably led to memory for letter identity, though reporting the color of a 'letter' did not. This result argues for a closer look at the role of conceptual activation and conceptual short-term memory (Potter, 1976) in perception and working memory.

Acknowledgement: NSF BCS-1829434 to TFB

56.350 **Independent attentional resources explains the object-based shift direction anisotropy** Adam J Barnas[1](ajbarnas@uwm.edu), Adam S Greenberg[1]; [1]Department of Psychology, University of Wisconsin-Milwaukee

In a series of recent experiments (cf. Barnas & Greenberg, VSS 2015-18) we demonstrated that reallocating object-based attention across the visual field meridians is faster horizontally than vertically, referred to as a 'shift direction anisotropy' (SDA). We revealed that the SDA is (1) observed whether attention shifts occur within or between objects, (2) not present when targets/objects are sequestered into quadrants, and (3) driven by target, rather than object, location. Here we present a theory, grounded in neurobiology, (along with new data) that accounts for these findings. We theorize that the source of the SDA depends upon anatomical segregations of the visual system that determine the manner in which pools of attentional resources resolve competition between targets. It is well-established that the left/right cerebral hemispheres are organized contralaterally, imposing an interhemispheric boundary along the vertical meridian (anatomically, the longitudinal fissure). Some suggest that this explains independent attentional capabilities between the hemispheres during attentional tracking (Alvarez & Cavanagh, 2005) and visual search (Clevenger & Beck, 2014). Additionally, lower/upper visual field representations are segregated anatomically, forming an intrahemispheric boundary along the horizontal meridian (anatomically, the dorsal and ventral aspects of retinotopic cortex). We extend the independent attentional resources explanation to object-based attention and propose that the SDA occurs due to impaired attentional reallocation across the intrahemispheric boundary. Vertical shifts experience a processing cost because stimuli compete within a single pool of attentional resources, requiring additional processing time to resolve the competition. Conversely, horizontal shifts experience a processing benefit because competition is resolved quickly due to two independent pools of attentional resources. Confirming this hypothesis, our new data show that a perceptually enhanced horizontal meridian is sufficient to create an artificial boundary that further subdivides attentional resources into four pools. As a result, competition across the intrahemispheric boundary is reduced, equating RTs and ameliorating the SDA.

Acknowledgement: US-Israel Binational Science Foundation, University of Wisconsin-Milwaukee Research Growth Initiative, and Greater Milwaukee Foundation

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56.351 **The Symmetry of Deception: Symmetrical Action Influences Awareness by Shifting Event Boundaries** Anthony S. Barnhart[1](abarnhart@carthage.edu), Dillon Krupa[1], Cheyenne Duckert[1]; [1]Department of Psychological Science, Carthage College

Many magical deceptions encourage audiences to interpret incomplete information using assumptions constructed from experience with environmental regularities. Symmetry is one such regularity that magicians exploit. Anecdotally, deceptive actions are more likely to evade detection if they are part of a symmetrical action sequence. This symmetry of action has been stressed in a piece of sleight of hand known as the top change, wherein a playing card in one hand is covertly switched for the top card of a deck held in the other hand. If the action underlying the switch is performed with mirror symmetry (i.e., the hand with a single card approaches the deck and then the hand with the deck retreats in the same direction of motion; see Figure 1), the sleight may be harder to detect. We tested this hypothesis across three experiments, varying the symmetrical qualities of viewed action patterns and the viewing behaviors of participants. Participants watched videos of top changes that were symmetrical or asymmetrical, pressing a button upon detecting a switch. Participants were significantly slower to detect sleights in symmetrical conditions than in asymmetrical conditions, but this tendency was not consistent across all forms of symmetry. We suggest that the symmetrical actions are more likely to be grouped together as a single event, whereas the asymmetrical actions are parsed as two separate events (an approach and a retreat). This parsing can influence memory for and attention to details falling near or far from event boundaries. However, differences in perceived intentionality may also drive variability across symmetry conditions.

56.352 **Putting spatial and feature-based attention on a shared perceptual metric** Daniel Birman[1](dbirman@stanford.edu), Justin L Gardner[1]; [1]Dept of Psychology, Stanford University

Behavioral tasks which engage visual attention ask observers to select some sensory stimuli while ignoring others. Such tasks can be split according to how observers select visual space: either by spatial location or according to stimulus features such as color or motion direction. Most task designs elicit one or the other form of selection--but how do these compare to each other? Here we designed an estimation task to measure perceptual sensitivity to visual stimuli selected by spatial location, feature dimensions, or both. Observers fixated while four patches of colored random dot motion were shown, with each patch moving in a different direction. Two of the patches overlapped on each side of fixation and within each overlapping pair one patch was colored yellow and one blue. Observers were asked to estimate the direction of the dots within a single patch, defined by color (yellow/blue) and location (left/right), using a rotating wheel. This meant that in advance observers could be cued about which side the relevant patch would be on and then post-cued about the color, or vice versa. In control conditions observers were told the exact patch to select in advance, or given no information. We also repeated the task asking observers to estimate the color of the dot patches while cueing by direction (i.e. the four patches had random colors, and moved in one of two directions on each side). A mixture of Von Mises model showed that as expected observers (n=5, >2000 trials each) were more accurate when cued in advance. But we also found that observers were equally capable of using cues about features or location prior to stimulus presentation. Our results suggest that although selection may be implemented in many different ways these all result in a common perceptual improvement.

56.353 **Development of children's capacity for multiple object tracking via multifocal attention** Tashauna L Blankenship[1](shaunalb@bu.edu), Roger W Strong[2], Melissa M Kibbe[1]; [1]Boston University, [2]Harvard University

By at least 6 years of age, children can engage in sustained, multifocal attention to track two moving objects among distractors (Blankenship, Strong, & Kibbe, 2018). Less is known about the development of this ability and its capacity in childhood. We investigated the development (Experiment 1) and capacity (Experiment 2) of multiple object tracking via multifocal attention in children. In Experiment 1, children ages 6-10-years were tasked with feeding an animal (presented at fixation) its favorite food (targets). On each trial, participants saw four dots presented in pairs; each pair consisted of one target and one distractor. The targets briefly flashed, and then target and distractor objects within each pair orbited each other while the pairs shifted across the screen. Children were then probed on one of the pairs and asked to select the target. The targets and distractors were paired to make tracking by grouping cues or by serial foveation difficult (Yantis, 1992). At all ages, children selected the target at above chance levels (all ps< .001), with 7-10-year-olds performing near ceiling. Six-year-olds performed worse than 7-, 8-, 9-, and 10-year-olds (p< 0.001), and there was no difference in performance between 7- and 10-years, suggesting multifocal attention may undergo significant development between 6- and 7-years of age. In Experiment 2 we focused on 6-8-year-olds, and examined how increasing the number of targets and distractors impacted children's ability to track multiple objects via sustained multifocal attention. The task design was similar to Experiment 1, except the number of targets (1-4) and distractors (7-4) varied. Data collection is ongoing, but results suggest a decline in performance as the number of targets increases, with poorer performance for tracking 3 and 4 targets versus 1 or 2. Together, these results shed light on the development and capacity of multifocal attention across childhood.

56.354 **Neural reconstructions of attended object features using fMRI and EEG** Jiageng Chen[1](chen.5805@osu.edu), Emma W Dowd[1,2], Maurryce D Starks[1], Julie D Golomb[1]; [1]Department of Psychology, The Ohio State University, [2]Division of Enrollment Management, The University of Texas at Austin

Spatial attention is thought to play an essential role in selecting relevant information and ignoring irrelevant information. But spatial attention is dynamic, constantly shifting and splitting across multiple objects and locations. How can we measure neural representations of visual features under conditions of dynamic attention, and how do these measurements link with behavior? Both fMRI (e.g., Brouwer & Heeger, 2009) and EEG (e.g., Garcia, Srinivasan & Serences, 2013) have recently been used to reconstruct object features. Here we ask whether these reconstruction techniques can be applied to behaviorally-relevant, attended features (from a multi-item display), and whether the quality of these reconstructions are linked to behavior. In an fMRI task, subjects were briefly shown an array of three colored and oriented gratings. Subjects were then asked to report either the color or orientation of the grating at a spatially pre-cued location. To manipulate dynamic attention, some trials included a second spatial pre-cue at a different location, such that subjects had to covertly shift attention and report the features of the object at the new location. In a similar EEG task, two gratings were shown on the screen, and subjects were asked to covertly attend to one of them to detect subtle orientation changes. Using both techniques, we were able to reconstruct the features of the attended item by applying an inverted encoding model (e.g., Sprague & Serences, 2015). In particular, we achieved reliable feature reconstructions only when the feature was relevant to the current task. Moreover, fMRI neutral reconstruction performance was linked to trial-by-trial behavioral errors. These results emphasize the role of focused spatial attention in the feature-binding process and illustrate the potential of these techniques to provide neural measurements of attended feature representations under dynamic conditions without requiring behavioral responses.

Acknowledgement: NIH R01-EY025648(JG), Alfred P. Sloan(JG)

56.355 **Multiple-object Control Predicts Movements of Attention During Free Viewing** Yupei Chen[1](yupei.chen@stonybrook.edu), Gregory Zelinsky[1,2]; [1]Department of Psychology, Stony Brook University, [2]Department of Computer Science, Stony Brook University

People spend a significant amount of their time freely viewing the world in the absence of a task. The dominant class of models attempting to explain this free-viewing behavior computes saliency, a measure of local feature contrast in an image, to obtain a strictly bottom-up attention priority map. Our contention is that the directionality of attention control may be exactly opposite; that free viewing may be guided by a top-down control process that we refer to as multiple-object search. Unlike standard search in which there is typically only a single target, multiple-object search distributes the target goal over several objects, thereby diluting the contribution of any one and creating a diffuse object-priority signal. To compute this signal we borrowed computer vision methods for localizing a trained object class in an image by backpropagating activity from a high-layer in a deep network to lower layers closer to the pixel space. Several object-localization methods exist, but we chose STNet (Biparva & Tsotsos, 2017) because it is inspired by the brain's attention mechanism. Using STNet we computed an object localization map for each of 1000 categories (ImageNet), which we averaged to create one top-down objectness map. We evaluated our method by predicting the free-viewing fixations in the MIT-ICCV dataset of 1003 scenes. For each scene, the location of maximum object-map activity was selected for fixation, followed by spatial inhibition and the iterative selection of the next most active location until six-fixation scanpaths were obtained. We also obtained scanpath predictions from several bottom-up saliency models. Using vector similarity for scanpath comparison, we found that predictions from objectness maps were as good as those from saliency maps, with

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the best predictions obtained by combining the two. This suggests that top-down attention control signals originating from learned object categories may influence even ostensibly task-free viewing behavior.

56.356 **Crossmodal correspondences between abstract shapes and nonsense words modulate a neuronal signature of visual shape processing** Vivian Ciaramitaro[1](vivian.ciaramitaro@umb.edu), Hiu Mei Chow[1], Erinda Morina[1]; [1]University of Massachusetts Boston, Psychology Department

Crossmodal correspondences highlight naturally occurring associations across our senses. In the bouba/kiki effect, abstract shapes are associated with nonsense words: round shapes matched to /bouba/ sounds and spiky shapes to /kiki/ sounds. Such associations are ubiquitous, found across cultures, languages, and development. We used steady state evoked potentials (SSEPs) to quantify how neural responses to a given visual feature depend on how the auditory feature is associated with the visual feature. We hypothesized enhanced neural responses to the same attended shape (e.g. spiky) for congruent (e.g. /ki/) vs incongruent (e.g. /ba/) sounds. Twenty-four subjects viewed one round and one spikey shape, each half-shape presented in a given visual hemifield. Shapes flickered at different frequencies (5.45, 7.5Hz) and were presented under different auditory conditions: no sound, /ba/ or /ki/ sound (3 Hz).Participants attended fixation to detect a color change, attended a shape to detect a border thickening, or attended a sound to detect a volume change. Signal-to-noise ratios for visual responses (electrodes Oz, O1, and O2) were measured at the fundamental frequencies of stimulus presentation to quantify visual shape processing as a function of attention and crossmodal congruency. We found: (1) enhanced neuronal responses for the attended shape when the unattended sound was congruent vs incongruent, (2) weaker enhancement when the shape was attended versus unattended to attend fixation (sound congruent to attended shape in both conditions) and (3) no difference for an unattended shape if a congruent vs incongruent sound was attended. This work extends studies investigating mechanisms of attention to features across our different senses for naturally occurring but abstract associations.

56.357 **Saccadic Pre-attentive Measures Provide Insight into Illusory Contour Detection in Children** Nicholas C Duggan[1](nduggan1@binghamton.edu), Emily C Blakley[1], Alecia Moser[1], Sarah Olsen[1], Peter Gerhardstein[1]; [1]Binghamton University

Hadad and colleagues (2010) found that the developmental trajectory for processing of illusory contours extends through early childhood, reaching adult-like levels in adolescence. Processing these contours requires interpolation between inducing elements, but assessing interpolation strength has been limited in prior tests (Shipley & Kellman, 1992). In the present study, visual processing of illusory contours in adults and 3- to 9-year-old children was examined using a gaze-contingent visual search task performed using eye-tracking. Participants were presented with inducer arrays; four inducers were arranged to display an illusory square, while others were randomly oriented. Arrays were presented with a set size of 4, 8, or 12 possible target locations. Inducer support ratios (a function of inducer size and spacing) ranged from 0.1 to 0.5. Saccades to the target were used to calculate response accuracy and timing. We also measured search efficiency by evaluating both reaction time across set size to locate the illusory target shape, and the time of participants' initiation of first saccades directed toward the target-defined area of interest. In a follow-up analysis, we sought to determine whether the illusory shape preattentively captured attention immediately after the initial saccade, particularly in children. Adults were considerably more accurate in detecting the illusory shape overall, and accuracy improved with age in children. Accuracy improved with increasing support ratio and this pattern was similar across adults and children. Adults demonstrated clear levels of preattentive detection in that they produced more first saccades to the target than children at most support ratios. Gaze contingent eye-tracking effectively measures attention processes; therefore, our data provide a more precise description of the development of illusory contour perception. This saccadic analysis extends findings and overcomes previous limitations by highlighting instances of maximum interpolation strength as assessed using eye-tracking and underscores prolonged development of contour perception in children.

56.358 **Attentional Color Selection Depends on Task Structure** Madison Elliott[1](maelliott1010@gmail.com), Ronald Rensink[1]; [1]University of British Columbia

Observers on a correlation perception task can select a target ensemble among distractor ensembles, even when the two have extremely high color similarity (Elliott & Rensink, VSS 2018). This does not follow predictions about color systems in feature-based attention (Nagy & Sanchez, 1990). To investigate further, we examined another task where attention is used to select a population for which statistical information is gathered—namely, the estimation of total number of items in one of two intermixed populations on the screen. Our number estimation task used intermixed target and distractor populations of squares that were distinguishable by color and number. Observers were asked to select a target ensemble based on its color (ignoring squares of the other color), and to report how many target color squares were in the display. We used the same experimental color space from Elliott & Rensink (VSS 2018) to vary distractors in equal perceptual steps along CIELAB color axes. This allowed us to examine how number and color feature differences influenced number estimation of the target population—a measure of attentional color selection of ensembles. Number estimation showed no interference from opposite-colored distractors, consistent with past work on visual search (Duncan & Humphreys, 1989), but inconsistent with work on correlation perception (Elliott & Rensink, VSS 2016; 2017; 2018). Targets and distractors of similar color led to large estimation errors, even for colors that could be easily separated in the correlation task. Interestingly, similar color distractors also caused lower estimation slopes, with overly high estimates for low numbers of squares and overly low estimates for high numbers. As such, these results show that the color system used in attentional selection depends on the nature of the task involved.

Acknowledgement: UBC 4-Year PhD Fellowship

56.359 **Surround Suppression in Attention to Spatial Frequency** Ming W.H. Fang[1](fangwan1@msu.edu), Taosheng Liu[1,2]; [1]Department of psychology, Michigan State University, [2]Neuroscience program, Michigan State University

Goal. While feature-based attention (FBA) enhances perception to an attended spatial frequency (SF), the precise profile of such attentional modulation remains unclear. The feature-similarity gain model predicts a monotonic modulation profile. However, the surround suppression model suggests a non-monotonic (Mexican hat) profile. Here, we investigated how the attentional modulation systematically varies as a function of the difference between the stimulus SF and the attended SF. Methods. We employed filtered Gaussian noise stimuli as target and unfiltered noise as mask in a two-interval forced choice paradigm. One interval contained the target of a particular SF and the other interval contained a scrambled version of the target as noise (masks were presented in both intervals to reduce visibility). Participants reported the interval that contained the target in two conditions. In a cueing condition, a fixed SF precue was presented before the stimuli, indicating the target SF in 50% of trials (valid). In the remaining trials (invalid), the target could be ±0.5, ±1, ±1.5, ±2 octaves away from the cued SF. In the neutral condition, no precue was presented which served as the baseline to assess the attentional modulation. Results. There was an enhancement for valid condition relative to the neutral condition. Importantly, for the invalid conditions, we found a suppression at +1 octave followed by a rebound at +1.5 octaves. However, the lower frequencies (i.e., -2 to 0 octaves) showed a monotonic profile. Thus, FBA elicited a surround suppression modulation for higher SF and a feature-similarity modulation for lower SF. This asymmetry in attentional modulation might be related to a wider neuronal tuning bandwidth toward higher frequencies on a linear scale. We performed model simulations to explore the potential interactions between neuronal tuning and FBA's modulation profile.

56.360 **Item-based and feature-based selection in working memory** Jasper E Hajonides vd Meulen[1,2](jasper.hajonidesvandermeulen@psy.ox.ac.uk), Freek Van Ede[2], Mark G Stokes[1], Anna C Nobre[1,2]; [1]Department of Experimental Psychology, University of Oxford, New Radcliffe House, 49 Walton Street, OX2 6AE, UK, [2]Oxford Centre for Human Brain Activity, Department of Psychiatry, Warneford Hospital, Oxford OX3 7JX, UK

The capacity of our brain to maintain visual information in working memory (WM) is limited. One of the ways in which the brain compensates for these limited resources is by employing selective attention. Selective attention serves to prioritise information during perception and also acts on mental representations maintained in WM. So far, studies have shown that retrospectively attending the spatial location of one of the items in WM improves performance on the subsequent recall when asked about a feature of that item. One recent study has shown a performance benefit by selectively attending feature dimensions of items in WM (Niklaus et al., 2017, Scientific reports). However, no study to date has directly compared item-based and feature-based attention nor their neural correlates, and much remains unknown about feature-based attentional cueing. We tested and compared the benefits of retrospective cues (retro-cues) orienting attention to an item location or feature dimension of the memoranda in WM in 30 participants. To chart neural effects, we recorded electroencephalography (EEG). Behavioural results show attentional benefits in both recall accuracy and response onset time following both item and feature cues. We used the EEG data to decode the 4 presented features on every trial and trace sensory and mnemonic representations of each feature following the item-based and feature-based retro-cues. Preliminary data analysis suggests that both item-based and feature-based attention upregulate representations of the task-relevant features compared to task-irrelevant features. The results challenge the strict notion of object binding, where upregulating one feature of an item necessarily upregulates the other feature of the same item in tandem. We argue that WM representations are stored in a goal-oriented format where relevant information – at both the item or the feature-level – can be prioritised in a format that optimises ensuing/anticipated task performance.

Acknowledgement: Wellcome Trust

56.361 **Examining the Role of Objects versus Location in Visual Selection Using Dynamic Displays** Qingzi Zheng[1](qingzi-zheng@uiowa.edu), Cathleen M Moore[1]; [1]University of Iowa

We used Ternus motion to test whether the selection of visual information can be mediated by the perceived object structure of dynamic displays separate from stimulus locations.Ternus displays consist of two cycling stimulus frames, separated by a blank interstimulus interval (ISI) of varying length. Each frame contains (for example) a row of three discs that are translated by one position between frames.At short ISIs, observers tend to perceive "element motion" where a single disc appears to "jump" from one end of the row to the other.At long ISIs, observers tend to perceive "group motion" where all three discs appear to translate back and forth together.These two percepts represent mutually exclusive perceptual organizations of which objects went where (i.e., object correspondence).We added a small gap in the upper-left, lower-left, upper-right, or lower-right of one disc of each of the final two frames of motion.Observers reported whether the final gap appeared on the left or right side of the disc.We measured response time (RT) as a function of ISI (short versus long) and the relative image-locations of the two discs in which gaps appeared (i.e., in the same image-location or adjacent image-locations). When the two gaps were presented in the same image-location, they were perceived as parts of the same object during element-motion (short ISIs), but as parts of different objects during group-motion (long ISIs). The reverse was true when the two gaps were presented in adjacent image-locations. Object status and image location are thereby dissociable through interactions between ISI and image location.In multiple variations of this experiment, reliable interactions between ISI and image location occurred.We conclude that the selection of visual information in dynamic displays is systematically mediated by the object organization of the scene, not simply stimulus location.

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56.362 **Neuronal Mechanisms of Attention Measured Through Multi-unit Recordings in LGN and V1** Makaila Banks[1](makaila.banks@gmail.com), Abhishek Dedhe[1], Tanique McDonald[1], Brianna Carr[1], Marc Mancarella[1], Jackie Hembrook-Short[1], Farran Briggs[1]; [1]Departments of Neuroscience and Brain and Cognitive Sciences University of Rochester

Understanding the neural mechanisms of attention has numerous applications to healthcare, education, and workplace efficiency. Despite its interconnected circuitry throughout the brain, the neurophysiological basis of attention is poorly understood. Previous research has shown that attention has an impact on the activity of single neurons in the visual thalamus (LGN) and primary visual cortex (V1). Our lab followed up on these findings by recording multi-unit activity from neuronal populations in the LGN and V1 while rhesus macaque monkeys were performing covert visual spatial attention tasks. Monkeys were trained to perform a contrast-change detection task and two versions of a discrimination task. All tasks required monkeys to focus on a central fixation dot that cued them to attend toward or away from a drifting grating stimulus placed in the lower hemifield and overlapping the receptive fields of recorded neurons. Monkeys indicated whether or not (contrast-change detection) and which direction (contrast, orientation, or color change discrimination) the grating stimulus changed, receiving a juice reward for correct answers. While monkeys performed these tasks, multi-unit activity was recorded in the LGN and in V1. V1 recording contacts were assigned to supragranular (SG), granular (G) and infragranular (IG) layers. Multi-unit recordings were sorted and analyzed using custom code and attention index (AI) values computed per contact as the difference divided by the sum of multi-unit firing rate across attention conditions. Comparison of the distributions of AI values across structures and layers revealed net suppressive effects of attention, supporting our hypothesis that attention facilitates a minority of feature-selective neurons in early visual structures. Further analysis of the tuning data for each multi-unit could reveal relationships between neuronal feature selectivity and attentional modulation across tasks.

Acknowledgement: This work was funded by NIH (NEI: EY018683, EY013588, and EY025219 to F.B. and EY023165 to J.R.H-S.), NSF (EPSCoR 1632738), and the Hitchcock Foundation.

56.363 **A new method to analyze the variations of neural tuning and its application to primate V1** Xuexin Wei[1,2,3](weixx-pku@gmail.com), Rong Zhu[1,2,3], Liam Paninski[1,2,3]; [1]Center for Theoretical Neuroscience, [2]Department of Statistics, [3]Columbia University

The tuning properties of neurons are often variable, and can be modulated by internal and external factors. Various schemes have been proposed to capture such variations, e.g., gain changes, baseline shifts, tuning shifts and tuning width changes, all of which have profound coding implications. However, neural systems may exhibit a mix of these different effects. Furthermore, neural data in the form of spikes require averaging over trials to obtain the tuning curves. These issues can complicate the interpretation of experimental data. To better characterize the variations of the neural tuning, we developed a new technique based on functional principal component analysis (fPCA). Specifically, we augmented the standard fPCA method by incorporating a Poisson observation noise model. Our new method, Poisson fPCA, takes the spike count data as the inputs, and generates a set of basis functions as outputs, providing a compact summary of the tuning variations. Importantly, our method can capture latent variations of tuning for a pre-specified stimulus dimension, making it different from pure regression-based methods such as generalized linear model (GLM), or latent-based methods such as PCA and its nonlinear extensions. We apply this method to previous published datasets collected from primary visual cortex (V1) of anesthetized primates. While most neurons exhibit gain fluctuations as previously reported, we also found that gain change is not a constant, and is highly correlated with the orientation tuning curve for many neurons. Furthermore, the fluctuations of the whole neural population collectively exhibit low dimensional structure, as well as specific spatial structure. In sum, we developed a new method to extract the variations of the neural tuning. While here we only use it to analyze the variability of orientation tuning in V1, our method is general and could be applied to other brain areas or sensory modalities as well.

Acknowledgement: NSF NeuroNex Award DBI-1707398, The Gatsby Charitable Foundation

56.364 **No modulation by expectation of the sensory response to object images as measured by MEG** Ying Joey Zhou[1](ying.joey.zhou@gmail.com), Alexis Pérez-Bellido[1], Saskia Haegens[1], Floris P de Lange[1]; [1]Donders Institute for Brain, Cognition and Behaviour, Radboud University

Several studies have found that expected stimuli evoke a reduced neural response compared to unexpected stimuli ("expectation suppression"). Using a statistical learning paradigm, we asked whether this neural response difference between expected and unexpected stimuli stems from i) a suppression of the expected, ii) an enhancement of the unexpected or iii) both. On Day 1, participants (N=34) were exposed to 9 leading and 6 trailing images, which were paired such that a leading image was followed either by a specific trailing image ("expected" pair), or by any of the trailing images equally likely ("neutral" pair). Participants' task was to respond when an image was presented upside-down. On Day 2, participants performed the same task, while their neurophysiological activity was recorded with MEG. The same images used on Day 1 were presented, with the only difference being that the leading images of those "expected" pairs were occasionally (8%) followed by any trailing image not paired with them before ("unexpected" pair). Immediately after MEG recording, participants were tested on their knowledge about the image pairs. Surprisingly, we did not observe any modulation of sensory activity by expectation, in either event-related fields, oscillatory low-frequency activity, or high-frequency band activity (70-150 Hz). Our results are unlikely due to participants' ignorance of the predictive relationship between images, given that participants exhibited reliable behavioral benefits for expected pairs in the post-MEG test, when they had to categorize the trailing images as fast as possible. These results are surprising given that robust expectation suppression effects in the visual ventral stream have been reported with statistical learning paradigms in both human fMRI and primate single-cell studies. As EEG/MEG activity primarily reflects population-level post-synaptic potentials generated within the apical dendrites of pyramidal neurons, our results may constrain the type and neural locus of neural activity modulations induced by expectation.

56.365 Effects of random fluctuations in alpha oscillations on orientation detection: an EEG study

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Alpha oscillations are known to impair detection of visual stimuli, but it is unclear if this is due to increased guess rate or decreased fidelity of the mental representation. Here we estimated quality and guess rate as a function of pre-stimulus alpha oscillations using an orientation detection task. In the current study, 21 participants performed a task that consisted of a target pointing in one direction followed by a backward mask. Target orientation was pseudo-randomly chosen from a list of 24 predefined, evenly spaced orientations. Following the mask offset and a 500 ms delay, a response screen appeared where participants used the mouse to rotate the pointing stimuli so that it matches the orientation of the target. Errors were quantified as the difference between the target orientation and the orientation of participants' response stimuli. During the task, EEG was recorded and the power of alpha was calculated on each trial time-locked to the onset of the target. A median split of alpha power prior to target onset was used to separate the trials into high and low alpha power. The errors of each participant on high and low alpha trials were fit to a standard mixture model to get the parameter values g (guess rate) and σ (precision). We found that g was significantly greater on trials with high alpha power compared to low alpha power. In addition, the σ did not differ significantly between low and high alpha trials. These results indicate that random fluctuations in alpha power can influence the biasing of perception but not the precision of mental representations.

56.366 The effect of eccenrticity on electrophysiological markers of attention

Orestis Papaioannou[1,2](orpapa@ucdavis.edu), Steven J Luck[1,2]; [1]Psychology, University of California, Davis, [2]Center for Mind and Brain, University of California, Davis

The N2pc ERP component has been widely used as a measure of lateralized visual attention. It is characterized by a sustained negativity contralateral to the attended location or target, and it is thought to reflect contralaterally enhanced processing of attended information in intermediate-to-high levels of the ventral visual pathway. Given that receptive fields in these areas often extend a few degrees across the midline, it is possible that near-midline stimuli might be processed equally by the contralateral and ipsilateral hemispheres, resulting in a diminished N2pc. However, little is known about the effect of eccentricity on the N2pc component. To address this gap in knowledge, we recorded the EEG while participants performed a discrimination task on stimuli presented at one of five eccentricities (0°, 0.05°, 1°, 2°, 4° and 8° between the inner edge of the stimulus and the midline). We found that the N2pc amplitude remained relatively constant across eccentricities, except for a significantly smaller N2pc at 8°. N2pc onset latency, however, became systematically shorter as the eccentricity increased (up to 4°). We also examined the contralateral positivity that often follows the N2pc. This positivity became progressively larger, and the transition from negative to positive occurred progressively later, as the eccentricity increased. These findings suggest that future experiments looking at the N2pc can be designed with stimuli anywhere within central vision (but not the far periphery) without compromising the N2pc amplitude. Implications about the neural generators of the N2pc are also discussed.

Acknowledgement: Grant R01MH076226 from the National Institude of Mental Health

56.367 Select, response, repeat: Electrophysiological measures of location and response repetition

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In the visual search literature, it has generally been shown that positive spatial priming occurs when a target requiring a discrimination response is presented at the same location as the preceding target. Two recent findings, however, provide important qualifications to such spatial priming.First, although spatial priming may be found with manual discrimination keypress responses, eye movements to repeated locations are inhibited. Second, what have been interpreted as spatial priming effects may largely be due to response repetition, rather than location repetition. Thus, the long-assumed relationship between spatial priming and attention is actually quite unclear. To provide clarity to this situation, we used the N2pc – an electrophysiological index of attentional selection – to reveal the effect of target-location and response repetition on deployments of covert attention. To accomplish this, participants completed a compound visual search task known to yield spatial priming. Each search display consisted of four chipped diamonds forming an imaginary square, centred around fixation. The target was a colour singleton, presented amongst homogeneously-coloured distractors. Participants made two-alternative-forced-choice discrimination responses to the shape of the target. Both the target's shape and location in the search array varied randomly across search displays. As expected, keypress response times (RTs) were faster when the target location repeated instead of switched, but this effect was qualified by the relationship with response repetition: there was a large priming effect if both response and target location repeated, but the priming effect disappeared when responses switched. Importantly, N2pc amplitudes were always reduced when the target location repeated, both when responses repeated and switched. These results suggest that, like overt orienting, covert deployments of attention are biased against a previously attended location, while RTs are facilitated by later decisional processes when the target location and response repeat.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grant to S. Ferber and J. Pratt and NSERC PDFs to H.E.P. Lagroix and M.D. Hilchey.

56.368 Post-stimulus, but not pre-stimulus alpha power changes track visual associative learning.

Kierstin Riels[1](kriels@ufl.edu), Rafaela Campagnoli[1], Nina N Thigpen[1], Andreas Keil[1]; [1]University of Florida

Oscillatory activity in the alpha band (8-13 Hz) is among the most prominent aspect of scalp-recorded EEG signal. Changes in alpha power have been related to a spectrum of behavioral and cognitive processes. Recent research has converged to demonstrate that alpha power is selectively heightened when participants report states of mind-wandering, active imagery, and internal/anticipatory processing, as well as suppression of distracting stimuli. A major portion of this research has involved trial averaging and shown paradigm-specificity along with pronounced inter-individual differences. The present study (N=20) examined the trial-by-trial covariance between occipital alpha power, time-varying associative strength, and self-reported expectancy of aversive events in a conditioning paradigm. A Gabor patch (serving as the conditioned stimulus, CS) was randomly paired with an aversive sound (US) in 60 of 120 trials. Participants were asked to rate the likelihood of a US occurring in the subsequent trial. Occipital alpha levels in the inter-trial interval were analyzed separately as a function of the expectancy ratings and associative strength (previous CS-US pairings). Behavioral data followed the gambler's fallacy effect, in which recently occurring outcomes are rated as less likely to happen in the future. In line with this finding, post-stimulus alpha power following two trials with no US was greater than alpha power following two trials with a CS-US pairing. By contrast, pre-stimulus alpha power following participant reports of high US likelihood in the upcoming trial was greater than alpha power following reports of low US likelihood. Fitting the trial-by-trial variability in alpha power with the Rescorla-Wagner model of associative learning converged with these findings, together suggesting that alpha power is sensitive to visuocortical changes during visual adaptive learning.

56.369 Voluntary attention modulates eye-specific neural responses without awareness of eye-of-origin information

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Attention acts by selectively processing relevant information among vast amount of visual input. Intuitively, top-down attention can only be directed to what we have conscious access of, such as a specific feature, object, or spatial location. Previously in a behavioral experiment we showed that surprisingly voluntary attention can modulate eye-specific visual processing in the absence of explicit knowledge of the eye-of-origin information (Zhang et.al, 2012). In the current study, we aim to provide direct neural evidence for this eye-specific modulation effect of top-down attention. A black mesh grid of 10x10 matrix was presented binocularly as background. Of the 100 grid cells, a quarter of them were luminance modulated at 7.5Hz in one eye, and another quarter were luminance modulated at 10Hz in the fellow eye. In the remaining 50 cells, 25 red and 25 blue dots were presented as monocular cues. The spatial locations of the monocular flickers and cues were mixed and non-overlapping. Observers were instructed to pay attention either to the red or blue dots, to detect occasional changes in dot size. Magnetoencephalography (MEG) were recorded to measure steady-state visual evoked responses (SSVER) to the monocular visual flickers. We found that the

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magnitude of SSVER was significantly larger when the attended dot cues were in the same eye as the visual flicker compared to when they were in different eyes, indicating an eye-specific modulation of neural responses by voluntary attention, despite the absence of awareness of eye-of-origin information.

56.370 **The effect of perceptual load on gaze and EEG signals in multi-target visual search with free eye-movements** Anthony M Harris[1](anthmharris@gmail.com), Joshua O Eayrs[1], Nilli Lavie[1]; [1]Institute of Cognitive Neuroscience, UCL

All search tasks are not created equal. The difficulty of search tasks varies considerably with the perceptual load of the task (Lavie & Cox, 1997; Roper et al., 2013). The neural correlates of perceptual load have typically been examined with tasks that require participants to maintain central fixation. Recently, however, there has been growing interest in investigating the neural correlates of attention in more naturalistic scenarios, such as free viewing, where gaze metrics and neural responses are measured simultaneously while participants explore a display with their eyes (e.g., Kamienkowski et al., 2012). Here we examined the neural correlates of perceptual load with eye-tracking and electroencephalography (EEG) while participants performed a free-viewing multi-target visual search task. Participants searched for either a shape feature (low load) or conjunctions of shape and colour (high load) and responded by holding fixation until the target disappeared (after 500ms), after which the search continued. Participants also detected an infrequent tone presented during fixation or saccade. Tone detection was significantly impaired under high (vs. low) load during both fixations and saccades, confirming the manipulation of perceptual load. Eye-tracking revealed that under high load participants fixated nontargets more often and for a significantly longer duration, and also made significantly shorter saccades, than under low load. EEG responses co-registered to the onset of nontarget fixations and matched for potentially confounding fixation parameters across load conditions, revealed a significantly larger P300 component under high than low load. High load search was also associated with significantly greater fixation-locked ~10 Hz oscillatory alpha power reduction than low load. These results demonstrate that the increased attentional requirements associated with high perceptual load (as reflected in the P300; Kok, 2001) recruit alpha-mediated attentional processes in a gaze-dependent manner under naturalistic search conditions.

Acknowledgement: EPSRC-Jaguar Land Rover TASCC project grant

56.371 **Neural correlates of target enhancement** Janir R da Cruz[1,2](janir.ramos@epfl.ch), Ophélie Favrod[1], Phillip R Johnston[3], Patrícia Figueiredo[2], Michael H Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland, [2]Institute for Systems and Robotics – Lisbon (LARSys) and Department of Bioengineering, Instituto Superior Técnico, Universidade de Lisboa, Lisbon, Portugal, [3]Rotman Research Institute of Baycrest Centre, University of Toronto, Toronto, Canada

When a task-relevant stimulus is presented for a brief duration or with low contrast, neural enhancement is needed to boost the weak responses to the target. Otherwise, the stimulus goes unnoticed, which is the default when the stimulus is task-irrelevant. Here, we used evoked-related potentials (ERPs) to investigate the neural mechanisms of target enhancement. The target consisted of a vernier, i.e., two vertical bars that are slightly offset in the horizontal direction. Observers discriminated the offset direction. First, we compared the ERPs elicited by the vernier when it was task-relevant vs. task-irrelevant. When the vernier was task-relevant, it elicited strong ERPs amplitudes at ~200ms after stimulus-onset with a bilateral negative occipital and positive fronto-central topography. This topography remained stable for around 140ms. When the vernier was task-irrelevant, similar ERPs were elicited but with much weaker amplitudes and for shorter topography durations. In a second experiment, we presented a mask after the target vernier, with varying inter-stimulus-intervals (ISIs). Performance on the target decreased linearly with the ISI, i.e., the shorter the ISI, the worse the performance. Interestingly, the ERPs amplitudes and topography durations decreased with the ISI. When the ISI was 0ms, performance was at chance level and ERPs amplitudes and topography durations were very similar to when the vernier was task-irrelevant. We propose that invisibility can come by either task irrelevance or masking. Under these two conditions, ERPs amplitudes and topographies are identical, suggesting similar brain processing.

Acknowledgement: This work was partially funded by the Fundação para a Ciência e a Tecnologia under grant FCT PD/BD/105785/2014 and the National Centre of Competence in Research (NCCR) Synapsy (The Synaptic Basis of Mental Diseases) under grant 51NF40-158776.

Multisensory Processing: Auditory 2

Tuesday, May 21, 2:45 - 6:45 pm, Pavilion

56.401 **Microsaccades and pupillary responses represent the focus of auditory attention** Hsin-I Liao[1](liao.hsini@lab.ntt.co.jp), Haruna Fujihira[1], Shimpei Yamagishi[1], Shigeto Furukawa[1]; [1]NTT Communication Science Laboratories

Previous studies have demonstrated that microsaccades and pupillary responses reflect visual covert attention (Engbert & Kliegl, 2003; Mathôt et al., 2013). However, it is unclear whether the effect is specific to vision and what processes are potentially underlying. In the current study, we investigated the sensitivities of microsaccades and pupillary responses to covert spatial attention in the auditory domain. In two experiments, participants listened to two different auditory streams presented dichotically through headphones: environmental sounds in experiment 1 and spoken sentences, one by a female and the other by a male, in experiment 2. Before the target presentation, the voice cue 'left' or 'right' (in expt. 1 and 2) or 'female' or 'male' (in expt. 2) was given to define the target sequence. The task was to report the content of the sequence presented in the cued ear after the target presentation. The visual display consisted of a luminance disparity between the left and right visual fields. Participants maintained their fixation at a central point for eye-tracker recording throughout the session from the cue presentation to task-related response. Results showed a decrease in the microsaccade rate corresponding to the cue and target appearances, indicating mental effort and/or attention engagement. There was a transient bias in the microsaccade direction towards the target location within one second after the target onset, but no such bias was found that locked to the cue presentation. In contrast, pupil size changed with the luminance of the attended direction as long as the target location was identified (regardless of whether the target appeared or not), and the effect lasted for several seconds until the response. The overall results indicate that both the microsaccades and pupillary responses reflect an endogenous shift of auditory attention, with processes differing in operating time courses.

56.402 **Neurophysiological responses on size perception: the influence of sound and visual adaptation.** Alessia Tonelli[1](alessia.tonelli@iit.it), Maria Bianca Amadeo[1,2], Claudio Campus[1], Monica Gori [1]; [1]U-VIP: Unit for Visually Impaired People, science and technology for children and adults, Istituto Italiano di Tecnologia, Genoa, Italy, [2]DIBRIS, University of Genoa, Genova, Italy

Size perception is influenced by several visual information such as spatial (Murray et al., 2006; Sperandio et al., 2012) and temporal contextual cues (Pooresmaeili et al., 2013), but there is also a functional contribution from other senses, such as audition (Jaekl et al., 2012; Takeshima and Gyoba, 2013). Moreover, we recently demonstrated how auditory information can influence a visual aftereffect, generated using an adaptation paradigm (Tonelli et al., 2017). In this study, we investigated the interaction between audition and size visual adaptation at the neural level. We modified our previous paradigm, presenting an adapter stimulus of constant size and, in the same portion of space, a test stimulus of three different sizes: half, equal and one fifth bigger than the adapter. We had two condition: one just visual and one in which, at the same time of the test, we bilaterally presented a sound at 9000hz. For each condition, we used the ERPs triggered by the adapter stimulus as baseline to obtain a delta for each size of the test stimulus, by subtracting the baseline from the test ERPs. In the posterior channels, we found different activations based on the size of the test stimulus after adaptation in the earliest (20-70ms) component and in the P1/N1 complex (120-170ms and 220-270ms). Interestingly, this modulation is greater in the presence of the sound that seems to boost the visual ERP components these time windows. Results suggest that auditory cues not only contribute to functional estimation of size perception, but can also influence the effect of visual size adaptation, by increasing the posterior activations.

56.403 **Auditory modulations on visual perception and metacognition** Da Li[1](r05227119@ntu.edu.tw), Yi-Chuan Chen[2], Su-Ling Yeh[1,3,4,5]; [1]Department of Psychology, National Taiwan University, [2]Department of Medicine, Mackay Medical College, [3]Graduate Institute of Brain and Mind Sciences, National Taiwan University, [4]Neurobiology and Cognitive Science Center, National Taiwan University, [5]Center for Artificial Intelligence and Advanced Robotics, National Taiwan University

The visual sensitivity (d') of a picture can be enhanced crossmodally by the presentation of an auditory cue that is semantically congruent rather than incongruent. Nevertheless, whether the metacognitive sensitivity (meta-d') of a picture processing (i.e., the ability to discriminate whether one's own perceptual judgment is correct) can be modulated by crossmodal semantic congruency remains unclear. We examined this issue by measuring the d' and meta-d' in a picture detection task following an auditory cue, and their quotient (meta-d'/d', called M-ratio) is an index of metacognitive efficiency which controls the influence of task difficulty. On each trial, either an object or a scrambled picture was presented briefly and sandwiched by two random-dot masks, and an auditory cue was presented before or simultaneously with the picture. Participants had to detect the presence of an object picture, and then to rate their confidence regarding the detection judgment. The auditory cue and the object picture were either congruent (e.g., a dog barking and a dog picture) or incongruent (e.g., a piano note and a dog picture). When a naturalistic sound was presented 350 ms before or simultaneously with the picture, and when a spoken word was presented 1000 ms before or simultaneously with the picture, the d' and meta-d' were higher in the congruent than in the incongruent condition. Interestingly, the M-ratio was higher in the congruent than in the incongruent condition only when the spoken word and the picture were presented simultaneously, while no such difference was observed in the other three conditions. Hence, hearing a semantically-congruent (as compared to incongruent) auditory cue can facilitate not only the d', but also the meta-d' of visual processing. Seeing an object while hearing its name is unique in that the visual processing is highly efficient from the perceptual up to the metacognitive level.

Acknowledgement: Ministry of Science and Technology in Taiwan (MOST 107-2410-H-715-001-MY2 and MOST 107-2410-H-002-129-MY3)

56.404 **Multisensory Integration of Visual and Auditory Signals during Second Language Learning** Guangsheng Liang[1](guangsheng.liang@ttu.edu), Vinh Nguyen[1], Kimi Nakatsukasa[1], Aaron Braver[1], Tommy Dang [1], Miranda Scolari[1]; [1]Texas Tech University

Extensive research indicates that visual cues are integrated with auditory information to influence speed perception (e.g., the McGurk effect). In a separate line of work, researchers have recently reported that hand gestures are an effective tool to enhance auditory perception during second-language (L2) learning in natural classroom environments. This is particularly true in languages like Japanese, where long and short vowel durations convey meaning in a way that does not exist in English. Here, we investigate whether multisensory integration is the mechanism behind this phenomenon. To remove all co-occurring cues in a natural teaching environment other than the visual gestures, we designed a digital avatar instructor to deliver a 40-minute computer-assisted language training session. Twenty-nine native English speakers enrolled in the beginning or intermediate Japanese were randomly assigned to receive instruction from either a gesturing or stationary avatar, where the inclusion of gestures was the only difference between each. Eye-tracking was performed during training to measure how subjects attended to different elements of the digital environment: they may attend to the avatar's moving mouth (matched with the audio), silent hand gestures signaling the length of the vowel sounds (in the gesture condition), or a blackboard displaying the written target word. Both a perception task and a pronunciation task were given prior to and after training to evaluate the gesture effect. For both the gesture and non-gesture groups, the digital training equally improved perception across all subjects. However, the eye-tracking data showed overtly attending to the gestures when present positively correlated with performance on the perception task. Conversely, attending the blackboard showed the greatest benefit for the non-gesture group. Our study suggests that visual cues may be integrated with auditory signals to disambiguate speed perception during second language acquisition. Furthermore, this effect is modulated by the learner's strategic attention deployments.

56.405 **Statistical learning of cross-modal correspondence with non-linear mappings** Kazuhiko Yokosawa[1](yokosawa@l.u-tokyo.ac.jp), Asumi Hayashi[1], Ryotaro Ishihara[1]; [1]The University of Tokyo

Cross-modal correspondences help us to determine which signals belong together when we receive information from multiple sensory systems. Many studies have shown people exhibit cross-modal correspondences involving features from various, different, sensory modalities. Moreover, some correspondences seem to reflect natural statistical mappings, thus implying that humans may acquire knowledge of cross-modal correspondences through daily perceptual experiences. We have demonstrated that participants can guess relationships between visual space and auditory pitch merely from perceptual experience, and predict visual stimuli according to audio stimuli (Hayashi & Yokosawa, 2018). However, such results can also be explained by considering evidence that they simply applied linear relationships to visual and auditory stimuli instead of assuming continuous relationship. Therefore, the present study aimed to clarify whether people can acquire complicated combinational relationship between visual and auditory feature. In this experiment, 5 or 15 stimulus pairs, presented consecutively, involved a pure tone and a small black disc (on a screen). Disc positions and tone pitch were determined by one of 8 kinds of curvilinear correlations in each trial. Also, the pairs were unrelated in some trials. After exposure to 5 or 15 pairs of stimuli, participants heard a pure tone of a particular (varied) frequency. Next, they guessed the spatial location of the disc previously related to frequency. Results show that participants extracted most of the complicated curvilinear relationships between visual and auditory feature, instead of just relying upon a linear relationship. Furthermore, participants could predict disc spatial positions more precisely after they were presented with 15 pairs of visual-audio stimuli than when they presented with 5 pairs of stimuli. In sum, participants learn perceptual relationships, even curvilinear ones. They can reconstruct non-linear continuous mapping of visual and auditory features from limited experiences.

56.406 **Visual signals removed by opaque contact lens blocks alpha oscillations: Resting state EEG effects** Joseph FX DeSouza[1](desouza@yorku.ca), Nevena Savija[2], Rebecca Barnstaple[1,3]; [1]Centre for Vision Research, Psychology, York University, [2]Biology, York University, [3]Dance, York University

We are interested in quantifying the influence of visual signals in the alpha oscillation when comparing eyes open (EO) and eyes closed (EC) conditions.Alpha rhythms are thought to be generated by reciprocal connections between the thalamus and posterior cortices (visual/parietal), and modulation has been associated with cognitive states including arousal, attention and inhibition. Alpha desynchronization or blocking occurs in EO versus EC conditions.Importantly, alpha oscillations appear to slow/weaken during the aging process in people with Alzheimer's, Mild Cognitive Impairment and Parkinson's disease. Methods: We studied alpha changes over a 6-hour period during which data was collected up to six times in 12-subjects (7 female, mean age = 26.25, range = 21-45) during a resting state EEG paradigm with EO/EC; subjects were fitted with opaque contact lenses after the first two sessions. Our aim was to compare across EO and EC in prolonged blindness of normally sighted participants. Between each six-minute rsEEG session, participants additionally underwent a sound localization task in which they were asked to point their heads to 16-speakers equally distributed in front of them in a dark sound attenuated room (Savija et al 2015, Society for Neuroscience). In all, participants experienced 6 sessions: 1 = Light/sighted, 2 = blindfold, 3 = blind, {90 min}, 4 = blind, {180 min}, 5 = Light/sighted, {+60 min}, and 6 = Light/sighted. Results: At timepoints 3 to 5, which correspond with those in which vision is totally occluded, alpha power decreased in the EC condition, an opposite effect of the historically observed alpha block in EO. At timepoint 6 (5 hours) when the contacts have been removed, there is a residual effect of minimal change in alpha EO/EC. These findings indicate that visual signals exert a high degree of influence in the alpha oscillation, an effect which merits further exploration.

Acknowledgement: NSERC Discovery

56.407 **Multimodal brain regions that process faces and voices** Olga A. Korolkova[1](olga.kurakova@gmail.com), Maria Tsantani[1], Nadine Lavan[2], Lúcia Garrido[1]; [1]Department of Life Sciences, College of Health and Life Sciences, Brunel University London, [2]Division of Psychology & Language Sciences, Faculty of Brain Sciences, University College London

We recognize people based on cues from different modalities, such as faces and voices, but the brain mechanisms underpinning their integration are not fully understood. One proposal is that multisensory information is integrated in dedicated multimodal regions. In two fMRI studies, we aimed to identify brain regions that respond to both faces and voices, and characterize their responses. All participants completed two runs of three functional localizers: visual (silent videos of non-speaking people, and scenes), auditory (voice recordings of people, and environmental sounds), and audiovisual (videos with speaking people, and scenes with respective sounds). Using data from study 1 (N = 30), we conducted a conjunction analysis to identify the multimodal regions. We considered a region multimodal if it responded more to faces, and voices, and people speaking, than to respective control stimuli. The only brain region that consistently showed people-specific activation (24 out of 30 participants) was located in right posterior STS. In study 2 (N = 12, data collection ongoing), we divided each participant's data in two halves. One half was used to define face-selective, voice-selective, and people-specific multimodal regions, and the other half was used to extract mean activation and response patterns in these regions. The people-specific multimodal region in right posterior STS responded significantly more to audiovisual stimuli than to just faces or voices, and it responded significantly

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more to voices than to faces. We then extracted multivoxel response patterns from this region. While face-responsive patterns correlated moderately with voice-responsive patterns, the correlations were significantly higher between the face- or voice-responsive patterns and the multimodal people-specific patterns. These results suggest that not all voxels in the people-specific multimodal posterior STS respond to faces and voices similarly. In sum, the two studies allowed to identify the region in posterior STS that shows consistent people-specific activation across modalities.

Acknowledgement: The study is supported by Leverhulme Trust research grant to Lúcia Garrido (RPG-2014-392).

56.408 **Altered Visual Processing in Migraine Not Associated with Auditory Abnormalities** Sarah M Haigh[1,2](shaigh@unr.edu), Alireza Chamanzar[3], Praveen Venkatesh[3], Pulkit Grover[3], Marlene Behrmann[1]; [1]Department of Psychology and Center for the Neural Basis of Cognition, Carnegie Mellon University, [2]Department of Psychology and Center for Integrative Neuroscience, University of Nevada, Reno, [3]Department of Electrical and Computer Engineering, Carnegie Mellon University

The diagnosis of migraine includes symptoms of photophobia (sensitivity to light) and phonophobia (sensitivity to sound). While there is much evidence for altered visual processing in migraine, there is little support for how auditory processing is affected. In the current study, we directly compared 18 individuals with migraine (12 with aura) and 18 age- and gender-matched headache-free controls on their event-related potentials to visual gratings alternating in contrast at 4Hz or 6Hz (SSVEPs) and auditory tones that were modulated using a carrier frequency at 4Hz or 6Hz (SSAEPs). The power evoked at the second harmonic of the 6Hz SSVEP was significantly greater in headache-free controls compared to individuals with migraine bilaterally over parietal-occipital areas (Cohen's d=0.74). There was no significant group difference in responses to the 4Hz SSVEP (d=0.12). However, there were no significant group differences to the SSAEPs to either the 4Hz (d=0.04) or the 6Hz (d=0.15) tones. This verifies that visual processing is altered in migraine, but offers no support for abnormal auditory processing. It is possible that auditory processing abnormalities are more subtle in migraine or may be specific to a subset of individuals with migraine. Further investigation in to the individual differences in sensory sensitivities in migraine is warranted.

Acknowledgement: CMU BrainHUB NARSAD YI award from BBRF (26282)

56.409 **Maximal Spatial Resolution Predicts Maximal Auditory Sensitivity in Human Adults** Russell Adams[1,2](michelem@mun.ca), Michele Mercer[1]; [1]Department of Psychology, Faculty of Science, Memorial University, St Johns, NL Canada, [2]Discipline of Pediatrics, Faculty of Medicine, Memorial University, St Johns, NL Canada

Purpose: In recent years (VSS 13,14,15), our lab has examined the interactions among different sensory modalities, namely whether there is a relationship between an individual's thresholds across various measures of spatial and temporal vision, hearing, and pain sensitivity.Our results show that in some cases (e.g. spatial contrast sensitivity vs. pain tolerance; contrast sensitivity vs. audibility) individual differences in performance appear to be retained across the senses. In the present work, we extend this work to examine a comparison between the two traditional clinical measures ofhuman vision and hearing, optotype visual acuity and pure-tone audiometry. Methods: Right eyes from 92 young adults, were tested monocularly at 3m witha LogMARletter optotype acuity chart(Precision Vision) . The same adults also completed a full (250 to 8000 Hz) audiometry exam (GSI 17)under-standard staircase test conditions.Only data from the right ear was used for analysis. Order of the hearing and vision tests was counterbalanced across adults. Results: Regression analysis was conductedbetween visual acuityand auditory thresholds ateach frequency and forthe average threshold across all frequencies.Results showed that for most comparisons there was no relationship between anindividual'svisual acuity and his/her auditory threshold. However at 4000 Hz, there was apositive relationship(r = 0.24, p = 0.02), indicating that those with better LogMAR visual acuity also hadsuperior auditory thresholds, at least at that frequency. Conclusions: What is interesting about this finding is thatfor most adults,4000 Hzrepresents the frequency at which we show maximum auditory sensitivity.Likewisevisual acuity is a measure thatassesses spatial vision at its maximal capacity (i.e. vision under high contrast and at its highest spatial frequency). This result suggests that individual adults may show consistency cross-modally at the absolute limits of their respective sensory functioning.

Acknowledgement: NSERC (Canada) Janeway Hospital Foundation

Perception and Action: Models, neural mechanisms

Tuesday, May 21, 2:45 - 6:45 pm, Pavilion

56.410 **Re-analyzing unconscious priming: Is there really an indirect task advantage?** Sascha Meyen[1](sascha.meyen@uni-tuebingen.de), Iris Zerweck[1], Catarina Amado[1], Ulrike von Luxburg[1], Volker Franz[1]; [1]Experimental Cognitive Science, Computer Science, University of Tübingen

Many studies in the field of priming claim that masked stimuli are processed without participants' conscious awareness of these 'prime'-stimuli. Evidence is often based on two tasks: In the 'direct' task, participants try to discriminate or identify the primes and perform close to chance level. This is seen as evidence that participants have no conscious awareness of the primes. Nevertheless, the same prime-stimuli produce clear effects on behavioral or neuro-physiological measures (e.g., reaction times/RTs, skin conductance, EEG, fMRI) in an 'indirect' task where participants respond to another 'target'-stimulus. For example, when prime and target belong to the same category, then there are clear congruency effects (e.g., faster RTs) even though participants only respond to the target but not to the prime. This is seen as evidence that participants discriminated the primes better in the indirect task (unconsciously) than in the direct task (consciously). Such an indirect task advantage (ITA) – that is better discrimination of the prime in the indirect than direct task – would be surprising because the primes are not even task-relevant in the indirect task. Independent of inferences about conscious/unconscious processing we demonstrate that the typical reasoning to conclude an ITA is flawed for statistical reasons. We present a method to re-analyze existing studies based on the typically published results (e.g., t-test or ANOVA). With minimal assumptions, this method allows to test directly whether the indirect task indicates superior processing compared to the direct task. We reanalyzed 13 highly influential studies (overall more than 2800 citations in WebOfScience) and show that – contrary to the original claims of these studies – there is little evidence for better discrimination of the prime in the indirect than direct task. This suggests that some caution is needed with respect to the literature on (unconscious) priming effects.

Acknowledgement: This project was supported by a grant to Prof. Volker Franz by the Deutsche Forschungsgemeinschaft (DFG) within the CRC 1233 "Robust Vision"

56.411 **Is there evidence for unconscious processing of digits?** Iris Zerweck[1](Iris.zerweck@uni-tuebingen.de), Sascha Meyen[1], Catarina Amado[1], Maren Klimm[1], Volker Franz[1]; [1]University of Tuebingen, Department of Computer Science, Experimental Cognitive Science

It is often argued that humans can discriminate stimuli outside consciousness. In a typical paradigm a stimulus (the 'prime') is masked such that participants are hardly aware of it. In a 'direct task,' participants discriminate the prime and are close to chance, suggesting that they do not perceive the prime consciously. In an 'indirect' task, participants discriminate a 'target' stimulus following the prime. Here, the prime has congruency effects on reaction times (participants are faster if prime and target belong to the same category). This is seen as evidence for better discrimination in the indirect task and preserved unconscious processing. However, this reasoning is only correct if the congruency effect is converted to an appropriate discrimination performance and then compared to the discrimination in the direct task (Franz & Luxburg, Psychological Science, 2015). Because this is rarely done, the literature on priming effects needs reconsideration. We performed two studies replicating and extending well established effects (cf. the behavioral experiments of Dehaene et al., Nature, 1998): Primes and targets were digits and participants discriminated their numerical size. In experiment 1 (N=18), we found a congruency effect of 11.3 ms ($t(17)=4.2$, $p< 0.001$) in the indirect task, replicating the literature. However, the discrimination performance in the indirect task (55.3 %) did not exceed the direct task performance (54.1 %, $t(17)=1.1$, $p=0.3$). In experiment 2 (N=20), prime visibility was varied using eight different prime contrasts. We again found congruency effects between 13 and 29 ms (all ps < 0.02), but no better discrimination in the indirect task. These results indicate that --- at least for our stimuli --- there is no better or preserved unconscious processing of the numerical value of digits in cases where conscious discrimination is close to chance.

Acknowledgement: This project was supported by a grant to VHF by the Deutsche Forschungsgemeinschaft (DFG) within the CRC 1233

56.412 **Testing accuracy, additivity, and sufficiency of human use of probability density information in a visuo-cognitive task**

Keiji Ota[1,3,4](keiji.ota.8127@gmail.com), Jakob Phillips[1], Laurence T Maloney[1,2]; [1]Dept of Psychology, New York University, [2]Center for Neuroscience, New York University, [3]Dept of Engineering, Tokyo University of Agriculture and Technology, [4]Japan Society for the Promotion of Science Research Fellow

Eighteen observers viewed samples of dots from a 2D Gaussian pdf on a display. One more dots is about to be drawn and the rewards associated with possible outcomes are marked on the display. What is the probability the next dot will fall into any specified region? What is the expected value (EV) of the dot? We compared human performance in reasoning about pdfs and value to ideal in two experiments. An ideal observer accurately estimates the probability induced on any region and satisfies additivity when estimating the probability of an outcome falling in either two disjoint regions. It also satisfies an additional property: sufficiency. The estimated mean and covariance parameters are sufficient statistics and the ideal observer will correctly ignore everything else. Exp1: Observers saw Gaussian samples of size 5 or 30. They were shown regions R marked on the display and asked to estimate the probability that the next dot from the same pdf would fall in the region. We compared their estimates to the correct estimates (accuracy). There were three types of regions: symmetric S around the mean and the other two being the upper (SU) and lower (SL) halves of S. These triples allowed a test of additivity: P[S] = P[SU] + P[SL]. Exp2: Observers saw similar samples but with a penalty boundary (PB) marked on the display. Observers moved the visible samples (and underlying pdf) to any location on the display. Then a new dot from the translated Gaussian distribution determined a score in the trial. If the point was above the PB they suffered the penalty, if below, the reward decreased linearly with distance from the PB. Results: Observers' estimates of probability were close to accurate but showed highly patterned super-additivity (roughly 7%). Observes violated sufficiency, assigning too much weight to extreme points.

Acknowledgement: KO: Japan Society for the Promotion of Science Research Fellowship, LTM: Guggenheim Fellowship

56.413 **Closed-loop vs predictive control characterized by inverse reinforcement learning of visuomotor behavior during target interception**

Kamran Binaee[1](kamranbinaee@mail.rit.edu), Rakshit S Kothari[1], Gabriel J Diaz[1]; [1]Rochester Institute of Technology

An attempt to intercept a quickly moving object in flight is preceded adjustments to gaze and hand position that can be modeled as an online coupling to visual sources of information about the target's trajectory. However, accurate tracking also requires short-term predictive mechanisms to compensate for visuomotor delay and brief occlusions. In this study, we ask what factors might contribute to the transition from online to predictive control strategies in visually guided actions. Subjects were immersed in a virtual reality ball catching simulation. To vary spatiotemporal constraints on visual tracking and the manual interception, balls approached along parabolic trajectories that varied in approach speed (fast vs slow). To investigate the accuracy of early vs late estimates, an occluder was placed along either the early or late portion of the ball trajectory (early, late, or no occlusion). All 23 subjects missed the ball most often in the early occlusion condition and the fast ball trajectory. Visual tracking and hand positioning varied systematically with both occlusion timing and temporal demands of the task. Although online and predictive control are often characterized as two separate modes of control, there are also intermediate/hybrid solutions. To explore these intermediate modes of control, data were used to train an inverse reinforcement learning (RL) model that captures the full spectrum of strategies from closed-loop to predictive control. Independent submodules characterized the position and velocity of the gaze vector relative to the ball. A comparison of time-varying recovered reward values between occlusion trials and no-occlusion conditions revealed a transition between online and predictive control strategies within a single trial. This suggests an RL based model for prediction vs online control characterized by independent oculomotor reward functions.

56.414 **Alpha Desynchronization is Modulated by Kinematic and Contextual Properties of the Observed Reach**

Rebecca E Hailperin-Lausch[1](rhailper@iu.edu), Elizabeth B daSilva[2], Bennett I Bertenthal[1]; [1]Department of Psychological & Brain Sciences, Indiana University Bloomington, [2]Department of Psychology, Indiana University Columbus

Considerable neurophysiological, neuropsychological, and behavioral evidence suggests that the observation of goal-directed actions is mapped to the motor cortex.Less clear is whether this neural processing is modulated by kinematic and contextual properties.In this study, we test whether EEG alpha desynchronization (8 – 12 Hz oscillations recorded from scalp regions overlying the sensorimotor cortex) is modulated by reach type (ipsilateral vs contralateral) or by the affordances of the object serving as the goal of the reach.Stimuli (Figure 1A) consisted of a 2,000 ms video of an adult male facing the observer and reaching for a cup (1,000 ms) and then holding it (1,000 ms).Twenty-four participants were tested with eight conditions:actor reaching ipsilaterally or contralaterally (hand crossing the body midline); cup oriented either upright or inverted; location of the cup's handle either congruent or incongruent with the reach.There were a total of 408 trials that included 24 probe trials for checking attention.EEG was recorded using an EGI 64-electrode Hydrocel Geodesic Sensor Net, sampled at 1,000 Hz, and segmented into 3,800-ms epochs (beginning 500 ms before and ending 3,300 ms after the onset of the stimulus). Time-frequency analyses were performed on each artifact-free trial with Morelet wavelets at 1-Hz intervals. EEGs from anterior, central, and posterior electrode clusters were analyzed from both hemispheres.The results revealed significantly greater desynchronization (stimulus event – baseline) from central electrodes in the left hemisphere with significant differences as a function of reach type and reach congruency for upright cups only (Figures 1B-C).Observing the video depicting the most discrepant stimulus - incongruent, ipsilateral reaches - resulted in the greatest desynchronization (Figure 1D). These results suggest that alpha desynchronization in the sensorimotor cortex is sensitive to not only goal-directed actions, but also to the reach type and affordance associated with the action.

56.415 **Decision making and avoidance of multiple moving objects**

Cristina de la Malla[1], Albert Castells[1], Joan López-Moliner[1]; [1]Vision and Control of Action (VISCA) group, Institut de Neurociències, Universitat de Barcelona

We often need to make decisions based on visual information we get from continuously changing environments. We here explore how the uncertainty of objects' speed affects decision making in a go/no-go task by analogy to crossing a busy street. Participants stood in front of a large screen, and saw in each trial two groups of three targets approaching the midline of the screen (one group moving leftwards and the other moving rightwards). In the bottom-centre of the screen there was a square that responded to the participants' go/no-go response. Participants had to decide whether to make the square cross the screen in 300 ms without being hit by the moving targets (go) or not (no-go), by pressing one of two keys of an input device accordingly. We manipulated the environment's uncertainty by having each group of targets with no, medium or high variability between the targets' speeds, resulting in 6 conditions (no-no, no-medium, no-high, medium-high, medium-medium, high-high). The average time it took for the groups of objects to reach the midline of the screen (TTM) was 0.6, 0.74, 0.9, 1.10, or 1.34 sec. The conditions and TTM were randomly interleaved across trials. If participants succeeded in making the square cross the screen they won 50 points, but if the square was hit by the moving targets participants lost 200 points. No-go responses were neither rewarded nor penalized. We fit psychometric curves to participants' go responses and compared them with what would be an optimal decision based on the probability of successful go responses across TTM and the reward. Results show that as soon as variability is introduced in a group of targets, the amount of no-go responses increases and decisions deviate from optimal (i.e. under-confident decisions). However, the variability does not influence the number of successful crossings.

Acknowledgement: Funding was provided by the Catalan Government (2017SGR-48) and grant PSI2017-83493-R (AEI/Feder, UE).

Tuesday PM

56.416 **How to move to catch flying balls with updating predictions** Borja Aguado[1,2](borja.aguado@ub.edu), Joan López-Moliner[1,2]; [1]Vision and Control of Action (VISCA) Group, Department of Cognition, Development and Psychology of Education, Universitat de Barcelona, [2]Institut de Neurociències, Universitat de Barcelona

How does an outfielder catch a ball? The mainstream approaches assume that players' behavior is controlled heuristically by online information obtained from the optic flow (e.g. LOT, McBeath, et al 1995 or OAC, Chapman 1968). These heuristics do not consider any predictive component and consequently can't account for unavoidable visuomotor delays. We propose a model that is a generalization of our previous work allowing the observer – at least theoretically – to predict where and when a parabolic flying ball will land. It proposes a prediction that is updated continually as the observer moves as a navigational strategy. We examine how well the model accounts for catching movements collected in one experiment. Participants had to solve a task similar to that of the outfielder problem in an augmented reality setup: We presented them with a soccer ball describing a parabolic movement starting at ($x = 0$, $z = -12$) m, with x and z being lateral and depth positions with respect to the observers' initial position (0, 0). The ball could travel to nine different ending positions that resulted from combining the coordinates $x = (-3, 0, 3)$ and $z = (-3, 0, 3)$ m. The participants used a joystick that allowed them to move in the x-z plane at up to 6 m/s. We showed two different motion durations: 1.5 and 3 s. In both cases, participants used a strategy consistent with the use of a predictive model. Interestingly, when the temporal constraints of the task are more demanding, the predictive strategy produces similar catching movements to those elicited by the heuristics described in the literature. Furthermore, unlike pure online approaches, the interplay of a predictive component allows our model to cope with visuomotor delays.

Acknowledgement: First author is supported by the fellowship FPU17/01248 from Ministerio de Educación (Spain, https://www.mecd.gob.es) The research group was funded by the Spanish government ref. PSI2017-83493-R (AEI/FEDER,UE).

56.417 **Attentional updating of perceived position can account for a dissociation of perception and action** Ryohei Nakayama[1,2](ryouhei.nakayama@gmail.com), Alex O. Holcombe[1]; [1]School of Psychology, The University of Sydney, [2]Center for Information and Neural Networks (CiNet), NICT

It has been proposed that the neural pathways for perception and action depend on distinct visual information. In support of this notion, Lisi & Cavanagh (2015) reported that although internal grating motion can accumulate over seconds into a large illusory position shift, this position shift is not reflected in saccade targeting (action). Another possibility however is that rather than saccades and other actions having privileged access to the correct position, the attention shift thought to precede saccades resets the accumulated position shift to zero. In support of this possibility, here we found that both transients near the moving object and an observer's button press subjectively timed to the object reaching a particular position could reset the accumulation of illusory position shift and, without saccadic eye movements, create an impression of the object jumping back to its actual position. Our results suggest that stimulus-driven attention and attention associated with control of action may update the perceived position of moving objects and mediate the previously reported dissociation between conscious perception and saccades.

Acknowledgement: Japan Society for the Promotion of Science

56.418 **Iron Deficiency Is Related to Altered Behavior After Rewards and Penalties** Lisa De Stefano [1,2](lisa.destefano@ou.edu), Stephanie E Rhoten[1], Michael J Wenger[1,2], Laili Boozary[1], Amy Barnett[1,2], Tory P Worth[3]; [1]Department of Psychology, The University of Oklahoma, [2]Celluar & Behavioral Neurobiology, The University of Oklahoma, [3]Center for Cognitive Neuroscience, Duke University

Iron deficiency (ID) is a highly prevalent nutrient deficiency that has been demonstrated to produce impairments in various aspects of perception and cognition. Animal models of ID have pointed to systematic effects on neurotransmitter synthesis and regulation, particularly with respect to dopamine, which plays a critical role in reward processing and learning. The present study tested the hypothesis that diminished iron levels would negatively affect learning and performance on a probabilistic reward task. Participants were 40 non-anemic women (hemoglobin >= 12 g/dL), 18 iron-sufficient (IS; serum ferritin > 16 μg/L) and 22 iron-deficient (ID; serum ferritin < 16 μg/L). Participants completed a version of the Iowa gambling task with simultaneous electroencephalography (EEG). In the task, there were four decks of cards, of which two were "good" (had net gain) and two were "bad" (had net loss). On each trial, they were offered the opportunity to "play" or "pass" a card from a randomly selected deck. If they chose to "play," a monetary reward or penalty was given. Choice behavior as a function of a previous reward or penalty was examined across groups; in addition, performance was examined with respect to correlations with the iron biomarkers. Results support the hypothesis that ID & IS participants differ in response selection after penalty. ID participants more frequently chose to "play" a deck after a previous penalty from the last encounter with the deck, and serum ferritin levels were negatively related to the proportion of post-penalty "play" selections. Additionally, median reaction times when electing to "play" post-reward/penalty differed by iron status. These results suggest that ID affects responses to rewards and penalties, perhaps due to deficits in encoding contingencies or integrating previous knowledge. EEG was also examined to assess the extent to which these measures correlated with physiological indices of reward processing.

Acknowledgement: University of Oklahoma Vice President for Research

56.419 **Ineffective single-blinding during 1mA transcranial direct current stimulation.** Gemma Learmonth[1,2](gemma.learmonth@glasgow.ac.uk), Larissa Buhôt[1], Lisa Möller[1,3], Robert Greinacher[1,4]; [1]School of Psychology, University of Glasgow, Glasgow, Scotland., [2]Centre for Cognitive Neuroimaging, Institute of Neuroscience and Psychology, University of Glasgow, Glasgow, Scotland., [3]Department of Neurology, University of Lübeck, Lübeck, Germany., [4]Quality and Usability Lab, Technische Universität Berlin, Berlin, Germany.

Introduction: Studies involving transcranial direct current stimulation (tDCS) typically include a "sham" (placebo) condition, with which performance during the "active" tDCS condition is compared. Sham tDCS usually involves only a few seconds of stimulation, and is assumed to be perceptually indistinct from active tDCS on the scalp. For this reason, tDCS is claimed to be an effective means of delivering double-blinded stimulation protocols. However, participants often show above-chance accuracy when asked retrospectively which condition involved sham. We aimed to probe the effectiveness of tDCS blinding in real-time during a reaction time experiment. Method: 32 adults were tested (pre-registered a priori sample size: $d=0.45$, $\alpha=0.05$, power=0.8). A forced-choice reaction time task was undertaken before, during and after active (10min of 1mA) and sham tDCS (20s of 1mA; both with 30s ramp-up/down). Conditions were applied on different days in a counterbalanced, double-blinded, within-subjects design. The anode was placed vertically over the left primary motor cortex (C3) to target the right hand, with the return on the right forehead. For 15min after the tDCS was initiated, 2 probe questions were interspersed within the task at 30s intervals ("Is the stimulation on?" & "How sure are you?"). Results: Active tDCS had no effect on reaction time compared to sham. Weighted responses were calculated for the probe questions, combining the yes/no guesses with confidence ratings. Confidence intervals were distinct for the anodal and sham conditions during most of the active stimulation period. This period began after the sham protocol had ended and lasted until the active stimulation had ramped down. Conclusion: Participants were clearly able to differentiate the active and sham conditions throughout the experiment, indicating that this method of blinding tDCS conditions may be ineffective. These results also add to the recent literature showing small, or no, overall behavioural effects of tDCS.

Acknowledgement: Wellcome Trust

56.420 **White-Matter Plasticity Following Sight-Restoration in Congenitally Blind Patients** Nathaniel P Miller[1](nathaniel.miller@wisc.edu), Tapan Gandhi[2], Pawan Sinha[3], Bas Rokers[1,4]; [1]Department of Psychology, University of Wisconsin – Madison, Madison, Wisconsin, United States of America, [2]Department of Electrical Engineering, Indian Institute of Technology, New Delhi, India, [3]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts, United States of America, [4]McPherson Eye Research Institute, University of Wisconsin School of Medicine and Public Health, Madison, Wisconsin, United States of America

In the developing world congenital cataracts are a major cause of visual impairment. While treatable, poor access to care means that many infants grow up effectively blind. Project Prakash, a humanitarian and scientific initiative based in India, has shown that congenitally blind children who receive cataract surgery in late childhood and adolescence can recover significant visual function. Here we evaluated the neuroanatomical basis for sight-restoration in these patients and its relationship to critical periods of human visual development. We assessed longitudinal white-matter changes in 10 congenital cataract patients (aged 12.6 ± 3.47 years) and 4 socioeconomically-matched controls (aged 16.5 ± 5.92 years) using diffusion weighted imaging (dMRI) tractography. Patients were screened and treated under the purview of Project Prakash (Delhi, India) and received bilateral cataract surgery with intraocular lens implantation. To track postoperative changes in white-matter structure, 1-6 longitudinal dMRI scans (AP phase-encoding, 40-directions, b=1000, 2 mm slices) were acquired for each participant. We assessed the structural integrity of 10 visual and non-visual pathways, measuring changes in mean diffusivity (MD) and fractional anisotropy (FA). We evaluated the effects of age, post-op time, and group (patient/control) on white-matter integrity with linear mixed effects models. Consistent with neural maturation, we found age-related changes in white-matter properties in most pathways. Evaluating structural changes specific to sight-restoration, we found little impact in early visual pathways (optic tract) and most non-visual pathways (both MD and FA FDR>0.05). However, significant effects of cataract surgery were observed in the optic radiation (FA, FDR=0.042), callosum forceps major (MD, FDR=0.015), and cingulum cingulate (MD, FDR=0.021). Critically, the nature of these changes in optic radiation and callosum forceps major depended on age. In summary, our results indicate that while sight-restoration has little effect on early visual pathways, it does lead to white-matter changes in specific later visual and visuo-motor pathways.

Acknowledgement: This work was supported by grants from the Wisconsin Alumni Research Foundation (WARF) and the National Eye Institute (EY020517).

56.421 An fMRI study identifying brain regions activated when performing well-learned versus newly learned visuomotor associations

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The current fMRI study identified brain regions implicated in performing well-learned versus new visuomotor associations. Stimuli were 2 sets of 6 abstract images, each paired arbitrarily with a unique hand gesture. Participants rehearsed one set of pairings over 4 days and learned the other set immediately prior to scanning. Data were obtained for 14 participants, who demonstrated an average 76ms motor reaction time advantage when performing the well-learned associations immediately prior to fMRI scanning. Regions-of-interest for the left lateral-occipital (LO), the left anterior intra-parietal (AIP) and left medial intra-parietal (MIP) areas were obtained by an independent functional localizer. Parameter estimates extracted from these regions demonstrate a greater BOLD response in left LO for new compared to well-learned associations ($t(13) = 3.322$, $p = .006$), but not left AIP or left MIP. Results suggest the left-hemisphere ventral stream is strongly activated before the automatization of visuomotor associations.

Acknowledgement: Australian Research Council DP170103189

56.422 Motion perception, form discrimination and visual motor integration abilities in mTBI patients

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Although former studies demonstrated that patients with mild traumatic brain injuries (mTBI) have abnormal visual motion sensitivityand motor difficulties (Spiegel et al., 2016), little is known about the effect of mTBI on form perception and visual motor integration. The aim of this study was to evaluate temporal resolution, motion, form, form-from motion perception and visual motor integration in mTBI patients. Eleven mTBI patients (2 females, mean age 22.8 years) and ten age-matched controls (4 females) participated in the study. Motion perception was evaluated with the motion coherence test (MC). Temporal resolution was evaluated with the critical flicker fusion test (CFF). Form discrimination was assessed with form coherence test (FC) and form-from-motion test (FFM). VMI-6 was used to evaluate visual motor integration. The MC, FC, and FFM were displayed in a foveal position, while CFF was assessed in central and peripheral positions. Generalized linear models evidenced differences between mTBI and controls in CFF test and in VMI tasks. In details, in CFF test the mTBI patients had lower performances in peripheral temporal resolution processing as compared to controls and in VMI-6 test they had lower motor and visual motor integration abilities. No difference was found between mTBI patients and controls in MC, FC, and FFM tasks showing similar performance in mTBI and controls in motion, form and form from motion perception. These results demonstrated that mTBI is associate with fine motor and visual motor integration deficits and confirmed anomalous temporal resolution in peripheral vision. Although we failed to find a more generalized visual perception impairment in motion and form perception, caution is needed in interpreting this result because of the small sample size.

56.423 A novel approach for the assessment of population receptive field mapping results

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Retinotopic maps estimated via population receptive field (pRF) mapping (Dumoulin et. al., 2008) are influenced by various factors, such as visual stimulus design, fMRI acquisition parameters, preprocessing, analysis and finally, thresholding. Usually decided on a best-practice basis, a threshold of explained variance should remove unreliable voxels, but still retain comprehensive pRF coverage of the visual field in healthy subjects. To this end, we use "quiver plots" to visualize the stability of estimated pRFs between runs based on different explained variance thresholds. Six healthy subjects (age: 25.8 ± 4.5 years; 3 female) were measured on a 3T Siemens TIM Trio scanner. The CMRR multiband sequence (Moeller et. al. 2010) was used to acquire two functional runs with TE/TR = 36ms/1500ms, voxel size = 1mm^3, 28 slices, MB = 2 and 224 volumes per run. The stimulus consisted of a flickering, traveling bar covering the central 18.8° visual angle. A structural MPRAGE image was recorded and segmented with the help of Freesurfer. Functional data was slice-time corrected and realigned using SPM12. PRF maps were estimated on gray matter voxels with mrVista. We created quiver plots by connecting estimated run 1 and 2 pRF centers of the same suprathreshold V1 voxels, where arrows indicate the direction of change. For a typical subject, increasing the threshold of explained variance leads to smaller average pRF center distances (0.98° ± 1.61° visual angle for a threshold of 0%, 0.54° ± 0.41° for 10% and 0.40° ± 0.26° for 50%). As pRF stability increases, pRF coverage of the visual field is reduced. Quiver plots can not only help to determine a sensible threshold of explained variance, but also to visualize differences of pRF mapping runs differing by stimulus, fMRI sequence, preprocessing, analysis or involving artificial scotomata.

56.424 Neural model of the visual recognition of social intent

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INTRODUCTION: Humans are highly skilled at interpreting intent or social behavior from strongly impoverished stimuli (Heider & Simmel, 1944). It has been hypothesized that this visual function is based on high-level cognitive processes, such as probabilistic reasoning. We demonstrate that several classical observations on animacy and interaction perception can be accounted for by simple and physiologically plausible neural mechanisms, using an appropriately extended hierarchical (deep) model of the visual pathway. METHODS: Building on classical biologically-inspired models for object and action perception (Riesenhuber & Poggio, 1999; Giese & Poggio, 2003), by a front-end that exploits deep learning (VGG-16) for the construction of low and mid-level feature detectors, we propose a learning-based hierarchical neural network model that analyzes shape and motion features from video sequences. The model consists of streams for form and object motion in a retinal frame of reference. We try to account with this model simultaneously for several experimental observations on the perception of animacy and social interaction. RESULTS: Based on input video sequences, the model successfully reproduces results of Tremoulet and Feldman (2000) on the dependence of perceived animacy on motion parameters and the body axis. In addition, the model classifies correctly six categories of social interactions that have been frequently tested in the psychophysical literature (following, fighting, chasing, playing, guarding, and flirting) (e.g. Scholl & McCarthy, 2012; McAleer et al., 2008). In addition, we show that the model can be extended for the processing of simple interactions in real-world movies. CONCLUSION: Since the model accounts simultaneously for a variety of effects related to animacy and interaction perception using physiologically plausible mechanisms, without requiring complex computational inference

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and optimization processes, it might serve as starting point for the search of neurons that are forming the core circuit of the perceptual processing of animacy and interaction.

Acknowledgement: HFSP RGP0036/2016 the European Commission H2020 COGIMON H2020-644727, BMBF FKZ 01GQ1704, and BW Stiftung NEU007/1

Attention: Shifting, tracking

Tuesday, May 21, 2:45 - 6:45 pm, Pavilion

56.425 Opposing Contextual Effects of High Dynamic Range (HDR) Luminance Dynamics on Orientation Discrimination

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Luminance can vary widely across a visual scene, by up to 106:1, requiring multiple luminance normalization mechanisms to support visual acuity. Cortical mechanisms underlying brightness perception and acuity are typically studied via laboratory stimuli at ~100:1 luminance contrast ratio ('standard dynamic range,' SDR). How the cortex processes scenes with contrast ratios over 1000:1 ('high dynamic range,' HDR) is poorly understood. We hypothesized that, because visual neurons encode both luminance and orientation, luminance and orientation processing may interact non-linearly during visual recognition depending on luminance dynamics. We measured EEG, eye tracking, and visual discrimination behavior under a two-alternative forced choice (2AFC) task. Stimuli consisted of 45- and 135-deg Gabors presented on a 5 × 5 grid of luminance patches (100:1 patch contrast, 10000:1 peak contrast including Gabors). The target was a contrast blend of Gabors at the two orientations, and subjects indicated via keypress the orientation with the higher contrast. In one condition ('similar'), the co-oriented flanker patches were similar in luminance to the target patch, and in the other condition ('brightest'), the co-oriented flanker patches were the brightest patches. Dependent variables included behavioral response time and accuracy, stimulus and ocular-locked EEG amplitude, latency and frequency, and pupil size. Our results showed that under decreasing luminance, responses are biased towards the orientation of flankers that are similar to the target luminance ('similar' condition), suggesting a facilitation effect that is luminance-context-dependent. The facilitation effect was abolished under the 'brightest,' increasing or stable luminance, and SDR luminance conditions. Under stable luminance and uniform flankers (same luminance and orientation), responses were biased away from the flankers, consistent with assimilation of co-oriented target and flanker Gabors and 'pop-out' of the orthogonal target Gabor. These results suggest that opposing luminance-orientation contextual mechanisms significantly bias orientation discrimination behavior, depending on dynamic luminance normalization and on surround uniformity.

Acknowledgement: Research was sponsored by the Army Research Laboratory and was accomplished under CAST 076910227001 and ARL-74A-HR53

56.426 Effect of blue light on the speed of attention shift

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Recent studies suggest that exposure to blue light not only contributes to vision, but also influences cognitive functions such as alertness, vigilance, and working memory.These blue-light-induced modulations are associated with higher brain activity of locus coeruleus (LC) which tends to facilitate task utility and inhibit disengagement. We hypothesize that blue light exposure would make the participants more difficult to disengage from current task and thus slows down the speed of attention shift. To test this hypothesis, we adopted the clock paradigm introduced by Carlson, Hogendoorn, and Verstraten (2006) to estimate the speed of exogenous/endogenous attention shift. Participants were asked to view ten running clocks shown in an imaginary circle. There are three conditions: in the peripheral-cue condition, the target clock flashed for 83 ms as an exogenous cue; in the central-cued condition, a line pointing to the target clock was presented for 83 ms at the fixation point as an endogenous cue; in the baseline condition, both the cuing line and the subsequently presented flashed clock were shown to guide participants' attention to the target clock, excluding time cost of attention shift as the control. Participants were required to report the time on a target clock when either the peripheral or the central cue were presented. The speed of attention shift was estimated by the time latency between the true and reported cue-onset time. We conducted experiments with blue and green background lights on two separated days. Results showed that latency under the blue background light was longer than the green background light for peripheral cues but not central cues, implying that exposure to blue light slowed down the speed of exogenous attention shift. This discovery expands the range of cognitive functions that could be modulated by blue light.

Acknowledgement: MOST104-2410-H-002 -061 -MY3

56.427 Oscillations modulate attentional search performance periodically

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Is attention processing information continuously, or as a discrete sequence of events, like samples from a video camera? If attention is periodically modulating behavioral performance, it should be supported by periodicity in its neural correlates. Previous studies have shown that attentional performance in visual search—looking for a target among similar looking distractors—is periodic at the theta frequency (~6Hz), and that this periodicity is underlined by brain oscillations at the same frequency. We hypothesize that if oscillations are the support of attentional periodicity, the more time one spends exploring the environment, the longer the neural oscillatory process should last. Participants (n = 12) performed a visual search task (looking for the letter T among Ls) in which we varied the number of elements in the set (4 vs. 8) and simultaneously measured electro-encephalography (EEG). The behavioral data show a better sensitivity and faster reaction time in the smaller set size condition, suggesting that attention was successfully manipulated, with no speed-accuracy trade-off. Moreover, we replicated previous results: the phase of pre-stimulus, spontaneous, low-frequency oscillations predicted attentional search performance, i.e. successful and unsuccessful search trials were associated with opposite oscillatory phases. We further observed that search performance was associated with different amounts of post-stimulus oscillatory phase-locking (i.e. phase coherence across trials) in the alpha (8-12Hz) and theta (4-7Hz) frequencies. The alpha effect peaked early, and was localized in the frontal electrodes. The theta effect peaked later and was localized in the occipital electrodes. We speculate that alpha reflects top-down, voluntary attention, while theta reflects attentional exploration. Our study suggests a close relation between attentional sampling and low-frequency brain oscillations.

Acknowledgement: ERC Consolidator grant P-CYCLES (614244) to RV NRJ grant to RV and LD

56.428 The utility of employing accuracy-based behavioral measures, when conducting psychopharmacological research of attentional performance

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Rationale: Most pharmacological interventions produce effects in multiple neurological networks, and hence have the potential of affecting several different aspects of cognitive function. However, the detailed effects of a treatment on specific perceptual and cognitive processes cannot be readily disentangled by the most commonly used behavioral attention paradigms. Since performance is often both evaluated over several seconds, and not parced into cognitive components, most tests are not sensitive to subtle temporal changes, or to divergent effects between components. Objective: In this talk, we present data from multiple pharmacological experiments in order to probe the utility of applying an experimental paradigm that allows for a description of the temporal dynamics of multiple distinct components of visual attention, when investigating potential effects of pharmacological intervention on visual attention. Methods: In a range of randomized double-blind placebo-controlled designs, young healthy human participants were tested on multiple attentional parameters, before and after receiving either a 3-week SSRI intervention, an acute nicotine treatment, or an acute NET/DAT-inhibitor treatment. Data were modelled with a computational theory of visual attention to derive independent estimates of five distinct components of visual attention. Results: The pharmacological interventions can produce diverse effects on different components of attentional function. Some of these effects are only seen at specific time scales. Conclusions: The talk will provide a novel description of the attentional dynamics affected by the pharmacological interventions in question. The methodological background for finding these differences is discussed, through the comparison of our data to previous findings and reviews on pharmacological attention effects. Thus, we aim to accentuate the utility of employing accuracy-based, behavioral measures of attentional performance when conducting psychopharmacological research.

56.429 **Pre-target oculomotor inhibition reflects temporal certainty** Shlomit Yuval-Greenberg[1,2](shlomitgr@tau.ac.il), Noam Tal[1]; [1]School of Psychological Sciences, Tel Aviv University, [2]Sagol School of Neuroscience, Tel Aviv University

Recent studies suggested that eye movements are tightly linked to temporal expectations. In these studies, target's temporal predictability was manipulated between blocks to be either completely predictable or unpredictable (varied randomly between a 4-5 options). Findings showed that, prior to target onset, oculomotor behavior was reduced in the predictable blocks relative to the unpredictable blocks. This oculomotor inhibition (OI) was interpreted as reflecting the formation of temporal expectations. However, it is still unknown whether the OI effect is a local or a global expectation effect: Does it reflect the global state of certainty during the predictable blocks? or the local trial-by-trial level of certainty regarding the time of specific targets? We examined this question by modulating the degree of certainty regarding the target time, in an orientation-discrimination task. Trials consisted of a cue, which was followed, after 1 or 2 seconds ("foreperiod"), by the target - a slightly-titled Gabor patch. The degree of certainty was manipulated between blocks by changing the distribution of foreperiods to: (1) Highly-certain (100% fixed foreperiod); (2) Partially-certain (one foreperiod in 80% of the trials and another in 20%); and (3) Highly-uncertain (20% for five different foreperiods). Local certainty was examined by comparing trials with 100%, 80% and 20% foreperiod-probabilities. Global certainty was examined by comparing targets of 20% foreperiod-probability of the partially-certain condition, with those of the highly-uncertain condition. Results showed that, for the 1s foreperiods, OI was enhanced by local certainty (100% > 80% > 20%). No effect of local certainty was found for the 2s foreperiods. However, for 2s foreperiods, OI effect was enhanced by global certainty. No similar effect was found with 1s foreperiods. We conclude that in different contexts OI reflects both local and global temporal certainty levels.

56.430 **Selection from concurrent RSVP streams: attention shift or buffer read-out?** Charles J H Ludowici[1](charles.ludowici@sydney.edu.au), Alex O. Holcombe[1]; [1]School of Psychology, The University of Sydney, Australia

Selection from a stream of visual information can be elicited via the appearance of a cue. Cues are thought to trigger a time-consuming deployment of attention that results in selection for report of an object from the stream. However, recent work using rapid serial visual presentation (RSVP) of letters finds reports of letters just before the cue at a higher rate than is explainable by guessing. This suggests the presence of a brief memory store that persists rather than being overwritten by the next stimulus. Here, we report experiments investigating the use of this buffer and its capacity. We manipulated the number of RSVP streams from 2 to 18, cued one at a random time, and used model-based analyses to detect the presence of attention shifts or buffered responses. The rate of guessing does not seem to change with the number of streams. There are, however, changes in the timing of selection. With more streams, the stimuli reported are later and less variable in time, decreasing the proportion reported from before the cue. With two streams - the smallest number of streams tested - about a quarter of non-guess responses come from before the cue. This proportion drops to 5% in the 18 streams condition. We conclude that it is unlikely that participants are using the buffer when there are many streams, because of the low proportion of non-guesses from before the cue. Instead, participants must rely on attention shifts.

56.431 **TVA in action: Attention capacity and selectivity during coordinated eye-hand movements** Philipp Kreyenmeier[1,2](philipp.kreyenmeier@googlemail.com), Nina M Hanning[1,3], Heiner Deubel[1]; [1]Allgemeine und Experimentelle Psychologie, Ludwig-Maximilians-Universität, Munich, Germany, [2]Graduate Program in Neuroscience, University of British Columbia, Vancouver, Canada, [3]Graduate School of Systemic Neurosciences, Ludwig-Maximilians-Universität, Munich, Germany

Goal-directed eye and hand movements are preceded by attention shifts towards the movement targets. Whether attentional resources can be allocated independently towards multiple effector target locations or whether a single attentional system underlies target selection for multiple effectors, is controversially debated. Here, we used the TVA approach (Theory of Visual Attention, Bundesen, 1990) to measure the distribution of attentional resources before single and combined eye-hand movements. We applied a whole report paradigm in which six letters arranged in a semi-circle were briefly (17-167ms) presented. Observers (n=8) performed single eye or hand movements, or combined eye and hand movements to centrally cued locations. Gaze and finger positions were recorded with a video-based eye-tracker and a touch screen. We used letter categorization performance as a proxy of attentional capacity and modelled the data according to the TVA framework. Additionally, we used the TVA-model to estimate the probability of correct categorization at motor targets and non-targets to evaluate attention selectivity. This allowed to directly determine attention capacity (processing speed) at multiple, movement-relevant and -irrelevant locations within a single trial. Our results show that total attention capacity is constant across the different action conditions and does not increase with the number of active effectors. However, attention is predominantly allocated towards the movement-relevant locations. The data demonstrate that attentional resources can be allocated simultaneously and independently towards both, eye and finger targets during the combined movements without competition, although associated with attentional costs occurring at movement-irrelevant locations. Overall, our findings suggest that attention can indeed be allocated towards multiple effector targets in parallel, as long as sufficient attentional resources are available. They also demonstrate, for the first time, that the TVA framework can be used as a sensitive tool to measure action-related shifts of visual attention.

Acknowledgement: This work was supported by the Deutsche Forschungsgemeinschaft, grants GI964/1-1 and DE336/5-1

56.432 **Effects of Wider Fields-of-View on Multiple-Object Tracking** Daniel Smith[1](dcsmith4@shockers.wichita.edu), Rui Ni[2], Dominic Canare[3], Brad Weber[4]; [1]Human Factors Psychology, College of Liberal Arts & Sciences, Wichita State University

Previous multiple-object tracking (MOT) studies have mainly focused on measuring tracking performance in a field-of-view (FOV) below 35° (Franconeri, Jonathan, & Scimeca, 2010; Meyerhoff, Papenmeier, Jahn, & Huff, 2016; Pylyshyn & Storm, 1988). However, real-world MOT tasks (e..g. driving, playing sports) require observers to track multiple objects in a much wider FOV. Objective: This study aims to test several hypotheses regarding MOT performance in wide FOVs: H1, the definition of close interactions (Factor 1) should scale up to account for cortical magnification in the periphery; H2, the duration of close interactions (Factor 2) should have a negative impact on tracking performance; H3, a wider FOV (Factor 3) will impair tracking performance due to a decrease in spatial resolution and attentional processing efficiency with increasing retinal eccentricity. Method: A within-subject design was used to measure MOT performance under three different conditions of FOV, including 34°, 44°, or 54°. Four targets and four distractors were presented to 21 undergraduate participants in each of the 30 trials in each FOV condition. Results: The data was analyzed using a general linear model. The results showed that tracking performance was significantly impaired by a wider FOV. Contributions of each factor were determined by calculating the change in Akaike information criterion (AIC) when said each of the three factors was added to the model. Conclusions: Hypotheses 1 and 3 were supported, but hypothesis 2 was not. Therefore, the results showed that both spatial resolution and attentional processing have contributed to the decreased MOT performance in wider FOVs. The current study suggests that an ecologically valid MOT test should take a wider FOV into account when being used to predict task performance in real-world environments (e.g. driving, sports playing).

Acknowledgement: Acknowledgment: Research reported in this abstract was partially supported by the Cognitive and Neurobiological Approaches to Plasticity (CNAP) Center of Biomedical Research Excellence (COBRE) of the National Institutes of Health under grant number P20GM113109.

56.433 **Jointly perceiving physics and mind** Haokui Xu[1](haokuixu@g.ucla.edu), Ning Tang[1], Mowei Shen[2], Tao Gao[1,3]; [1]Department of Statistics, UCLA, [2]Department of Human Behavior and Psychological Sciences, Zhejiang University, [3]Department of Communication, UCLA

Physics and mind are "dark matters" governing the structure of a visual scene. Even a simple physics-mind combination can generate remarkably rich events. In a leashed-chasing display introduced here, a disc ("wolf") has the mind of chasing another disc ("sheep"), while the wolf is physically constrained by a leash controlled by a third disc ("master"). Competing forces from physics and mind can cause complicated motions, such as a wolf being dragged away from the target it is chasing. Therefore, the task of vision is to jointly infer the physics-mind combination that can best explain the

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observed motions. Guided by this theory, we demonstrate four discoveries with the leashed-chasing display. First, social perception of the wolf's mind is robust, even when its motion severely deviates from its goal, provided the deviation can be explained away by physics. Second, social perception is robust even when the wolf is not shown as an isolated object by explicitly drawing a line connecting it to its master, provided the line is modeled as a physically realistic spring. Third, disrupting physics impairs social perception. By simply offsetting the master's trajectory by 500ms in the visual display, the wolf-master system cannot be modeled by any intuitive physics. Accuracy of perceived chasing dropped dramatically, as there was no physics to "explain away" the wolf's deviation from its goal. Fourth, disrupting an agent's mind impairs the perception of physics. The mind of the wolf is disrupted by making it chase a "phantom", achieved by turning its target invisible. Observers were asked to report whether the leash is a physically realistic spring, or just an arbitrary line connecting two independently moving objects. The results showed that accuracy of spring detection dropped dramatically when the wolf's mind was disrupted. These results collectively demonstrate a joint perception of physics and mind.

56.434 **Multitasking and MOT in bilinguals** Josee Rivest[1,3](jrivest@yorku.ca), Ana Janic[1,2], Patrick Cavanagh[1,3,4]; [1]Department of Psychology, Glendon College, Toronto, ON, Canada, [2]Institute of Medical Sciences, University of Toronto, Toronto, ON, Canada, [3]1. Centre for Vision Research, York University, Toronto, ON, Canada, [4]1. Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH, USA

Introduction. Speaking more than one language has been associated with enhanced cognitive capacities (e.g. Bialystok & Craik, 2010; Kapa & Colombo, 2013, Bialystok & Viswanathan, 2009, Marian & Shook, 2012). Here we evaluated whether bilingual individuals also have advantages in a purely visual task: attentive tracking. Method. Adult bilingual (n=35, age: M = 20.03, SD = 2.74) and monolingual (n=36, age: M = 20.43, SD = 3.06) participants ran in the Multiple Object Tracking task (MOT, TELlab) in which three out of eight randomly moving disks were targets. To determine a 75% correct speed threshold, the speed of the disks increased from 3.58 to 8.68 deg/s across 5 sessions. In one condition, the MOT was performed while participants counted backward out loud in their mother tongue, and in a second condition, it was performed without the distracting task. Results. As expected, the speed threshold was lower (performance is worse) when counting backward for both monolinguals and bilinguals, $F(1, 68) = 436.94$, $p < 0.000001$, $h2 = 0.87$, $\alpha = 1.00$. Without distraction, the bilinguals' threshold did not differ from that of monolinguals' (6.80±0.84 vs 7.19±0.92 deg/s), whereas with distraction, bilinguals's threshold was significantly higher (better) that of monolinguals [5.84±0.89 vs 4.36±0.62 deg/s (interaction between the Language Ability and Distractor, $F(1, 68) = 106.27$, $p < 0.000001$, $h2 = 0.61$, $\alpha = 1.00$). The difference in the effect of distraction is striking: for bilinguals, counting backward barely decreased their threshold (0.96 deg/s), but, for monolinguals, it decreased three times as much (2.94 deg/s). Conclusion. Bilingualism confers advantages in a purely visual attention task when multitasking is required. Our results represent additional evidence that bilingualism affords cognitive benefits beyond that of verbal domain.

56.435 **Tracking multiple moving auditory targets** Lauri O Oksama[1,2,3](loksama@utu.fi), Timo Heikkilä[4], Lauri Nummenmaa[4], Jukka Hyönä[4], Mikko Sams[5]; [1]Human Performance Division, Finnish Defence Research Agency, [2]National Defence University, [3]Academy of Finland, [4]Department of Psychology, University of Turku, [5]Department of Neuroscience and Biomedical Engineering, Aalto University

Multiple identity tracking – tracking of distinct moving objects - has been studied in the visual modality for 15 years (see Oksama & Hyönä, 2004, 2008, 2016; Horowitz et al., 2007). However, the visual modality is not the only modality to be used for tracking moving object identities in every-day environments. In real-life there are many occasions when we do not see the targets but we can hear them. For instance, in the military context, a dismounted soldier may hear gunshots around him/her without seeing the shooters. It is extremely important for him/her to able to track the whereabouts of the auditory sources. This raises an important question of the efficiency of tracking multiple moving target identities in the auditory modality. Is the tracking capacity for the auditory modality similar to that in the visual modality (estimate is about 2-3, see Horowitz et al., 2007; Oksama & Hyönä, 2008)? Maybe the auditory modality makes multiple identity tracking more difficult? Alternatively, the capacity limitation may be constrained by higher level cognition and would not be affected by modality. To our knowledge, there is no previous research on this matter. To study this question, we conducted an old-school non-computerized auditory tracking experiment in a gym hall. Participants (N=30), seated in the center of the hall, tracked distinct moving auditory target identities. Four assistants moved quasi-randomly around the blindfolded participant and at the same time repeated orally their names. Two, 3 or 4 moving assistants were designated as targets. The results showed that the auditory tracking accuracy decreased sharply as a function of target-set size (2 targets: 86%; 3 targets: 72 %; 4 targets: 57%). The comparison of the present results to visual tracking suggests that the auditory tracking capacity is much smaller than visual capacity, maybe only a bit more than one target.

Acknowledgement: Academy of Finland, grant #273413

56.436 **Orienting attention based on the gaze of a dog** Tazeen Ishmam[1](tazeen_ishmam@mymail.eku.edu), Muna Amry[1], Shane Baker[1], D. Alexander Varakin[1]; [1]General Psychology, Eastern Kentucky University

Other people's eye gaze is a cue for observers about where to direct attention. Research suggests that gaze cues induce rapid and automatic attentional shifts (Ristic et al., 2007, Psychonomic Bulletin & Review). Research also indicates that dogs respond to human gaze cues (e.g. Duranten et al., 2018, Royal Society Open Science). Do humans orient attention based on dog gaze cues? We used a gaze cueing paradigm with photorealistic and emoji versions of human and dog faces. On each trial, a face appeared, shifted gaze left or right, and after a 100-, 200-, or 400-millisecond stimulus onset asynchrony (SOA), a target appeared on the left or the right. The gaze cue was non-predictive, being valid on 50% of the trials. Participants (N = 72) responded based on target location. With mean response time (RT) as the dependent variable, there was a statistically significant validity effect that was qualified by several significant interactions, including a four-way interaction that included SOA, whether the picture was an emoji or not, and whether the face was human or dog. A cueing effect (faster RT for valid than invalid trials) was obtained with each face type at each SOA. For the dog face and human emoji, the cueing effects were 24ms and 29ms (respectively) at the 100ms SOA, but declined to 5ms and 12ms (respectively) at the 400ms SOA. The cueing effect for the human face and dog emoji were less affected by SOA. The human face cueing effect was 13ms at the 100ms SOA, and about 8ms for longer SOAs. The dog emoji cueing effect was 7-8ms for each SOA. While this specific pattern of data may be due to the particular faces we used, the results nonetheless demonstrate that humans may shift attention based on dog gaze cues.

56.437 **The Influence of Context Representations on Cognitive Control States** Reem Alzahabi[1](reem.alzahabi@tufts.edu), Erika Hussey[1,3], Matthew S Cain[1,3], Nathan Ward[2]; [1]The Center for Applied Brain and Cognitive Sciences, Tufts University, [2]Department of Psychology, Tufts University, [3]U.S. Army Natick Soldier Research, Development, and Engineering Center

Cognitive control operates via two distinct mechanisms, proactive and reactive control.These control states are engaged differentially, depending on a number of within-subject factors, but also between-group variables. While research has begun to explore if shifts in control can be experimentally modulated, little is known about whether context impacts which control state is utilized.Thus, we explored if contextual factors temporarily bias the deployment of a particular control state.Participants were exposed to a context manipulation designed to promote proactive or reactive processing, followed by an AX-CPT task, where we assessed immediate transfer on preferential adoption of one control mode over another. The context manipulation involved a task-switching paradigm, where a randomly selected cue on each trial indicated to participants to either classify a number as odd/even or a letter as consonant/vowel.The context varied such that the preparation time for task-switching was either short or long to prompt reactive and proactive states, respectively.In the AX-CPT task, participants were asked to make a target response when they detected an "AX" sequence in a continuous stream of letters.In combination with performance on AX trials, non-AX pairs, (AY, BX, and BY), were used as measures to delineate the strategic effects of proactive and reactive control.Results revealed that following both short and long preparation contexts, participants equally engaged proactive and reactive control.Average error rates, $F(1, 43) = 0.30$, $p = 0.59$, and response times, $F(1,42) = 0.03$, $p = 0.87$, in the AX-CPT were no different as a function of context.Three other indices reflecting the use of proactive control (d'-context, A-cue bias, and the Proactive Behavioral Index) were also computed, and revealed no significant differences as a function of context.Together, these data suggest that contextual representations may not always impact which cognitive control state is utilized.

Tuesday PM

56.438 **Hierarchical motion structure is employed by humans during visual perception** Johannes Bill[1](Johannes_Bill@hms.harvard.edu)**,** Hrag Pailian[1]**,** Samuel J Gershman[1]**,** Jan Drugowitsch[1]; [1]Harvard University

Making sense of the hierarchical arrangement of form and motion is central to visual scene perception. For example, while driving, other vehicles' locations must be anticipated from the traffic flow even if they are temporarily occluded. Despite its ubiquity in everyday reasoning, surprisingly little is known about how exactly humans and animals employ motion structure knowledge when perceiving dynamic scenes. To investigate this question, we propose a formal framework for characterizing structured motion and generating structured motion-stimuli, which supports a wide range of hierarchically arranged real-world motion relations among stimulus features. A key benefit is that the joint distribution of generated stimulus trajectories is analytically tractable, which allowed us to compare human performance to ideal observers. To do so, we first introduced structured motion in the well-established multiple object tracking task. We found that humans performed better in conditions with structured than independent object motion, indicating that they benefitted from structured motion. A Bayesian observer model furthermore revealed that the observed performance gain is not due to the stimulus itself becoming simpler, but due to active use of motion structure knowledge during inference. A second experiment, in which trajectories of occluded objects had to be predicted from the remaining visible objects, provided a fine-grained insight into which exact structure human predictions relied on in the face of uncertainty: Bayesian model comparison suggests that humans employed the correct or close-to-correct motion structure, even for deep motion hierarchies. Overall, we demonstrated – to our knowledge – for the first time that humans can make use of hierarchical motion structure when perceiving dynamic scenes, and flexibly employ close-to-optimal motion priors. Our proposed formal framework is compatible with existing neural network models of visual tracking, and can thus facilitate theory-driven designs of electrophysiology experiments on motion representation along the visual pathway.

56.439 **Effects of task difficulty and attentional breadth on tonic and phasic pupil size** Yavor Ivanov[1](yivanov94@gmail.com)**,** Ana Lazović [1]**,** Sebastiaan Mathôt[1]; [1]Department of Psychology, University of Groningen, The Netherlands

Psychological factors such as task difficulty and attentional breadth (i.e. the eccentricity at which covert spatial attention is allocated) have been shown to affect pupil size. Most studies investigating these factors looked at their effect on phasic pupil responses (e.g. moment-to-moment fluctuations in pupil diameter), and it is still unclear whether they affect tonic pupil size (e.g. baseline levels of pupil diameter). Our study aimed to address visual and attentional-load confounds found in previous research by varying attentional breadth and task difficulty independently. We conducted two experiments investigating the effects of: (1) attended eccentricity; and (2) task difficulty, on both tonic and phasic pupil size. Participants performed a visual discrimination task with targets appearing bilaterally at different eccentricities. In Experiment 1, we varied both factors independently in a blocked manner, which allowed us to assess only differences in tonic pupil size. Task difficulty did not affect tonic pupil size, which is striking because its effects on phasic pupil size are well documented. Attended eccentricity also did not affect tonic pupil size. In Experiment 2, we wanted to assess the effects of attended eccentricity on phasic pupil size, in line with previous studies. We found that phasic pupil responses to stimuli were larger when participants directed covert attention towards more eccentric regions, even when controlling for visual input and task difficulty. As in Experiment 1, tonic pupil size had no relation with task difficulty. In general, our experiments show that changes in task difficulty are likely not reflected in changes in tonic pupil size. Furthermore, our results suggest that pupil size increases with increasing eccentricity of covert spatial attention (attentional breadth), even when keeping task difficulty constant.

56.440 **Processing capacity for moving objects in artificial worlds** Nicole L Jardine[1](nicole.jardine@northwestern.edu)**,** Steven L Franconeri[1]; [1]Psychology, Northwestern University

Substantial research over the last 30 years of vision science has illuminated how we understand a dynamic world. Studies of ensemble processing tell us what kinds of motion, like linear translation and global optic flow, can be easily used by human vision perceive coherent object trajectories and estimate time-to-contact (Whitney & Leib, 2018; Van den Berg, 1992). Studies of multiple object tracking tell us how we use information to know that a given object is the same one over space and time (Flombaum, 2009; Scimeca & Franconeri, 2014). Every one of these studies has been inspired by the dynamic natural world that the visual system evolved in. But we also spend several hours daily immersed in artificial worlds that use moving displays for information. Dynamic data visualizations, map transformations, and diagrams are used for data analysis, navigation, and education. These dynamic displays are comprised of multiple dynamic objects that, across domains, demand many of the same visual processing capacities we have long studied in the lab. Empirically determining when these dynamic displays are (and aren't) effective allows us a fresh scenario for understanding how we process dynamic scenes, while at the same time allowing research outputs to inspire interventions to help create more effective displays for students, scientists, and the general public. We present a theory-driven analysis of these displays and the visual processing demands they invoke. We show that visual processing capacities in perception and attention (ensemble processing, tracking object individuals and groups) are what help us see patterns in artificial displays, and that we fail to see patterns when processing capacity is exceeded. Visualizations that defy categorization within this framework can uncover new basic research directions. This domain presents use-inspired basic research by vision scientists to test visual thinking in the constructed, dynamic displays of everyday visual experience.

Acknowledgement: NSF DRL 1661264

Attention: Reward

Tuesday, May 21, 2:45 - 6:45 pm, Pavilion

56.441 **Emotional Primes Affects Global versus Local Processing Differently: The Effect of Arousal** Michaela Porubanova[1](misel99@gmail.com)**,** Maria Kuvaldina[1]**,** Andrey Chetverikov[2]; [1]Farmingdale State College, [2]Radboud University

Strong positive emotional primes reduce global precedence effect and facilitate processing of local information (Noguchi & Tomoike, 2016). On the contrary, it has been suggested that positive mood facilitates processing of global features through broadening of one's attention while negative moods enhance a local processing style by narrowing it (Frederickson & Branigan, 2005). In our study, we aimed to understand how primes of different arousal and valence combination influence processing of global and local visual information. In a series of 400 trails, participants were asked to identify a target letter (F/L in one block and H/T in another) which could be either the local or global object. Each trial commenced with a fixation cross presented for 1000ms and followed by a real-world scene prime (neutral, negative high arousal, negative low arousal, positive high arousal, positive low arousal, or a filler). Subsequently, the target letter appeared for 5s until participants responded. The findings show that even though emotional and neutral primes did not impact the reaction time to global features, emotional primes impaired processing of local features in comparison to neutral primes. Interestingly, high arousal primes of both valence (positive and negative) impaired both local and global processing to a greater extent than low arousal primes. However, compared to neutral primes, both low and high arousal decreased the difference in processing efficiency between global and local targets. Our results do not provide support for the link between emotional valence and differences in processing of local or global information when the arousal is controlled for. We also found that even low-arousing pictures decrease the efficiency of global processing, suggesting that the reduction in the global precedence occurs not only for strongly motivating information but for to emotional scenes in general.

56.442 **Learning to Attend in a Brain-inspired Deep Neural Network** Gregory J. Zelinsky[1,2](Gregory.Zelinsky@stonybrook.edu)**,** Hossein Adeli[1]; [1]Department of Psychology, Stony Brook University, [2]Department of Computer Science, Stony Brook University

How is attention control learned? Most neuro-cognitive models avoid asking this question, focusing instead on how the prioritization and selection functions of attention affect neural and behavioral responses. Recently, we introduced ATTNet, an image-computable deep network that combines behavioral, neural, and machine-learning perspectives into a working model of the broad ATTention Network. ATTNet also has coarse biological plausibility; it is inspired by biased-competition theory, trained using deep reinforcement learning, and has a foveated retina.Through the application of reward during search, ATTNet learns to shift its attention to locations where there are features of a rewarded object category. We tested ATTNet in the context of two different "microwave oven" and "clock" search tasks using images of kitchen scenes (Microsoft COCO) depicting both a microwave and a clock (target present) or neither a microwave nor a clock (target absent). This design therefore perfectly controls for the visual input; any difference in the model's behavior could only be due to target-specific applications of reward. Similar to the eye movements of our behavioral participants (n=60)

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searching the same scenes for the same target categories, ATTNet preferentially fixated clocks but not microwaves when previously rewarded for clocks, and preferentially fixated microwaves but not clocks when previously rewarded for microwaves. Analysis of target-absent search behavior also revealed clear scene context effects; ATTNet and participants looked at locations along walls when searching for a clock, and looked at locations along countertops when searching for a microwave. We therefore suggest a computational answer to one fundamental question; that the simple pursuit of reward causes, not only the prioritization of space in terms of expected reward signals, but the use of these signals to control the shift of what the literature has come to know as spatial attention.

Acknowledgement: This work was funded by NSF IIS award 1763981.

56.443 Physical, mental and social stress selectively modulate inhibitory control during search of natural scenes

Tom W Bullock[1,2](bullock@psych.ucsb.edu), Mary H MacLean[1,2], Alex P Boone[1,2], Tyler Santander[1,2], Jamie Raymer[1,2], Alex Stuber[1,2], Liann Jimmons[1,2], Gold N Okafor[3], Scott T Grafton[1,2], Michael B Miller[1,2], Barry Giesbrecht[1,2]; [1]Institute for Collaborative Biotechnologies, University of California, Santa Barbara, CA, [2]Dept. of Psychological and Brain Sciences, University of California, Santa Barbara, CA, [3]Dept. of Psychology, University of California, Berkeley, CA

Acute stress can affect cognitive performance.The goal of this study was to test the impact of several different types of acute stress on inhibitory control during a task involving search for people in natural scenes.Participants completed a go/no-go task where they were required to view a pseudorandomized stream of scenes (1 Hz presentation) and respond immediately to each image unless there was a human present in the image (p=.07) or if the image was repeated (p=.07).This task was designed to be demanding and to induce frequent errors of commission.Participants completed the task in three sessions on three separate days: baseline, treatment and control.Baseline was always completed first, followed by treatment and control in a counterbalanced order.During the treatment session, stress was induced prior to the task with either the cold pressor test (CPT, n=44), a 2-hour mentally fatiguing scheduling task (MF, n=31) or the Trier Social Stress Test (TSST, n=28). During the control session participants were exposed to stress-specific scenarios that matched the stress conditions on key factors.Different patterns of behavior were observed as a function of each stressor.During CPT participants made fewer errors of commission during both treatment (.34±.03), and control sessions (.36±.03) relative to baseline (.42±.03) [p< .05], indicating a learning effect during both sessions.In contrast, participants made more errors of commission during MF in treatment (.45±.03) relative to baseline (.40±.03) but not control (.39±.03) [p< .05, p>.05, respectively]. Error rates were not modulated by the TSST in either the treatment (.45±.03) or control (.44±.03) sessions relative to baseline (.45±.04) [p>.05]. These data suggest that although there may be learning due to repeated exposures, different types of acute stress selectively impact inhibitory control during search of natural scenes.

Acknowledgement: This work was generously supported by US Army Research Office Grant W911NF-09-0001

56.444 Reward learning biases the direction of saccades in visual search

Ming-Ray Liao[1](m4liao@tamu.edu), Brian A Anderson[1]; [1]Texas A&M University

The role of associative reward learning in guiding feature-based attention and spatial attention is well established. However, no studies have looked at the extent to which reward learning can modulate the direction of saccades during visual search. Here, we introduced a novel reward learning paradigm to examine whether reward-associated directions of eye movements can modulate performance in different visual search tasks. Participants had to fixate a peripheral target before fixating one of four disks that subsequently appeared in each cardinal position. This was followed by reward feedback contingent upon the direction chosen, where one direction consistently yielded a high reward. Thus, reward was tied to the direction of saccades rather than the absolute location of the stimulus fixated. Participants made an average 80.5% and 73.8% of saccades in the high reward direction, collapsed across all trials, for Experiment 1 and 2 respectively, demonstrating robust learning of the task contingencies. In an untimed visual foraging task that followed, which was performed in extinction, participants fixated on disks until a hidden target was revealed (Experiment 1). Early saccades were reliably biased in the previously rewarded-associated direction. However, no directional bias was found in a speeded, shape search task where participants had to fixate a target that could appear in one of four cardinal positions (Experiment 2). Our findings suggest that rewarding directional eye movements biases search patterns in a foraging context in which the location of the target is unknown, but such biases do not effectively compete with feature-based attentional guidance during goal-directed visual search.

56.445 Reward Experience Modulates Endogenous Attentional Cueing Effects

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Attentional control has traditionally been categorized into exogenous (bottom-up) and endogenous (top-down) processes. However, a number of studies have demonstrated that attentional selection can also be controlled by past rewarding experiences. While previous studies suggest that exogenous and endogenous factors interact with each other, less is known about how reward-based selection is integrated within an attentional priority map. In this study, we addressed the question whether reward outcomes modulate voluntary controls of attention observed in endogenous cueing effects. In two experiments, we manipulated the association between cue validity (i.e., valid/invalid) and the magnitude of reward (i.e., high/low) in endogenous spatial cueing tasks. In the congruent condition, trials in the valid condition were followed by a high reward and those in the invalid condition were followed by a low reward. In the incongruent condition, those mappings of cue validity and reward were reversed and participants were given a low reward following valid trials and received a high reward following invalid trials. Experiment 1 showed that the validity effect (i.e., reaction time difference subtracting the valid condition from the invalid condition) in congruent trials was significantly larger than that in incongruent trials. In Experiment 2, we further tested whether the modulation of endogenous attentional cueing effects observed in Experiment 1 reflected the difference in motivations due to the difference in the expected value between congruent and incongruent trials. The results in Experiment 2 replicated the results of Experiment 1 even when both congruent and the incongruent trials have the same expected value, suggesting that not expected values, but reward outcomes affect observers' strategic control of attentional deployment. Together, these findings indicate that a rewarding experience modulates endogenous attentional cueing effects.

Acknowledgement: Grant No. 16J04500 from the Grants-in-Aid for Scientific Research (KAKENHI) program of the Japan Society for the Promotion of Science

56.446 Incentive Cue Related Signal Suppression in Adolescents and Adults: An EEG study

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Stimuli signalling the opportunity to gain a reward have been shown to bias cognition in adolescents more than in adults. However, it remains unclear whether rewards strengthen top-down control (proactive control) or cause adolescents to reactively initiate attention control to gain rewards. To address this, we examined electrophysiological responses to incentive cues in adolescents (~17 years) and adults (~29 years) in a task where cognitive responses to incentives cues were irrelevant to a rewarded attention task. First, in a conditioning task, participants learned that specific (white) abstract symbols signalled that choosing an appropriate coloured disk from a subsequently presented 2-disk array (one orange, one purple) would yield a high or no reward. Then, in a separate session, ERPs were recorded as participants viewed a horizontally arranged 2-symbol array with one conditioned symbol and one non-conditioned symbol. Then a vertically arranged 2-letter array (with pre-defined target and distractor; one purple the other orange) was presented. Correct performance was rewarded depending on the incentive symbol. In adolescents, when symbols signalled a reward, colour congruency between the target and the colour associated with the symbol speeded response times, an effect not seen in adults or with no-reward symbols. ERP activity to symbol arrays showed a Pd for no-reward trials only in adolescents, suggesting reactive suppression of no-reward cues, but not reward cues. In adults, colour congruency and Pd effects were non-significant. However, right-hemisphere pre-symbol alpha activity was greater in adults than adolescents, suggesting greater proactive control. Together, these data suggest that adults and adolescents utilise proactive and reactive control differently. Adolescents are more likely to prioritise stimuli reactively, using strategies that maximise learned reward prospects, even when doing so is harmful to current task performance.

Acknowledgement: ESRC UK, ES/L00210/1

56.447 **Automatic biases of attention towards positive and negative stimuli: the role of individual differences** Ludwig P Barbaro[1, 2, 4](L.P.Barbaro@bham.ac.uk), Marius V Peelen[3, 4], Clayton M Hickey[1, 2, 4]; [1]School of Psychology, University of Birmingham, UK, [2]Centre for Human Brain Health, University of Birmingham, UK, [3]Donders Institute for Brain, Cognition and Behaviour, Radboud University, The Netherlands, [4]Center for Mind/Brain Sciences, University of Trento, Italy

INTRODUCTION: Previous work has shown that perceptual bias towards visual stimuli paired with reward correlates with indices of individual variability, such as personality scores and activation of reward-related structures (eg. dopamine-releasing neurons in Substantia Nigra (SN)). Whether a similar correlation exists with respect to sensitivity to punishment, and how this influence is related with the reward-driven bias, is less clear. METHODS: Here, participants looked for categories of objects (people, cars, trees) in naturalistic scenes and received different types of motivational feedback (rewarding, neutral or punishing) for correctly detecting these objects. Importantly, accurate task performance led in reward and punishment conditions to an equal financial benefit. At the same time, the two conditions presented opposite emotional valence for the subject, respectively garnering constant monetary gain or loss in spite of optimal performance. We subsequently looked at the representation of these stimuli in occipito-temporal object-selective cortex (OSC) using MVPA of fMRI data. RESULTS: We found that two measures of individual variability predicted the way in which stimuli paired with gain and loss were represented with respect to one another in OSC across subjects. On one hand, increased representation of rewarding stimuli was tracked in activity in the SN. On the other, increased representation of aversive stimuli was tracked in a personality questionnaire, the behavioural inhibition scale (BIS). Importantly, multiple linear regression showed that the contribution of these two variables was independent and additive. Two separate, but comparable, experiments garner equal results. CONCLUSIONS: These studies suggest that, across subjects, sensitivity to reward and to punishment separately contribute to the non-strategic prioritization of positively and negatively valenced stimuli with respect to each other.

56.448 **Watch Out - Snake! Threat Captures Attention Independent of Low-Level Features** Drew Weller[1](drew.weller@unco.edu), Joanna Lewis[2]; [1]University of Northern Colorado

Research suggests that threatening stimuli may capture human attention. The rapid, automatic allocation of attention to threat signals (e.g., the sight of a snake in the grass) is assumed to be evolutionarily advantageous, but it is not yet well understood whether it is low-level perceptual properties of threatening images driving attentional capture (e.g., the continuous contour of a snake's body contrasted against short, separate blades of grass) or whether it is perception of the threat as a whole.To explore this question, we chose snakes and garden hoses as stimuli for our visual search task as they share similar low-level characteristics: tubular shape, length, and continuous contour contrasted against a natural background. Garden hoses stimuli share these visual properties with the snake stimuli, but only the snake is potentially threatening. The visual search task used shape-singleton targets (yellow or blue colored circles or squares) framing task-irrelevant photographs of either snakes (threat stimuli) or garden hoses (non-threat stimuli).Participants responded with a key press for the target singleton shape (Experiment 1) or shape singleton color (Experiment 2).We used two set sizes of stimuli (4 and 8). Every trial contained one threat stimulus. The threat stimulus was framed by the target shape at chance (threat-target trials), and for all other trials the threat stimulus was framed by a distractor shape (threat-distractor trials). Measures related to anxiety and snake phobia were collected. Our results indicate that target-detection slows for threat-distractor trials compared with threat-target trials, specifically with an additive threat-distractor reaction time cost at the larger set size when the task requires attentional shifts for target color discrimination (Experiment 2). These findings indicate that it is not low-level contour or contrast that drives attentional capture, but potentially the perception of a threat resulting in an attentional prioritization despite task irrelevance.

Acknowledgement: n/a

56.449 **Association between a spatial preference toward highly rewarded locations and explicit awareness** Caitlin Sisk[1](siskx024@umn.edu), Roger W Remington[1], Yuhong V Jiang[1]; [1]Department of Psychology, College of Liberal Arts, University of Minnesota

Mounting evidence suggests that monetary reward induces an implicit selection bias toward highly rewarded features. Whether reward has similar effects on spatial attention, however, has been controversial. Here we ask whether spatial biases toward highly rewarded locations are learned implicitly, or are instead biases in choice driven by explicit knowledge of reward structure. Participants completed a hybrid search/choice task involving multiple targets among multiple distractors. Targets garnered varying magnitudes of reward, and participants were instructed to search for targets and guess and click on the one that they think will yield the highest reward on each trial. Unbeknownst to participants, one side of the display offered higher reward than the other side of the display. We measured the spatial bias for targets on the high-reward side of the screen and probed explicit awareness via a multi-question post-task interview. Participants who were aware of the reward structure (N=48) showed a selection bias for targets appearing on the high-reward side of the screen. Contrary to previous findings, unaware participants (N=24) showed only a central bias, despite spending as much time as aware participants on the task. The strong association between explicit awareness and reward-driven spatial attention distinguishes this form of attention from other kinds of implicit guidance of spatial attention, as well as implicit selection biases toward highly rewarded non-spatial features.

Acknowledgement: National Sciences Foundation Graduate NRT Program

56.450 **The influence of hunger on visual processing of objects** Elizabeth E Kruhm[1,2](ee.kruhm@gmail.com), Antoinette DiCriscio[1], Vanessa Troiani[1]; [1]Geisinger's Autism and Developmental Institute, [2]Susquehanna University

The focus of this study is to assess the influence of individuals homeostatic state (i.e. hunger) on visual processing of objects using measures of spontaneous eye blink and pupil response. Spontaneous eye blink and pupil response are closely linked with cognitive state as well as underlying neurophysiologic function, specifically autonomic function, arousal, and homeostatic state. Data was collected across two visits, one in a fasted state and another in a satiated state. Participants (current N=9; data collection ongoing) were randomly assigned to either the fasted condition or satiated condition at their first visit and completed the opposite condition at their 2nd visit. Prior to the fasting session, individuals went 8 hours with no food. For the satiated session, individuals were given food (pastries and juice) prior to participation and were instructed to "eat until you feel satiated". At each visit, participants were presented with 256 images of faces, food, places, and visual 'white noise' divided across two experimental blocks. Images were presented for 2.5 seconds. Images were chosen to include categories that were relevant to the altered homeostatic drive state (food) and categories that have rewarding properties but are not relevant to the drive state (faces). Eye tracking was used to collect measures of spontaneous eye blink and pupil response while participants monitored the stimuli for the appearance of a white fixation cross.Preliminary results indicate that both pupil size and blink rate increase during the fasting state, with the greatest changes occurring in response to food images. This study suggests an influence of internal state on visual processing of object images. The impact of altered homeostatic drive appears to impact both domain-general and domain-specific responses to objects that are reflected in pupil response and blink rate.

56.451 **Reactivation of reward-color association reduces retroactive inhibition from new learning** Zhibang Huang[1,2,3](382551921@qq.com), Sheng Li[1,2,3]; [1]School of Psychological and Cognitive Sciences, [2]Beijing Key Laboratory of Behavior and Mental Health, [3]PKU-IDG/McGovern Institute for Brain Research

Introduction: Consolidated memory can return to a labile state after being reactivated or retrieved. Under this state, it has been shown that the reactivated memory can be interfered by new learning. In the present study, we investigated the influence of memory reactivation on reward learning and attentional selection of reward-associated features. Experiment 1: Two groups of subjects (24 in each group) learned reward-color associations with a visual search task (Anderson, Laurent, & Yantis, 2011). After the learning, the first group demonstrated a typical attentional capture effect driven by reward salience in a test. The second group, who learned a new reward-color association before the test, demonstrated a reduced capture effect for the originally learned high reward color, indicating a retroactive inhibition caused by the new learning. Experiment 2: A group of 24 subjects completed the same procedure as the second group in Experiment 1, except that the originally learned reward-color associations were reactivated before new learning. The results showed that reactivation of the original learning prevented it from the retroactive inhibition from new learning. Experiment 3: A group of 24 subjects completed the same procedure as in Experiment 2, except that there was a six-hour interval between reactivation and new learning, ensuring the reactivated memory to be reconsolidated. The results showed that new learning again induced retroactive inhibition to the original learning after the reconsolidation, arguing against the possible practice effect

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during reactivation in Experiment 2. Conclusion: We propose that retroactive inhibition occurred because new memory competed with the consolidated original memory. However, with memory reactivation, novel experience under a similar context is learned by integrating it with the original memory in labile state, rather than forming a competitive trace. These effects of reactivation and reconsolidation have significant influence on the selective attention of reward-associated features.

Acknowledgement: National Natural Science Foundation of China (31470974) and National Key R&D Program of China (2017YFB1002503)

56.452 **EEG and fMRI Decoding of Emotional States: Temporal Dynamics and Neural Substrate** Ke Bo[1](dibanboye@ufl.edu), Siyang Yin[1], Yuelu Liu[2], Jacob Jenkins[1], Andreas Keil[3], Mingzhou Ding[1]; [1]J Crayton Pruitt Family Department of Biomedical Engineering, University of Florida, [2]Center for Mind and Brain, University of California at Davis, [3]Department of Psychology and the NIMH Center for Emotion and Attention, University of Florida

Both positive and negative emotional stimuli attract more attentional resources than neutral stimuli. It has been further suggested that negative stimuli evoke faster and stronger neural responses compared to positive stimuli. To date, ERP studies testing this proposition has produced mixed results. Here, we examined this problem by applying multivariate pattern analysis (MVPA) to EEG and fMRI data simultaneously recorded from healthy human subjects viewing pleasant (erotic and happy scenes), unpleasant (disgust and attack scenes), and neutral (household and people scenes) pictures from the IAPS library. On each trial the picture was shown for 1000ms. The inter-trial interval varied randomly from 6000 to 9000ms. Applying the support vector machine (SVM) technique to single-trial EEG and fMRI responses, we decoded pleasant-versus-neutral and unpleasant-versus-neutral emotional states, and found the following results. First, pleasant-versus-neutral decoding became above-chance level at ~180ms after picture onset, whereas unpleasant-versus-neutral decoding became above-chance level at ~240ms, suggesting that the processing of negative information is not prioritized, timing-wise, over positive information. Second, across subcategories of pictures, erotic scenes were the earliest to be decoded, followed by disgust scenes, attack scenes and happy scenes, suggesting that the timing of neural information processing is specific to picture content. Third, both positive and negative emotions were maximally decoded at around 500ms after picture onset, and the maximum EEG decoding accuracy was correlated with fMRI decoding accuracy in ventral visual cortex, suggesting that reentrant projections into ventral visual cortex from higher order emotional structures play a role in generating the neural representations of affective pictures.

56.453 **Immersive experience of awe increases the scope of visuospatial attention: A VR study** Muge Erol[1](erolm712@newschool.edu), Arien Mack[1]; [1]New School for Social Research

Earlier we reported evidence that awe increases attention to global over local features (Erol & Mack, 2018). The current study investigates whether awe increases the breadth of visuospatial attention as measured by Functional Field of View (FFOV). FFOV is "the area around the fixation point from which information is being briefly stored and read out during a visual task" (Mackworth, 1965, p.67). Each participant first completed 80 FFOV trials, then observed a mood induction video, and finally repeated the FFOV test. Each of 45 participants (15 per group) was exposed to one of 3 possible ~3 minute, 360° immersive virtual reality videos: one induced awe, one amusement, and one was neutral. The FFOV task entailed arrays containing one letter (D, G, J or L) at fixation and 40 small rectangles, each placed at 5 increasing degrees of eccentricity (3° through 15°) from fixation in 8 possible directions, presented for 50ms and masked for 250ms. On each trial, a different digit (1 through 9) appeared randomly inside one of the rectangles. Participants immediately reported the central letter, and then identified and localized the peripheral digit. There were no pretest differences among the groups at any eccentricity. Importantly, after mood induction, the awe group improved significantly at identifying ($F(2,42)=3.405$, $p< .05$) and localizing ($F(2,42)=3.879$, $p< .05$) the digit at 12°, and localizing it at 15° ($F(2,42)=4.061$, $p< .05$). Moreover, higher self-reported awe ratings correlated with improved performance in digit identification at 9° ($r=.29$) and 12° ($r=.35$) and digit localization at 12° ($r=.33$) and 15° ($r=.39$). These results indicate that awe increases the breadth of spatial attention and taken together with our earlier findings, suggest that awe has a predictable broadening and globalizing effect on perception. They are the first reported evidence of the impact of awe on what we see.

Motion: Local, higher order

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56.454 **Embeddedness of Local Gravity in Perception & Action** Abdul H Deeb[1](abdul-rahim_deeb@brown.edu), Evan Cesanek[1], Fulvio Domini[1]; [1]Brown University

Understanding and making predictions about the physical forces determining object motion could greatly facilitate the perception of dynamic events. To be optimal, trajectory judgments of a falling object should be consistent with the physical laws that govern object motion, however previous studies show that beliefs often violate Newtonian laws. The aim of this study was to determine whether human observers integrate Newtonian predictions of object motion with noisy sensory information to reduce ambiguity in the perception of dynamic events. When a ball rolls off a surface, the trajectory of its descent is determined by a relatively constant horizontal velocity and a downward acceleration caused by gravity. For this experiment, we simulated this dynamic event in virtual reality: participants viewed a marble-sized ball fall from a tabletop under two different horizontal velocities and seven different downward accelerations (one matching Earth's gravity, three lower, and three higher, spanning the range from Mercury's gravity to Jupiter's gravity). On each trial, participants indicated the perceived trajectory of the falling ball by adjusting the curvature of a parabolic arc. Each participant's internal prediction about local gravity in this virtual environment was assessed using trials where the ball rolled up to the edge of the tabletop, then disappeared, and the participant indicated the expected continuation of the trajectory (as opposed to the perceived trajectory indicated in other trials). Although participants' internal predictions were biased to underestimate the true gravity of Earth (which may serve a practical role for guiding interceptive actions), their perceptual judgments reflected a combination of this prediction with the available visual information. Furthermore, the combination process appears to be consistent with maximum likelihood estimation, as the influence of the internal prediction increased proportionally with the amount of sensory noise, which we varied by manipulating the amount of time the ball's descent was visible.

56.455 **Characterizing Global Motion Perception Following Treatment for Bilateral Congenital Cataracts** Sruti Raja[1](srraja@mit.edu), Sharon Gilad-Gutnick[1], Shlomit Ben-Ami[1], Priti Gupta[2], Pragya Shah[2], Kashish Tiwari[2], Suma Ganesh[3], Pawan Sinha[1]; [1]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, [2]The Project Prakash Center, [3]Department of Ophthalmology, Dr. Shroff's Charity Eye Hospital

Visual motion plays a fundamental role in our ability to interpret visual scenes. Previous findings suggest that dynamic information in visual stimuli greatly improves interpretability over still images, especially under conditions of reduced visual acuity. The importance of motion is the motivation for characterizing global motion sensitivity in children who have experienced prolonged periods of visual deprivation prior to treatment. Here, we report results from eighteen children who received treatment for bilateral congenital cataracts several years after birth. We examined their sensitivity to global motion at multiple time points post-operatively. The stimuli consisted of limited life-time kinematograms. Each trial comprised a two-second video of dots moving at a speed of 18° s-1. The field of view was 20 degrees by 20 degrees of visual angle and contained 300 black dots against a white background in each frame. A certain percentage of the dots moved either upwards or downwards, while the remainder of the dots moved in random directions. A staircase procedure was used to determine the subjects' coherence thresholds. We partitioned the participants into two groups: those who could perform the task pre-operatively and those who could not. For the participants who could perform the task pre-operatively, the motion coherence thresholds remained relatively stable even after sight onset. For the remainder of the participant group, significantly impaired pre-operative vision had rendered them unable to perform the task prior to surgery. After first eye surgery, this subgroup showed significant improvements in performance. Their thresholds after surgery were comparable to the coherence thresholds of the other, less impaired, group. Performance on the global motion task did not correlate with visual acuity or age.

56.456 **Effects of local motion ambiguity on perceptual confidence** Angela M.W. Lam[1](lammanwai1028@gmail.com), Alan L.F. Lee[1]; [1]Department of Applied Psychology, Lingnan University, Hong Kong

Perceptual confidence refers to an observer's judgment about his/her own performance in a perceptual task. It has been found to correlate with task performance in general, and is believed to be independent of stimulus

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features. However, certain stimulus feature could induce a subjective sense of uncertainty, which could potentially influence confidence judgments beyond task performance. The present study aimed at assessing the effects of the ambiguity of local motion signals on perceptual confidence on a global-motion task. The stimulus was a multiple-aperture array consisting of 188 randomly-oriented elements. Each element was either a Gabor, which is ambiguous in signaling a global motion direction, or an orthogonal plaid, which consists of an unambiguous local motion signal. In each trial, participants discriminated the global motion direction on a Gabor pattern and a plaid pattern, one after another. Then, they performed a two-interval, forced-choice confidence task by choosing which of the two perceptual responses they were more confident in being correct. Perceptual task performance was controlled by varying coherence, defined as the proportion of elements signaling a coherent global motion (leftward or rightward). A range of differences in coherence between Gabors and plaids was tested to create differences in perceptual task performance between the two types of stimuli. This allowed us to measure bias in confidence choices by fitting a psychometric function for confidence choices across differences in performance between Gabors and plaids. We found that the point of subjective equality (PSE) for confidence choice tended to favor better perceptual performance for Gabors. In other words, observers chose plaids more often than Gabors when task performance was matched between the two patterns. This suggests that, at the same level of objective task performance, ambiguous local motion signals are perceived to be more uncertain than unambiguous ones.

56.457 **Reverse Phi: Effect of Contrast Reversals on Perceived Speed** Mohana Kuppuswamy Parthasar[1](kp.mohana@gmail.com), Vasudevan Lakshminarayanan[1]; [1]School of Optometry and Vision Science, University of Waterloo

Purpose: When the contrast of successive displays is reversed in an apparent motion stimulus, the perceived direction is reversed. We investigated if contrast reversal affects speed perception relative to regular phi motion. Methods: Ten normal subjects (age range: 18-40years) were included. Two types of motion stimuli were used: regular phi and reverse phi, the only difference between the two being alternating contrast polarity in the latter condition. Random dot kinematograms (RDK) with 500 dots were presented sequentially in a central 8x8deg window with a limited dot lifetime of 3 frames. The temporal interval was 16.7ms. Standard speed used was 18 deg/s and the test speeds were +/-25%, +/-30%, and 60%. These speeds resulted in the spatial offsets of 0.2deg to 0.5deg. The inter-stimulus interval between the intervals was 250ms. On a 3-alternative forced choice paradigm, the subjects responded to the fastest motion (first/second) or equality. The direction of perceived motion was the same on both intervals. The interval containing the standard speed and the motion type was randomized. Stimulus duration was 0.5s or 1s. Each trial was presented 10 times randomly and hit rates were calculated. The speed discrimination thresholds were calculated at 66.7% probability and compared between the motion types. Results and Conclusion: Subjects confirmed perceiving a reversed direction on a reverse phi stimulus using single RDK. Speed discrimination threshold for regular phi and reverse phi was 12.4deg/s and 13.8deg/s. There was no significant difference between the two threshold values (p=.13). This suggests a similar neural mechanism for both motion types. However, when the perceived speed of reverse phi and regular phi was compared, reverse phi was perceived as being faster about 88% of times when the actual speed of the two motion types was the same, despite randomizing the order of the presentation.

Acknowledgement: None

56.458 **Orthogonal and parallel rebounding aftereffects produced by adaptation to back-and-forth apparent motion** Nathan H Heller[1](nathan.h.heller.gr@dartmouth.edu), Patrawat Samermit[2], Nicolas Davidenko[2]; [1]Dartmouth College, [2]University of California Santa Cruz

It has been shown that adaptation to superimposed, balanced opposite motion directions (i.e. transparent motion) induces unidirectional motion aftereffects along the axis orthogonal the adaptation directions, not parallel to them (Grunwald & Lankheet, 1996). However, we recently showed in a striking new effect that adaptation to alternating (rather than superimposed) balanced motion directions leads to percepts of rebounding or back-and-forth motion that is parallel to the adaptation directions. In order for adaptation to produce these parallel rebounding aftereffects, the transition between alternate opposing directions must be sufficiently slow, around 1-3Hz (Davidenko, Heller, Cheong, & Smith, 2017; Davidenko & Heller, 2018; Heller & Davidenko, 2018). Here we asked whether adaptation to alternating directions at higher speeds would produce orthogonal rebounding aftereffects. In this study participants adapted for 2, 2.667, or 3.333 seconds to rapidly alternating horizontal or vertical motion (9 Hz alternating speed; 18, 24, or 30 alternations) or slowly alternating motion (1.5 Hz; 4, 5, or 6 alternations). Participants then reported perceived direction on two ambiguous test frame transitions composed of uncorrelated random dots presented at 1.5 Hz. We coded responses as parallel rebounding aftereffects if reports followed the same axis as the adaptation (e.g. LEFT-RIGHT-LEFT-RIGHT followed by LEFT-RIGHT response). When responses switched axis (e.g. LEFT-RIGHT-LEFT-RIGHT followed by UP-DOWN response) we coded those as orthogonal rebounding aftereffects. The proportion of orthogonal and parallel rebounding aftereffects were significantly modulated by alternation speed [paired t test: $t(33) = 2.9$, $p = .007$], with the orthogonal effect reported on 23.1 % of fast trials and 15.1% of slow trials, and parallel effect reported on 16.4% of fast trials and 20.3% of slow trials. Thus, adapting to opposing directions not only result in unidirectional orthogonal aftereffects, but also leads to rebounding orthogonal or parallel aftereffects, depending on the speed of the adapting, rebounding motion.

56.459 **Manual tracking of the double-drift illusion** Bernard M 't Hart[1](thartbm@gmail.com), Denise Y.P. Henriques[1], Patrick Cavanagh[1,2,3]; [1]Centre for Vision Research, York University, Toronto, ON, Canada, [2]Department of Psychology, Glendon College, Toronto, ON, Canada, [3]Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH, USA

When a target has poor position information, vision may take the target's motion into account in generating its perceived location, resulting in conflicts between apparent and actual position. The double-drift illusion (Lisi & Cavanagh, 2015) is one such case in which the internal motion of the target drives an accumulating perceived offset that, after as much as 2 to 4 seconds, reaches some saturation limit where the accumulation stops or resets to the physical location. To investigate this illusion and its limits, we asked participants to move a pen over a drawing tablet to continuously track where they perceived the stimulus. By interposing an angled mirror, the participants were able to see the target moving on the same horizontal surface where they moved the stylus but could not see their hand or the stylus. We found that the manual tracking data showed the double-drift illusion and that its magnitude was sensitive to the internal and external speeds of the moving gabor, being largest when the external speed was slow and the internal speed high. This indicates that the manual tracking data can in principle be used to follow the perceived target location moment by moment to investigate how and when the illusory position shift saturates.

Acknowledgement: Department of Psychological and Brain Sciences, Dartmouth College (PC) and NSERC (DYPH)

56.460 **Aftereffects of apparent motion adaptation depends on adaptation duration** Wei Wei[1](wei.wei@louisville.edu), Teng Leng Ooi[2], Zijiang J He[1]; [1]Dept. Psychological and Brain Sciences, University of Louisville, [2]College of Optometry, Ohio State University

We previously reported a negative, non-location-specific aftereffect of apparent motion (AM) adaptation.For example, perceived AM direction of a bistable motion quartet stimulus spanning a small area (~4x4 deg) exhibited a horizontal bias after 75 seconds of adaptation to a vertically directed AM adaptation stimulation spanning a large area (~8x8 deg).We now further investigated the characteristics of such an AM adaptation phenomenon as a function of adaptation duration (3, 5, 8,10, 12, 15, 30, 45, 60, and 75 seconds). The adapting AM stimulus (~8x8 deg; motion token diameter=1 deg; frame duration=200 msec; ISI=0) was rendered to move back-and-forth horizontally or vertically.The AM test stimulus (~4x4 deg; motion token diameter=1 deg; frame duration=150 msec; ISI=0) was displayed for 15 seconds and the observer was to continuously report the perceived motion direction by holding down on selected keys. Overall, we found a positive AM aftereffect with short adaptation durations (3 and 5 seconds), which switched to a negative AM aftereffect with adaptation durations beyond 8 second. Further analysis of the perceived AM direction immediately upon termination of the AM adaptation revealed a relationship between the immediately-perceived AM duration (AMimmediate_percept) and AM adaptation duration (Durationadaptation), where AMimmediate_percept = 8.286*log(Durationadaptation) - 6.607.Notably, AMimmediate_percept became zero when Durationadaptation was 6.3 sec, revealing a critical adaptation duration, Durationcritical_adaptation.Therefore, when Durationadaptation > Durationcritical_adaptation, the AM aftereffect was negative whereas it was positive when Durationadaptation < Durationcritical_adaptation. Interestingly, the latter reveals an AM priming effect.Of significance, these findings suggest stimulus-driven attention-shift by itself is a driver of AM perception. Specifically, short duration of AM stimulation in one direction (horizontal or

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vertical) facilitates the stimulus-driven attention-shift mechanism in the same direction.Conversely, a longer AM stimulation duration fatigues the stimulus-driven attention-shift mechanism.This consequently biases the perceived AM toward the orthogonal direction.

Acknowledgement: NIH Grant EY023561 and EY023374

56.461 **Motion-Defined Form Discrimination in Human V5/ MT+** Samantha L Strong[1](s.l.strong1@bradford.ac.uk), Edward H Silson[2], André D Gouws[3], Antony B Morland[3,4], Declan J McKeefry[1]; [1]School of Optometry and Vision Science, University of Bradford, UK, [2]Laboratory of Brain and Cognition, National Institute of Mental Health, Bethesda, USA, [3]York Neuroimaging Centre, Department of Psychology, University of York, UK, [4]Centre for Neuroscience, Hull-York Medical School, University of York, UK

Human V5/MT+ is a motion-sensitive cortical region that can be parcellated into at least two smaller sub-divisions: MT/TO-1 and MST/TO-2 (Amano et al., 2009). Previous work using functional magnetic resonance imaging (fMRI) and transcranial magnetic stimulation (TMS) has shown that these areas possess distinct functional preferences. For example, both MT/TO-1 and MST/TO-2 appear to process low-level local motion directions (translational), whilst processing of more complex global motion directions (radial/rotational) appears to be restricted to MST/TO-2 (Smith et al., 2006; Strong et al., 2017). However, it is rare to experience a natural visual scenario in which stimuli constitute only one direction of motion, so the next step would be to work towards determining whether these areas also contribute to 'higher-level' motion processing. One example of this type of processing is motion-defined form, i.e. a shape possessing borders defined by moving stimuli as opposed to a static outline. This project utilised fMRI-guided repetitive TMS (25Hz; 70%; 200ms) in order to determine the roles of MT/TO-1 and MST/TO-2 in a two-interval forced choice (2IFC) shape discrimination task. This involved identifying which interval contained the more circular of a camouflaged ellipse. This ellipse was defined by a region of supra-threshold coherently moving (translational) dots immersed within an aperture of moving noise dots. The relative size difference in semi-minor axis of the ellipse was set to each individual's pre-determined threshold level. Results (percent correct responses) revealed that application of TMS to MST/TO-2 can disrupt ability to perceive these motion-defined shapes (MST/TO-2 versus MT/TO-1, $p< 0.05$; MST/TO-2 versus Baseline, $p< 0.05$; MST/TO-2 versus Control, $p< 0.05$). Overall, although both MT/TO-1 and MST/TO-2 maintain some responsibility for processing translational motion directions, discrimination of shapes defined by supra-threshold translational motion appears to be restricted to MST/TO-2. This suggests that processing of 'higher-level' natural stimuli may begin in MST/TO-2.

Acknowledgement: BBSRC

56.462 **The history of the elements influences object correspondence in the Ternus display** Madeleine Y Stepper[1](madeleine.stepper@uni-tuebingen.de), Bettina Rolke[1], Elisabeth Hein[1]; [1]University of Tübingen

We perceive an object, e.g., a frog jumping around, as a continuous entity, even if the object temporarily disappears behind other objects on its path. In order to solve this correspondence problem our visual system has to connect the right instances of an image across space and time. It has been suggested that this process can depend on image-based information, i.e., the retinal size of an object, as well as on object-based information, i.e., the perceived size of an object. Manipulating object-based information, however, often leads to changes of image-based information, e.g., luminance contrast, as well. Our aim was to clearly distinguish between these two levels by manipulating the temporal history of objects without changing the objects themselves. We used a Ternus display, an ambiguous apparent motion display. Depending on how correspondence is solved, the Ternus elements are perceived either as moving together (group motion) or as one element jumping across two others (element motion). We manipulated the temporal history of the Ternus elements by showing a short movie prior to presenting the Ternus display itself. In the movie, the Ternus elements either moved together along the same trajectory (common history) or separately (separate history), in order to manipulate how much the elements were perceived as connected to each other. If the object-based information about the history of the Ternus elements plays a role for establishing correspondence, we expected more group motion percepts in the common compared to the separate history condition. We found the expected result, but only if the motion in the movie was similar to the Ternus motion. In addition, this history effect could be generalized to another type of history, i.e. synchronized and desynchronized luminance changes. Our findings confirm that object-based information can influence object correspondence strengthening the evidence in favor of an object-based correspondence mechanism.

Acknowledgement: This study was supported by the German Research Foundation (HE 7543/1-1).

56.463 **Hierarchical Bayesian modeling of the psychometric function (and an example application in an experiment on correspondence matching in long-range motion).** Nicolaas Prins[1](nprins@olemiss.edu); [1]Department of Psychology, College of Liberal Arts, University of Mississippi

I introduce and investigate a user-friendly hierarchical Bayesian method for fitting psychometric functions (PFs) across multiple conditions and subjects simultaneously. The method incorporates the generalized linear model to allow reparameterization of the four parameters of the PF independently across conditions, for example to define main effects and interactions in a factorial design. Posterior distributions across any or all of the four parameters of a PF for individual observers as well as their location and dispersion parameters across observers are derived using Markov Chain Monte Carlo sampling as implemented in JAGS (Plummer, 2003: http://citeseer.ist.psu.edu/plummer03jags.html). Results of simulations indicate that using a hierarchical structure to model PFs across multiple conditions and observers reduces bias in parameter estimates significantly compared to fitting PFs individually. It is further shown that the method converges successfully using priors that are essentially non-informative, even for modestly-sized experiments. This feature makes the method easy to use for those new to Bayesian modeling and perhaps also more acceptable to critics that are concerned by the use of informative prior distributions. The method is further demonstrated by analyzing human data in an experiment that investigated the effect of attention on correspondence matching in an ambiguous long-range motion display. PFs were estimated simultaneously for five observers in each of 24 conditions in a 2x2x2x3 factorial design. Location and slope parameters of the PF were both reparameterized across the 24 conditions in order to code for factor main effects and interactions. The lapse rate parameter was allowed to take on different values across conditions differing in their attentional load but were otherwise constrained. Results show that observers only favored feature-preserving correspondence matches when explicitly asked to consider which token pairs matched featurewise before motion onset, suggesting that the influence of feature matches was realized by a purely conscious and deliberate process.

56.464 **Adaptation to an illusory aspect ratio distorted by motion induced position shift** Hoko Nakada[1](hoko@g.ecc.u-tokyo.ac.jp), Mizuki Kiyonaga[1], Ikuya Murakami[1]; [1]Department of Psychology, the University of Tokyo, Tokyo, Japan

It is widely known that a stationary contour of a stimulus that contains visual motion inside is perceptually shifted in the direction of the motion (motion-induced position shift). Although a lot of studies have examined various kinds of motion that can induce illusory position shifts and explored relationship between position perception and motion processing, how these motion induced position shifts have effects on other visual attributes have been rarely studied. Thus, we focused on perception of aspect ratio, which is one kind of shape perception producing a negative aftereffect, and investigated whether perceived aspect ratio was affected after adaptation to a shape comprised of patches yielding illusory position shifts caused by motion, namely Gabor patches with drifting sinusoidal carriers. The static contrast envelope of each Gabor patch appears to be shifted in the direction of motion, thus perceptually deforming the global shape defined by these patches. In this experiment, a number of drifting Gabor patches were geometrically arranged to comprise a diamond with a physical aspect ratio of 1:1, and its perceptual aspect ratio was distorted vertically or horizontally by motion-induced position shift. Participants were adapted to these diamonds that appeared to have a distorted aspect ratio, and were immediately tested for the aftereffect by indicating whether a diamond consisting of stationary Gaussian luminance blobs was elongated vertically or horizontally. We found that the perceptually distorted aspect ratio did not cause the negative shape aftereffect, whereas a physically distorted aspect ratio did. These results were at odds with some previous researches claiming that the aspect ratio aftereffects seemingly arise from a perceived difference between the adapting and test stimuli, rather than a difference in physical aspect ratio. We will discuss the relationship between perceived position distorted by motion and dedicated visual mechanisms for aspect ratio.

Acknowledgement: Supported by KAKENHI 18H01099

56.465 **Distance not time imposes limits on accumulation of illusory position shifts in the double-drift stimulus** Sirui Liu[1](sirui.liu.gr@dartmouth.edu), Peter U. Tse[1], Patrick Cavanagh[1,2]; [1]Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH 03755, USA, [2]Department of Psychology, Glendon College, Toronto, ON, M4N 3M6, Canada

When the internal texture of a Gabor patch drifts orthogonally to its physical path, its perceived motion deviates dramatically from its physical path. The local position shifts orthogonal to the motion path accumulate to create the deviation so that, for example, a 45° oblique physical path will appear to be vertical. However, at some point, a limit is reached where the path resets back to its physical location and a new accumulation starts, making a new perceived vertical segment parallel to the first but offset horizontally. This reset can be forced by introducing a temporal gap in the path and the perceived offset reveals the magnitude of the accumulation up to the reset. If the accumulation has been linear and free of loss during the first segment, it must 70.7% (=1/√2) of the physical path length for the 45° angle of the illusory deviation (Lisi & Cavanagh, 2015). Anything less than 70.7% indicates that some reset or saturation has occurred before the temporal gap. Here, we test whether this reset depends on the time (using different motion speeds) or the distance of the accumulated position errors. We presented three different motion speeds and two different path lengths before the temporal gap, followed by a similar continued motion after the gap. Perceived offsets were similar for these three speeds and were close to the expected illusion size for the shorter path length (deviation from the expected offset -15±18% of path length). However, for the longer path length at the same external speeds, overall perceived offsets were notably less than predicted (deviation -40±12%). There was no main effect of speed or interaction between path length and speed. Our results imply that accumulation of position shifts depends on distance, suggesting a spatial, not temporal, upper limit for the motion-position integration of this stimulus.

56.466 **Attention filters for motion tracking** Austin Kuo[1](austinchkuo@gmail.com), Kathryn L. Bonnen[4], Alexander C. Huk[2,3], Lawrence K. Cormack[2,3]; [1]Center for Perceptual Systems, University of Texas at Austin, [2]Institute for Neuroscience, College of Natural Sciences, University of Texas at Austin, [3]Department of Psychology, College of Liberal Arts, University of Texas at Austin, [4]Center for Neural Science, Faculty of Arts and Sciences, New York University

Introduction: Feature-based visual attention can be quantified by deriving "attention filters" for any continuously-variable feature (e.g. contrast) using the centroid paradigm (Sun et al., 2016, AP&P, 78: 474-515).In this paradigm, subjects attempt to estimate the centroid of items with a certain feature value (e.g., the next-to-lowest contrast) among distractor items with other feature values (e.g. higher and lower contrasts).In this work, we introduce a dynamic version of the centroid paradigm, and use it to derive attention filters for motion statistics. Methods: Subjects (15 naïve, two authors) were instructed to follow, using a trackpad, the centroid of a target subset of small elements (11x11 arcmin, light gray against darker background) that moved with a certain distribution of temporal frequencies amongst two distractor subsets that had different temporal frequency distributions. Results: Attention filters were basically optimal when only a single target was tracked, but became less so overall as the number of targets increased.Subjects performed the task well when asked to track targets with the highest and lowest average speeds, weighting the targets more highly in their centroid estimates than the distractors. However, subjects performed poorly when asked to track targets with the middle average speed, instead weighting the slow-moving distractors more heavily than the actual targets in their centroid estimates, in most cases. Discussion: The continuous-tracking version of the centroid task allows the study of motion statistics as the bases for attention or stimulus segregation.It also adds tremendous power in that the response data are collected at 60 Hz, leading to very stable filter estimates in a very short amount of experimental time.Further, naïve subjects found the task to be intuitive; with no explicit training their data were not only very stable but also indistinguishable from those of experienced observers.

Acknowledgement: R01 EY-020592, U01 NS094330

56.467 **Rebounding illusory apparent motion in three dimensions using virtual reality** Benjamin P Hughes[1](bephughe@ucsc.edu), Hunter Delattre[3], Nathan H Heller[2], Patrawat Samermit[1], Nicolas Davidenko[1]; [1]Psychology Department, University of California, Santa Cruz, [2]Psychological and Brain Sciences Department, Dartmouth College

Adapting to a rebounding apparent motion sequence (e.g. LEFT-RIGHT-LEFT-RIGHT) leads to illusory apparent motion (IAM) upon subsequent presentation of random frames that rebounds along the adapting axis (Davidenko et al., 2017; Davidenko & Heller, 2018). However, this phenomenon has only been examined in the horizontal-vertical plane. The present study investigated whether IAM extends to three-dimensional space by adapting participants to rebounding motion along the three cardinal axes using virtual reality. Participants (N=20) viewed dense arrays of small white cubes in an otherwise dark virtual environment through a head-mounted display. Each participant completed four "catch" trials and twelve "real" trials. In the catch trials, 70% of the cubes rebounded back and forth along a cardinal axis at 1.5Hz for six frame transitions, while the remaining 30% of cubes moved randomly. In the real trials, the first four frame transitions showed 70% of the cubes rebounding along a cardinal axis, but in the final two frames 100% of the cubes moved randomly. Following each trial, participants verbally indicated which axis the cubes appeared to move along during the final two frame transitions, or indicated "random" if their percept was inconsistent with motion along a single axis. A 2-way repeated measures ANOVA revealed a significant interaction between the adapted and reported axes ($F(4,179)=3.97$, $p=0.006$). Excluding "random" responses (with proportions 0.55, 0.26, and 0.29 following depth, horizontal, and vertical adapters, respectively), IAM reports were more frequent along the adapted axis compared to the non-adapted axes (see Figure 1). However, depth IAM was reported less frequently than horizontal or vertical IAM, which may be due to depth adapters being harder to detect, as suggested by catch trial performance (Figure 2). Overall, our results provide novel evidence that rebounding IAM can be experienced beyond the horizontal-vertical plane.

56.468 **Fast motion drags shape** Mark Wexler[1](mark.wexler@parisdescartes.fr), Patrick Cavanagh[2,3,4]; [1]Labotatoire Psychologie de la Perception, CNRS & Université Paris Descartes, Paris, France, [2]Department of Psychology, Glendon College, Toronto, ON, Canada, [3]Centre for Visual Research, York University, Toronto, ON, Canada, [4]Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH, USA

Fast motion on the retina causes salient visual smear. At moderate speeds, this smear is suppressed when the motion lasts 30 ms or more (Burr, 1981). In contrast, smear from motion at saccadic speeds of several hundred degrees per second is not diminished at any duration. It is suppressed, however, if the motion is preceded by a static image of the moving object at the starting point and then finishes with a static image at the endpoint. The static endpoints create a paradoxical perception of a clear, moving object, but moving so fast that no clear shape should be seen. We examined whether this percept arises from de-smearing the actual moving shape, or whether it is an interpolation of the static endpoints. Observers discriminated between two shapes that moved over 10 deg at 200 deg/s (on a display refreshed at 1440 Hz). Without the static endpoints the shapes could be discriminated with near-perfect accuracy. We then displayed one of the shapes statically at the start and then at the end of the trajectory. The moving shape could be the same as the static shapes or not. When the duration of the static endpoints was over 50 ms, observers could no longer identify the moving shape. Instead, they reported that the clear moving shape was the shape of the static endpoints. We argue that the effect is distinct from apparent motion, and is not due to weighted averaging between the static and moving shapes. The effect breaks down for lower speeds, or motion that is sampled below 200 Hz. We conclude that fast, smooth motion can drag the percept of a briefly shown static shape along the motion path. This effect has obvious parallels to saccadic suppression and may explain why we perceive a clear world during saccades.

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Perception and Action: Decision making, neural mechanisms

Wednesday, May 22, 8:15 - 10:00 am, Talk Room 1

Moderator: Megan Peters

61.11, 8:15 am **Rythmic modulation of V1 BOLD response (7T) after a Voluntary action** Maria Concetta Morrone[1,2](concetta@in.cnr.it)**,** Alessandro Benedetto[1]**,** Mauro Costagli[3]**,** Michela Tosetti[2,3]**,** Paola Binda[1]; [1]Department of Translational Research on New Technologies in Medicines and Surgery, University of Pisa, Via San Zeno 31, 56123 Pisa, Italy, [2]IRCCS Stella Maris, Calambrone, Pisa, Italy, [3]IMAGO 7, Calambrone, Pisa, Italy

To interact effectively with the external world, motor and visual processing need to be tightly synchronized in time. One possible synchronization mechanism may be phase resetting of endogenous rhythms of motor and visual cortex. In previous studies we have shown that voluntary actions can induce long-lasting rhythmic (5-7 Hz) oscillations in visual contrast sensitivity, even for stimuli irrelevant to that action. Here we demonstrate that BOLD responses of early stages of visual processing are rhythmically modulated in synchrony with a voluntary action, with ultra-high field MRI (7T) measurements during a 2AFC task. Participants discriminated the spatial frequency of two brief (33 ms) gratings of 1.0 and 1.1 c/deg, presented randomly in the upper or lower visual field: participants initiated each trial in the scanner by a button press, at will. The stimulus was displayed randomly with either 70 ms or 150 ms delay, corresponding to the minima and the maxima of the first oscillation in visual discrimination sensitivity, and subjects responded after a delay (>20s). Results from 10 participants indicate that visual stimuli presented at 150 ms delay (oscillation peak) elicited stronger responses than those presented at 70 ms delay (oscillation trough), for all stimulated eccentricities. However, the button press alone (without visual stimulation) elicited no response in V1, at any retinotopic eccentricity. The modulation of BOLD responses occurred at all early visual areas, including V1, V2, V3 and V4, and was consistent with the behavioral performance measured outside the scanner for the same task. These results suggest an early visuo-motor interaction, at the level of V1. The rhythmic modulation points to synchronization of vision and action that shapes vision by alternatively suppressing and enhancing processing.

Acknowledgement: ERC grant ESCPLANE

61.12, 8:30 am **Graded, multidimensional representations of sensory evidence allow for dissociable performance in second-choice and confidence judgments.** Tarryn Balsdon[1,2]**,** Valentin Wyart[2]**,** Pascal Mamassian[1]; [1]Laboratoire des systèmes perceptifs, Département d'études cognitives, École normale supérieure, PSL University, CNRS, 75005 Paris, France, [2]Laboratoire de neurosciences cognitives computationelles, Département d'études cognitives, École normale supérieure, PSL University, INSERM, 75005 Paris, France

Perceptual decisions are made on the basis of complex and often ambiguous sensory evidence. Whilst the outcome of sensory evidence accumulation may reflect the mere crossing of a decision criterion, it is well known that human observers have access to a far richer representation of their sensory environment. Indeed, it is this rich representation that allows observers to assess the accuracy of their perceptual decisions, as in confidence judgements, and to offer a second choice judgement when deciding between more than two options. In this experiment, we examine human observers' ability to use this graded, multidimensional representation of sensory evidence to make second-choice judgements, and how this second-choice process relates to their metacognitive ability. On each trial we presented observers with a series of oriented Gabors, drawn from one of three categories, defined by circular Gaussian distributions centred on -60°, 0° and 60° relative to vertical. Observers' task was to decide which distribution the Gabors were drawn from, by accumulating the evidence for each category over the stimuli presented to them. After making their first choice, observers then provided a second choice – which is the next most likely category? Over pairs of trials, observers also chose which trial they were more confident that they made a correct first choice. A computation model was fit to each observer's first choice decisions to determine their sensory internal noise. An ideal observer that was only limited by this sensory noise was then defined to predict performance in the second choice and confidence judgments. Observers underperformed in the second choice task, but overperformed in the metacognitive decision, relative to the ideal observer. This suggests that these two ways in which observers access the sensory evidence are dissociable, and thus, that these decisions target different aspects of the sensory evidence representation, utilizing distinct computations.

Acknowledgement: CNRS, INSERM

61.13, 8:45 am **Tuned normalization in perceptual decision-making circuits can explain seemingly suboptimal confidence behavior** Brian Maniscalco[1](bmaniscalco@gmail.com)**,** Brian Odegaard[2]**,** Piercesare Grimaldi[3]**,** Seong Hah Cho[4]**,** Michele A. Basso[3,5,6,7]**,** Hakwan Lau[2,4,7,8]**,** Megan A.K. Peters[1,2,9,10]; [1]Department of Bioengineering, University of California Riverside, [2]Department of Psychology, University of California Los Angeles, [3]Departments of Psychiatry and Biobehavioral Sciences, University of California Los Angeles, [4]Department of Psychology, University of Hong Kong, [5]Department of Neurobiology, University of California Los Angeles, [6]Semel Institute for Neuroscience and Human Behavior, University of California Los Angeles, [7]Brain Research Institute, University of California Los Angeles, [8]State Key Laboratory of Brain and Cognitive Sciences, University of Hong Kong, [9]Interdepartmental Graduate Program in Neuroscience, University of California, Riverside, [10]Department of Psychology, University of California, Riverside

Current dominant views hold that perceptual confidence – e.g., in visual perceptual decisions – reflects the probability that the relevant decision is correct. Although these views have enjoyed some empirical support, recent behavioral results indicate that confidence and the probability of being correct can be dissociated. An alternative hypothesis suggests that confidence instead reflects the magnitude of evidence in favor of a perceptual decision while being relatively insensitive to the evidence opposing the decision. We considered how this alternative hypothesis might be biologically instantiated by developing a simple leaky competing accumulator neural network model incorporating a known property of sensory neurons: tuned normalization. The key idea of the model is that each accumulator neuron's normalization 'tuning' dictates its contribution to perceptual decisions versus confidence judgments. We demonstrate that this biologically plausible model can account for several counterintuitive findings reported in the literature, where confidence and decision accuracy in visual tasks were shown to dissociate -- and that the differential contribution a neuron makes to decisions versus confidence judgments based on its normalization tuning is vital to capturing some of these effects. One critical prediction of the model is that systematic variability in normalization tuning exists not only in sensory cortices but also in the decision-making circuitry. We tested and validated this prediction in macaque superior colliculus (SC; a region implicated in decision-making). The confirmation of this novel prediction provides direct support for our model. We will also present pilot data from an exploratory fMRI paradigm investigating this Tuned Normalization model's predictions in humans. These findings suggest that the brain has developed and implements this alternative, heuristic theory of perceptual confidence computation by capitalizing on the diversity of neural resources available

Acknowledgement: This work was partially supported by the National Institutes of Health (R01NS08862801 to HL R01EY13692 to MAB).

61.14, 9:00 am **Speed-accuracy tradeoff heightens serial dependence** Farshad Rafiei[1](farshad@gatech.edu)**,** Dobromir Rahnev[1]; [1]School of Psychology, College of Sciences, Georgia Institute of Technology

Perceptual decisions are heavily influenced by previous stimuli and decisions. This serial dependence has been the subject of extensive study but a mechanistic understanding of this phenomenon is yet to emerge. One difficulty with understanding the nature of serial dependence is that it is unclear what factors modulate its strength. Here we examined whether serial dependence is affected by speed-accuracy tradeoff (SAT). We created five different SAT conditions by designing a payoff structure that increasingly punished long reaction times (RTs). This design allowed us to study serial dependence

across a wider range of SAT conditions than what is normally done. Subjects (N = 20) came for five separate sessions, completing a total of 5,000 trials each of a Gabor orientation discrimination task. We analyzed whether the SAT condition modulated several different types of serial dependence. First, we performed regression analyses to understand how RT and accuracy on the current trial are influence by RT and accuracy on the previous trial. We found that serial dependence in RT increased with higher speed stress ($F(4,60) = 3.2$, $p = 0.019$). A similar effect was obtained for RT on the previous trial predicting accuracy on the current trial. Second, we computed the lag-1 and lag-2 autocorrelation in subjects' choices and found that both increased with increasing speed stress (lag-1: $F(4,60) = 10.95$, $p < 0.0001$; lag-2: $F(4,60) = 22.27$, $p < 0.0001$). In addition, these results were modulated by accuracy such that previous corrected responses tended to lead to more response repetitions, especially for high speed stress conditions ($F(4,60) = 4.22$, $p < 0.0044$). These results demonstrate that greater speed stress almost universally increases serial dependence and suggest that serial dependence may be the result of automatic processes that can be partly suppressed by increased deliberation.

61.15, 9:15 am **Pointing adaptation changes visual depth perception** Tatiana Kartashova[1](tatiana.kartashova@hhu.de), Maryvonne Granowski[1], Eckart Zimmermann[1]; [1]Perceptual Psychology, Institute of Experimental Psychology, Heinrich Heine University Düsseldorf

In order to know how far objects are away from us, the brain might use the coordinates contained in plans of movements that would reach the object. We investigated whether adaptation of pointing movements changes the visual perception of depth. We presented three-dimensional stimuli in a virtual environment using head mounted displays and controllers to track pointing movements. The pointing targets – small red spheres – were presented at the eye level at two distances on two sides of the observers' midline. In adaptation trials, observers were asked to point at one of four possible targets as accurately as possible. After each pointing movement, visual feedback was provided about their terminal hand position. When targets were shown on the left side, pointing feedback represented the observers tracked pointing, whereas on the right side it was distorted. In separate sessions, the distorted feedback was shown either further in depth or closer to the observer's body. Therefore, we obtained a split-field that contained an adapted region on the right and a non-adapted on the left. Aftereffects indicated that observers adapted to the distortion selectively in the right field. In the visual task observers compared the size of two flashed spheres, one shown in the adapted and one in the non-adapted region. We found that spheres presented in the adapted region appeared smaller after we adapted subjects to point further into depth, as if visual space had been shifted in direction of the motor adaptation of pointing movements. Consistently, spheres appeared bigger when we reversed the direction of the distortion. These results show that depth perception is shaped by motor adaptation and support the idea that depth perception is constituted by the coordinates contained in three-dimensional pointing movements.

Acknowledgement: ERC Grant

61.16, 9:30 am **Predictive eye and head movements when hitting a bouncing ball** David L Mann[1](davidlindsaymann@gmail.com), Hiroki Nakamoto[2], Nadine Logt[1], Lieke Sikkink[1], Eli Brenner[1]; [1]Department of Human Movement Sciences, Amsterdam Movement Sciences and Institute of Brain and Behavior Amsterdam, Vrije Universiteit Amsterdam, [2]Faculty of Physical Education, National Institute of Fitness and Sports in Kanoya, Kagoshima

Predictive eye movements targeted towards the direction of ball-bounce are a feature of gaze behavior when intercepting a target soon after it has bounced (Land & McLeod, 2000). However, there is conjecture over the strategy that is used when generating these predictions and why they would be necessary. In particular, some studies have reported that gaze as a result of those predictions 'lies-in-wait' for the ball at the location of bounce (Land & McLeod, 2000; Mann, Spratford & Abernethy, 2013) whereas other studies suggest that exquisite predictions are made to relocate gaze towards where the ball will be at some point following bounce (Diaz, Cooper, Rothkopf & Hayhoe, 2013). The aim of this study was to better understand the nature of the predictive eye movements that are made when hitting a bouncing ball. We tracked the eye and head movements of 23 novice participants who attempted to hit approaching tennis balls that bounced at different distances from them in a virtual environment. Results revealed that participants made predictive saccades in advance of ball bounce in half of all trials, with saccades directed several degrees above the bounce rather than towards or beyond it. Instead of gaze after the saccade lying-in-wait for the ball to catch-up, gaze instead moved throughout the bounce period. Ongoing head movements ensured that gaze continued to follow the ball laterally during bounce, while vertical eye movements realigned gaze with the ball often within the first 100ms after bounce, which, given the visual-motor delay, suggests that corrective eye movements were planned in advance of the bounce. Participants do not appear to use predictive eye movements to ensure gaze 'lies-in-wait' for the ball at or beyond bounce, but rather seem to use predictions to guide ongoing eye and head movements throughout the moment of bounce.

61.17, 9:45 am **Action-based predictions affect visual perception, neural processing, and pupil size, regardless of temporal predictability** Bianca M van Kemenade[1](biancavankemenade@gmail.com), Christina Lubinus[2], Wolfgang Einhauser[3], Florian Schiller[4], Tilo Kircher[1], Benjamin Straube[1]; [1]Department of Psychiatry and Psychotherapy, Philipps-University Marburg, [2]Department of Neuroscience, Max-Planck-Institute for Empirical Aesthetics, Frankfurt am Main, [3]Chemnitz University of Technology, Institute of Physics, Physics of Cognition Group, [4]Department of Psychology, Justus Liebig Universität Giessen

Sensory consequences of one's own action are often perceived as less intense, and lead to reduced neural responses, compared to externally generated stimuli. It has been proposed that such sensory attenuation is due to predictive mechanisms based on the efference copy, which is a copy of the motor command. However, sensory attenuation has also been observed outside the context of voluntary action, namely when stimuli are temporally predictable. Here, we investigated whether attenuation of sensory action consequences is due to action-based predictive mechanisms or rather due to differences in temporal predictability. 25 participants took part in our fMRI study. During fMRI data acquisition, participants had to judge which one of two visual stimuli was brighter. In predictable blocks, the stimuli appeared temporally aligned with their button press (active) or aligned with an automatically generated cue (passive). In unpredictable blocks, stimuli were presented with a variable delay after button press/cue, respectively. Eye tracking was performed to investigate pupil-size changes and to ensure proper fixation. Self-generated stimuli were perceived as darker and led to less neural activation in visual areas than their passive counterparts, indicating sensory attenuation for self-generated stimuli. These effects were accompanied by a larger pupil size during self-generated stimuli, which correlated negatively with BOLD response: the larger the pupil, the smaller the BOLD amplitude in visual areas. An effect of temporal predictability was not found. Therefore, our results suggest that sensory attenuation in visual cortex is mainly driven by action-based predictive mechanisms, not by temporal predictability. This effect may be mediated by changes in pupil diameter. Altogether, these results emphasize the role of the efference copy in the processing of sensory action consequences.

Acknowledgement: SFB/Transregio 135 (DFG), IRTG 1901 (DFG), STR 1146/8-1 (DFG) and STR 1146/9-1 (DFG)

Visual Memory: Long term memory

Wednesday, May 22, 8:15 - 10:00 am, Talk Room 2

Moderator: John Wixted

61.21, 8:15 am **Image memorability is driven by visual and conceptual distinctivenes** Qi Lin[1](qi.lin@yale.edu), Sami R Yousif[1], Brian Scholl[1], Marvin M Chun[1]; [1]Department of Psychology, Yale University

What drives image memorability? Previous work has focused almost exclusively on either specific dimensions of the images themselves or on their local categories. This work has typically involved semantic properties (e.g. whether an image contains a human, or whether it is an instance of a forest), but we have also demonstrated visual memorability: even when semantic content is eliminated (e.g. via phase-scrambling), some images are still consistently more likely to be retained in short-term memory. Beyond individual feature dimensions and image categories, here we ask whether the memorability of an image is also influenced by its distinctiveness in a much broader multidimensional feature space. We first measured distinctiveness behaviorally, by calculating the conceptual and perceptual distinctiveness of images based on pairwise similarity judgments of each type.We then also measured distinctiveness computationally, by calculating the average distance of each target image to all other images in a ~10,000-image database, at different layers of a CNN trained to recognize scenes and objects (VGG16-Hybrid1365). For intact vs. scrambled images, we observed opposite patterns of correlations between distinctiveness and short-term memorability. For intact images, short-term memorability was primarily a function of

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how conceptually distinct an image was. And strikingly, this was mirrored in the CNN analysis: distinctiveness at later (but not earlier) layers predicted memorability. For scrambled images, in contrast, the reverse was true. Collectively, these results suggest that memorability is a function of distinctiveness in a multidimensional image space — with some images being memorable because of their conceptual features, and others because of their perceptual features. Moreover, because distinctiveness in the CNN was computed over all images in the much larger database, the relevant measure of distinctiveness may reflect not just the local statistics of an experimental image set, but also the broader statistics of our natural environment as a whole.

Acknowledgement: SRY was supported by an NSF Graduate Research Fellowship. BJS was supported by ONR MURI #N00014-16-1-2007.

61.22, 8:30 am **Iterated learning Revealed Color-contigent Structured Priors in Visual Memory**Yang Wang[1](wangy0802@hotmail.com), Edward Vul[1]; [1]Psychology, University of California, San Diego

Visual working memory is a reconstructive process that requires integrating multiple hierarchical representations of objects. This hierarchical reconstruction allows us to overcome perceptual uncertainty and limited cognitive capacity, but yields systematic biases in working memory, as individual items are influenced by the ensemble statistics of the scene, or of their particular group. Given the importance of the hierarchical encoding of a display for visual memory, we aim to characterize what structured priors people use to encode visual scenes. To discover these priors, we use an iterated learning task, in which participants recall the locations of 15 dots and the report of one person becomes the stimulus for the next person in the "chain". Over many iterations of such a chain, reported locations will increasingly reflect the prior biases that people bring to bear on the encoded visual display. Previously, we showed that such iterated learning chains reveal the patterns of spatial grouping people expect when encoding homogenous positions -- priors that appear to correspond to the Gestalt rules of proximity, continuity and similarity. The current study further examines how surface features (namely colors) influence encoding of visual displays and influence spatial grouping in visual working memory. We found that distinct colors dominate spatial factors (such as proximity and continuity) in grouping. The reported positions tend to converge toward tight, segregated color clusters that are increasingly linear, and regularly spaced. This indicates that distinct colors dominate spatial proximity and continuity in visual working memory grouping. We built several ideal observer clustering models to identify which assumptions are critical to emulate human behavior, and find that human performance is consistent with spatial clustering under strong assumptions of within-group color homogeneity.

61.23, 8:45 am **Generating reliable visual long-term memory representations for free: Incidental learning during natural behavior** Dejan Draschkow[1](draschkow@psych.uni-frankfurt.de), Melissa L.-H. Võ[1]; [1]Department of Psychology, Goethe University Frankfurt

In comparison to traditional laboratory studies in which the capacity of our cognitive apparatus gets benchmarked, natural interactions with our environment can reveal its actual usage. In natural behavior we rarely use cognitive subsystems (e.g. WM) to capacity or follow a strict top-down encoding protocol (e.g. explicit memorization). In fact, we often act short-term goal and task-oriented, which results in a behaviorally optimal representation of our environment. In a series of computer-based, virtual-reality, and real-world experiments we investigated the role of sampling information during natural tasks (via eye movements and incidental exposure durations) for the generation of visual long-term memories (VLTMs). Even after incidental encounters with thousands of isolated objects, VLTM capacity for these objects is reliable, however, the detail of these representations is quite sparse and does not increase if the incidental encounters are longer (Study1). When searching for objects in an actual real-world environment – where locomotion is necessary – fixation durations on objects predict subsequent location memory, as measured with surprise memory tests (Study2). Incidental representations generated during search are more reliable than memories established after explicit memorization in a realistic virtual environment (Study3). Further, in a real-world object-sorting task, eye movements used for minimizing WM load and instead gathering task-relevant information just before it is required, significantly predict long-term location memory of objects (Study4). Finally, in a virtual-reality paradigm (Study5), we show that spatial priors can be activated within the first fixation into a new environment in a one-shot manner. Together, this rich set of studies shows that incidental information acquisition during natural behavior establishes reliable VLTM representations, which can be used to guide ongoing behavior in a proactive fashion. In conclusion, utilizing our inbuilt mechanism for efficient and goal-directed short-term task completion strongly contributes to the generation and utilization of VLTM.

Acknowledgement: This work was supported by DFG grant VO 1683/2-1 and by SFB/TRR 135 project C7 to MLV.

61.24, 9:00 am **The Number of Encoding Opportunities, but not Encoded Representations in Visual Working Memory Determines Successful Encoding into Visual Long-Term Memory** Caitlin J. I. Tozios[1](caitlin.tozios@mail.utoronto.ca), Keisuke Fukuda[1]; [1]Department of Psychology, University of Toronto

Visual long-term memory (VLTM) allows us to store a virtually unlimited amount of visual information (e.g., Brady et al., 2008). Despite its unlimited capacity, not all visual information gets encoded into VLTM. One robust way to improve VLTM encoding is to restudy the visual information. However, the exact mechanism underlying this restudy benefit is not clear. In a series of four experiments, we examined following three hypotheses. First, the restudy benefit stems from the increase in the number of visual working memory (VWM) representations encoded as the visual information is restudied. Second, instead of the increase in the number of VWM representations, the restudy benefit stems from the increase in the total number of encoding opportunities. Lastly, the encoding benefit stems from successful recognition of the encoded information when it is restudied. To dissociate the number of encoded VWM representations from the number of encoding opportunities, we presented varying numbers of copies of the same visual information at each restudy opportunity. To measure the number of VWM representation encoded at each restudying opportunity, we utilized two previously-established EEG correlates of VWM representations, namely the posterior alpha power suppression and the posterior sustained negativity (Fukuda, Mance, & Vogel, 2015). Here, we found that 1) it is the number of encoding opportunities, rather than the number of encoded VWM representations, that leads to the restudy benefit and that 2) successful retrieval during restudying augments VLTM encoding in addition to the effect of the number of encoding opportunities. Taken together, our results specify the nature of visual working memory's contribution to VLTM encoding.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (RGPIN-2017-06866), and the Connaught New Researcher Award from the University of Toronto

61.25, 9:15 am **Long-term spatial memory representations in human visual cortex** Serra E Favila[1](serra.favila@nyu.edu), Brice A Kuhl[2], Jonathan Winawer[1]; [1]Department of Psychology, New York University, [2]Department of Psychology, University of Oregon

Space is a primary organizing dimension in the visual system, with over 20 visual field maps identified in human neocortex. Activity evoked in neocortical areas during perception is thought to be reinstated during later memory retrieval. Memory-driven activity is unlikely to be identical to perceptual activity, but how it differs is unknown. We used fMRI to investigate whether and how remembering learned visual stimuli evokes topographically organized responses in many visual areas. We first trained human subjects to associate colored fixation dot cues with spatially localized stimuli. Stimuli were four unique radial frequency patterns presented at 45°, 135°, 225°, or 315° of polar angle and 2° eccentricity, each paired with a different fixation color. After subjects demonstrated reliable memory performance, we collected fMRI data while subjects either viewed or recalled these stimuli in separate scans. We used population receptive field (pRF) models estimated from independent data to evaluate the BOLD response during memory retrieval as a function of preferred visual field location. We found that memory reactivation is precisely retinotopically mapped, with peak activation during memory at cortical locations whose pRF centers matched the location of the remembered stimulus. There were also clear systematic differences between perception and memory. Memory activation was lower amplitude than visual activation, and this difference was largest for early visual areas. Further, while the spatial profile of visually-driven responses became increasingly broad in higher visual areas (V1: 51°; V3ab: 148°, FWHM), the spatial profile during memory retrieval was similarly broad in all visual areas measured (V1: 123°; V3ab: 109°). We simulated a simple hierarchical model of cortical feedforward and feedback responses that may account for these observations. Our findings support the hypothesis that memory representations make use of sensory maps, but point to differences in how feedforward and feedback activity may propagate through this system.

Acknowledgement: NIH Blueprint D-SPAN F99/K00 Award

See page 3 for Abstract Numbering System

61.26, 9:30 am **The contributions of visual details vs semantic information to visual long-term memory** Kelvin Lam[1], Mark W Schurgin[1], Timothy F Brady[1]; [1]Department of Psychology, University of California, San Diego

Visual long-term memory can store thousands of objects with significant detail. However, the contribution of semantic information to this memory for visual details remains relatively understudied. To investigate this issue, we utilized stimuli known as "texforms" – spatially-constrained textures generated from objects, which contain the same low- and mid-level feature information but obscure object identity (Freeman & Simoncelli, 2011; Long & Konkle, 2017). Since participants cannot recognize the texforms, they cannot use semantic information to inform memory. In Experiment 1, participants memorized texforms presented sequentially for 3 seconds each. After a delay, they were shown old and new images of texforms and had to judge how confident they were the image was old or new. Participants were able to remember texforms well above chance (d_a=0.45), suggesting they had some ability to remember visual information without semantic information; and this pattern was replicated in a control with verbal suppression at encoding. Experiment 2 aimed to discern the role of semantic information in memory. Specifically, semantic knowledge may improve long-term memory either (1) by directing attention and encoding resources to the relevant and informative features of a particular object, or (2) by providing a relevant and distinctive retrieval-cue (Eysenck 1979). Thus, in Experiment 2, texforms were primed with an image of the original object for 100ms at encoding. This allowed participants to briefly recognize the object from the texform but not to hold onto this interpretation indefinitely. With priming, participants remembered texforms, (d_a=0.49) but no better than without priming (compared to Exp. 1: t(38)=0.39, p=0.70). These results demonstrate a new method for isolating the contributions of different kinds of information in visual long-term memory. Moreover, they suggest that the benefit of semantic knowledge to long-term memory may arise more by providing a useful retrieval-cue than by affecting how items are encoded.

Acknowledgement: NSF CAREER BCS-1653457 to TFB

61.27, 9:45 am **The extraordinary capacity of visual long-term memory (including eyewitness memory)** John Wixted[1](jwixted@ucsd.edu); [1]UC San Diego

The capacity of the human brain to store detailed information in visual long-term memory – even after a single exposure to each item – is massive. For example, Brady, Konkle, Alvarez and Oliva (2008) presented subjects with 2,500 images of objects, and subsequent memory performance was above 87% correct (d' > 2.2), even when visual details were necessary at test. Given how impressive visual long-term memory is, a natural prediction would be that eyewitness identification (e.g., recognizing a perpetrator from a police lineup) would be similarly impressive. Yet nearly every experimental psychologist believes that eyewitness memory is extremely unreliable. What explains this apparent contradiction? Previous theory-free efforts to quantify the recognition memory performance of eyewitnesses tested using a lineup have been highly misleading. With the advent of signal detection theory in the 1950s, the field realized that there is no way to measure recognition memory performance without (implicitly or explicitly) embracing a theory. When the performance of actual eyewitnesses to stressful robberies was recently measured in terms of signal detection theory, d' was estimated to exceed 2.5. In other words, the memory of eyewitnesses to serious crimes in the real-world is impressive. This was true even though (1) the average delay between the crime and lineup memory test was 4 weeks, (2) the witnessed crimes were stressful, (3) most of the crimes involved the presence of a weapon, and (4) most involved a perpetrator from a different race than the witness (factors that serve to impair memory relative to more ideal conditions). Most importantly, eyewitness confidence was strongly related to accuracy (contrary to decades of erroneous research), with high-confidence accuracy approaching 100% correct. Clearly, visual long-term memory is impressive, whether you are a subject in a lab or an eyewitness to a serious crime (contrary to what every psychology textbook implies).

Perceptual Learning

Wednesday, May 22, 11:00 am - 12:45 pm, Talk Room 1

Moderator: Takeo Watanabe

62.11, 11:00 am **Orientation specificity and generalization of perceptual learning in n-AFC spatial frequency identification.** Barbara Dosher[1](bdosher@uci.edu), Jiajuan Liu[1], Zhong-Lin Lu[2]; [1]Cognitive Sciences, UC Irvine, [2]Psychology, The Ohio State University

Specificity and transfer of perceptual learning has generally been measured in two-alternative tasks. And, although learning has rarely been reported for spatial frequency judgments, we recently showed learning in a majority of observers in 8-alternative spatial frequency (8AFC) identification (Dosher, Liu, & Lu, VSS 2017). However, little is known about specificity or generalization in nAFC tasks. Here, we examined whether learning in 8-alternative spatial frequency identification was specific to the orientation of the training stimulus. Stimuli were Gabors of 8 spatial frequencies (0.50 to 5.68 cpd, in half-octave steps) in 5 orientations (-55.5° to 34.5° relative to vertical, in 22.5° steps) and embedded in Gaussian external noise (sigma=0.24); observers were trained to identify which of the 8 spatial frequencies was displayed in each trial.Learning and transfer were evaluated by comparing 8AFC judgments in a post-test after training to a pre-test. Four different groups were trained for 5 sessions of 960 trials each with either the leftmost, middle, or rightmost orientation, or a mixture of all five orientations in three Gabor contrasts (0.3, 0.6, 1.0). Consistent with the earlier report, there was modest learning in each training condition; training in the mixed condition ("roving" the non-judged orientation) or in the middle orientation condition if anything showed larger improvements. There was orientation-specificity in the leftmost and rightmost training conditions, seen in the degree of transfer over orientations. A simulation of the n-AFC integrated reweighting theory (IRT, Dosher et al., 2013; Dosher, Liu, & Lu 2017) without orientation invariance spatial frequency representations predicts more specificity than observed in the human data. Example simulations suggest a possible role for orientation-invariant representations mediating orientation transfer in a way analogous to the role of location-invariant representations in transfer over retinal locations, consistent with orientation invariance in higher visual cortical regions.

Acknowledgement: Supported by the National Eye Institute Grant # EY–17491.

62.12, 11:15 am **Increasingly complex internal visual representations in honeybees, human infants and adults** Beáta T Szabó[1,2,3](szabo.beata.tunde@gmail.com), Aurore Avarguès-Weber[4], Gergő Orbán[3,5], Valerie Finke[4], Márton Nagy[3], Adrian Dyer[6], József Fiser[3]; [1]Faculty of Information Technology and Bionics, Pázmány Péter Catholic University, Budapest, Hungary, [2]Institute of Cognitive Neuroscience and Psychology, Research Centre for Natural Sciences, Hungarian Academy of Sciences, Budapest, Hungary, [3]Department of Cognitive Science, Central European University, Budapest, Hungary, [4]Centre de Recherches sur la Cognition Animale, Centre de Biologie Intégrative, Université de Toulouse, Toulouse, France, [5]Department of Theoretical Physics, Wigner Research Centre for Physics, Hungarian Academy of Sciences, Budapest, Hungary, [6]Bio-inspired Digital Sensing Lab, School of Media and Communication, RMIT University, Melbourne, Australia

Although some animals such as honeybees (Apis mellifera) are excellent visual learners, little is known about their spontaneously emerging internal representations of the visual environment. We investigated whether learning mechanisms and resulting internal representations are similar across different species by using the same modified visual statistical learning paradigm in honeybees and humans. Observers performed an unrelated discrimination task while being exposed to complex visual stimuli consisting of simple shapes with varying underlying statistical structures. Familiarity tests was used for assessing the emergent internal representation in three conditions exploiting whether each of three different statistics (single shape frequencies, co-occurrence probabilities and conditional probability between neighboring shapes) were sufficient for solving the familiarity task. We found an increasingly complex representation of the visual environment as we moved from honeybees to human infant and to adults. Honeybees automatically learned the joint probabilities of the shapes after extended familiarization but didn't show sensitivity to the conditional probabilities and they didn't learn concurrently the single-element frequencies. As we know from previous studies, infants implicitly learn joint- and conditional probabilities, but they aren't sensitive to concurrent element frequencies either.

Adult results in this study were in line with previous results showing that they spontaneously acquired all three statistics. We found that these results could be reproduced by a progression of models: while honeybee behavior could be captured by a learning method based on a simple counting strategy, humans learned differently. Replicating infant's behavior required a probabilistic chunk learner algorithm. The same model could also replicate the adult behavior, but only if it was further extended by co-representation of higher order chunk and low-level element representations. In conclusion, we've found a progression of increasingly complex visual learning mechanisms that were necessary to account for the differences in the honeybee, human infant- and adult behavioral results.

Acknowledgement: This research has been partially supported by the European Union, co-financed by the European Social Fund (EFOP-3.6.3-VEKOP-16-2017-00002)

62.13, 11:30 am **Perceptual Learning Benefits From Strategic Scheduling of Passive Presentations and Active, Adaptive Learning.** Everett W Mettler[1](mettler@ucla.edu), Austin S Phillips[1], Timothy Burke[1], Patrick Garrigan[2], Christine M Massey[1], Philip J Kellman[1]; [1]UCLA, [2]St. Joseph's University

Perceptual learning (PL), improvements in perception due to practice (Gibson, 1969; Kellman, 2002), appears to be influenced by effects found in non-perceptual learning (NPL) domains. For example, spacing and interleaving effects in factual learning also appear in perceptual category learning (Mettler & Kellman, 2014; Carvalho & Goldstone, 2015). As in NPL domains, learning in PL can be either passive (requiring only observation) or active (requiring active responses followed by feedback). Here we study the effects on PL of active vs. passive presentations and their combination, previously investigated primarily in NPL domains . Method: Stimuli were organized into 12 categories of butterfly genera with 9 exemplars per genus. Participants learned to match genus names to exemplar images. Training conditions consisted of either: a) passive presentations only, b) 2 initial blocks of passive presentations followed by active, adaptive learning, c) 1 initial passive presentation per category, followed by active, adaptive learning, or d) active adaptive learning only. Adaptive schedules adjusted spacing based on learner performance (Mettler, Massey & Kellman, 2016) and trained learners to a criterion; Passive Only schedules had a fixed number of trials. For each training category, one exemplar was withheld from training and used as a test of generalization at posttest. Participants received a pretest, immediate posttest, and one week delayed posttest. Efficiency, accuracy adjusted for trials invested in training, was compared across conditions. Results: Initial blocks of passive trials followed by active adaptive learning resulted in the most efficient learning. Active Only, Passive Only, and Passive Initial Exemplar conditions fared worse. Results were similar across familiar and novel exemplars. Conclusion: PL with initial blocks of passive trials followed by active adaptive learning enhanced PL. These results are similar to effects found in factual learning, suggesting that common learning principles and/or mechanisms underlie passive-active synergies in PL and NPL domains.

Acknowledgement: Supported by NSF Grant DRL-1644916

62.14, 11:45 am **An expert advantage on detection of unfamiliar patterns before and after practice** Zahra Hussain[1](zahra.hussain@aub.edu.lb); [1]Department of Psychology, American University of Beirut

This study examined whether naturally acquired expertise in object classification provides an advantage on an unfamiliar detection task. Ten radiologists with a range of clinical experience, and forty novice subjects performed detection of textures in noise on two consecutive days. The textures were bandlimited noise patterns of low, medium and high spatial frequency content shown in two levels of external Gaussian noise. Subjects performed a yes-no task in which signal contrast was varied using the method of constant stimuli, and signal present probability was 50%. A fixed set of five textures were used on both days in each spatial frequency condition. Spatial frequency and noise conditions were blocked, with a total of 1008 trials per session (168 trials x 3 spatial frequency x 2 external noise conditions). Sensitivity (d'), criterion location (c), and relative criterion location (c'), were calculated in each condition on both days. Contrary to previous work showing domain-specific effects of expertise, the radiologists showed superior performance to novices on both days in all conditions. Both groups improved from day 1 to day 2, with larger improvement at the medium and high spatial frequencies in low noise. Perceptual strategies differed between groups: experts were more liberal than novices at baseline, and showed a conservative shift with practice in low noise, whereas practice did not alter the novice group's criterion in any condition. These group differences were less pronounced in the relative criterion. Overall, the results suggest that expertise can benefit perceptual judgements outside the trained domain, and that the expert advantage may include a strategic component that is modified through experience.

Acknowledgement: University Research Board (URB) grant, American University of Beirut

62.15, 12:00 pm **Trans-saccadic perceptual learning of orientation discrimination is not location specific** Lukasz Grzeczkowski[1](lukasz.grzeczkowski@gmail.com), Heiner Deubel[1]; [1]Allgemeine und Experimentelle Psychologie, Department Psychologie, Ludwig-Maximilians-Universität München, Munich, Germany.

Perceptual learning is the ability to improve perception through practice. The hallmark of perceptual learning is its specificity for the trained visual features such as the stimulus orientation and location. For example, training in discriminating Gabors' orientation improves performance. However, that training does not improve Gabor orientation discrimination at untrained locations. Perceptual learning is mostly studied without eye movements. Nevertheless, in everyday life, a given stimulus is actively explored through eye movements, resulting in successive projections of that stimulus at different retinal locations. Here, we studied perceptual learning of orientation change discrimination across saccades. In Experiment 1, observers trained to discriminate orientation changes of a Gabor grating presented in the periphery while fixating in the center. Before and after training (pre- and post-training tests), observers were tested with the same task but with an orthogonal orientation at the trained location, and the trained orientation at an untrained location. Expectedly, observers improved performance, and perceptual learning was orientation and location specific. In Experiment 2, instead of fixating, observers in training and pre- and post-training test trials saccaded to the peripheral grating, and discriminated the orientation change occurring during the saccade. Orientation and location conditions were the same as in Experiment 1. Interestingly, we found trans-saccadic perceptual learning for orientation change discrimination. This perceptual learning did not transfer to the untrained orientation. Surprisingly however, we found transfer to the untrained location. Additionally, after the trans-saccadic training, observers also improved their performance at discriminating orientation changes in the fixation condition such as described in Experiment 1. We propose that perceptual learning within an active perception framework might reflect different mechanisms than classic perceptual learning.

Acknowledgement: This work was supported by grants of the Deutsche Forschungsgemeinschaft to HD (DE336/6-1).

62.16, 12:15 pm **A new type of long-lasting adaptation that is feature-unspecific, task-specific and occurs only in a plastic state** Andreas Marzoll[1](andreas_marzoll1@brown.edu), Isha Chavva[1], Takeo Watanabe[1]; [1]Dept. of Cognitive, Linguistic and Psychological Sciences, Brown University, Providence, RI

Previous studies found that visual high- and low-frequency stimulation (dubbed "LTP/LTD-like") can facilitate or impair perceptual abilities (Beste et al., 2011; Marzoll, Saygi & Dinse, 2018). Here we report that LTP-like and LTD-like stimulation results in an adaptation that has never been reported. After 7 days of training on an orientation detection task which led to perceptual learning (Watanabe & Sasaki, 2015; Sasaki, Náñez, & Watanabe, 2010), LTP-like or LTD-like stimulation was applied to subjects (n=12 for LTP-like and n=12 for LTD-like). The stimulation consisted of a Gabor flickering on and off either intermittently at 10 Hz (LTP-like stim.: 1 s stimulus train, 5 s break) or continuously (LTD-like stim.: 1 Hz). 90 min and 1 d after the stimulation, signal-to-noise thresholds were measured in both groups for both the stimulated orientation and for an orthogonal control orientation. We found the following aspects. First, threshold elevation did not occur until 90 min after stimulation offset and lasted for at least ~180 min after offset. Second, correlative analysis of individual data suggests a persistence for the subjects most strongly affected on the previous day ($\alpha s = .63$; $p < .001$), ruling out mere fatigue. Third, on the following day, performance returned to baseline levels on the population level. Fourth, significant threshold elevations were obtained not only for the stimulated orientation (LTP-like: +66%; LTD-like: +27%) but also for the control orientation (LTP-like: +81%; LTD-like: +27%). Fifth, the threshold elevation was obtained only when the stimulation was given after detection performance was enhanced due to detection training ($\alpha s = -.45$; $p < .03$). These properties are contrasted to the orientation aftereffect (OA), which is strongest after the offset of stimulus exposure and is highly specific for the exposed orientation. This new type of adaptation by LTP/LTD-like stimulation thus differs markedly from the OA.

Acknowledgement: BSF2016058, R01EY027841, R01EY019466

Wednesday AM

62.17, 12:30 pm **Learning to ignore: Neural mechanisms underlying expectation-dependent distractor inhibition** Dirk van Moorselaar[1](dirkvanmoorselaar@gmail.com), Heleen A Slagter[1]; [1]Vrije Universiteit Amsterdam

Although ignoring visual distractions is paramount to efficient attentional selection, recent behavioral studies demonstrate that suppression is not under volitional control. Instead, suppression appears to only emerge when distractor information can be derived directly from experience, through statistical learning. In line with influential predictive processing theories, this may suggest that the brain may stop regarding a distractor as a distractor when it is fully expected, and raises the question how 'learning to ignore' is neurally implemented. In two behavioral and one EEG experiment we addressed this outstanding question and specifically examined how learned spatial and feature expectations influence pre-distractor anticipatory activity and distractor processing. Across searches the distractor, which accompanied the target on the majority of trials, appeared in one location more frequently. At this high probability distractor location distractor interference and target selection efficiency reduced, demonstrating learned spatial suppression. Compared to baseline, where targets and distractors only differed subtly (same spatial frequency), this spatial suppression benefit reduced when the task allowed for a unique attentional distractor set and was smallest when in addition a unique attentional target could be formed. Supporting the notion of a pre-stimulus distractor template, not only the target but also the distractor could be decoded prior to search display onset. However, spatial expectations did not modulate pre-stimulus alpha-band activity, a marker of top-down inhibition, nor could we decode the distractor location in anticipation of visual search. Instead, spatial expectations were only evident during stimulus processing. Distractors at predicted locations no longer elicited the Pd ERP component, indicating that attentional suppression or reorienting is no longer necessary when distractors can be expected. Together these findings demonstrate how spatial and feature expectations interactively shape attentional priorities and shed novel light on how learning to ignore is neurally implemented.

Motion Perception

Wednesday, May 22, 11:00 am - 12:45 pm, Talk Room 2

Moderator: Larry Cormack

62.21, 11:00 am **An integrated neural model of robust self-motion and object motion perception in visually realistic environments** Scott T Steinmetz[1](scott.t.steinmetz@gmail.com), Oliver W Layton[2], N. Andrew Browning[3], Nathaniel V Powell[1], Brett R Fajen[1]; [1]Cognitive Science Department, Rensselaer Polytechnic Institute, [2]Department of Computer Science, Colby College, [3]Perceptual Autonomy

Over the past decade, considerable progress has been made in understanding and modeling the neural mechanisms that support the perception of self-motion and object motion in humans. Building upon the neural architecture introduced in the STARS (Elder et al., 2009) and ViSTARS (Browning et al., 2009) models, Layton and Fajen have steadily developed a competitive dynamics model of MT/MST that uses optic flow to estimate heading and detect and perceive independently moving objects. The aim of this study was to systematically test the accuracy, stability, and robustness of model estimates in visually realistic environments. Our approach was to couple the model to Microsoft AirSim, a high-fidelity simulation platform built on the Unreal Engine. This allowed us to generate various scenarios involving self-motion in complex, visually realistic environments. We conducted a series of experiments to test the accuracy and robustness of model estimates in the presence of (1) globally discrepant motion by introducing blowing snow, (2) locally discrepant motion introduced by moving objects (e.g., people), (3) variations in lighting and contrast, (4) intermittent blackout, and (5) perturbations resulting from collisions that abruptly alter the direction of self-motion. The model generates accurate and stable heading estimates in static environments, and like humans, is weakly affected by locally and globally discrepant optic flow. Object motion estimation is more affected by discrepant optic flow and dependent on the location of objects relative to the focus of expansion. We will also discuss attempts to adapt the model for eventual use on-board small aerial robots, where constraints on payload and power supply encourage the use of vision-based solutions. In that context, we discuss strategies for speeding up model performance to enable self- and object-motion estimation from video in real time.

Acknowledgement: ONR N00014-18-1-2283

Wednesday AM

62.22, 11:15 am **Subjective confidence judgments for motion direction discrimination are centrally biased despite matched objective performance in the periphery** JD Knotts[1](jeffreydknotts@gmail.com), Alan L.F. Lee[2], Hakwan Lau[1,3,4,5]; [1]Department of Psychology, University of California, Los Angeles, USA, [2]Department of Applied Psychology, Lingnan University, Tuen Mun, Hong Kong, [3]Brain Research Institute, University of California, Los Angeles, USA, [4]Department of Psychology, University of Hong Kong, Pok Fu Lam, Hong Kong, [5]State Key Laboratory of Brain and Cognitive Sciences, University of Hong Kong, Pok Fu Lam, Hong Kong

While dissociations between objective and subjective perception are well known in the case of blindsight (Weiskrantz, 1999), finding such a dissociation in normal observers has proven difficult (Kolb & Braun, 1995; Morgan, Mason, & Solomon, 1997; Peters & Lau, 2014; Knotts et al., 2018). Here, we report a dissociation between objective performance (measured by d') and perceptual confidence judgments on a central-peripheral 2-AFC motion direction discrimination task. Subjects were simultaneously presented with central and peripheral dot motion stimuli and were asked to indicate both the direction of coherent motion in each stimulus and the stimulus (central or peripheral) in which they were more confident in their motion discrimination decision. We found that subjects were strongly biased towards indicating higher confidence in centrally presented stimuli, even when peripheral and central discrimination d' were matched. This effect was quantified by fitting individual type 2 psychometric curves to individual subject data in which the tendency to bet on the central stimulus was plotted as a function of the difference in d' between central and peripheral stimuli. Subjects consistently indicated higher confidence in the central stimulus at the psychometric point of objective equality. The paradigm used here may therefore represent a powerful psychophysical tool for isolating subjective visual awareness from objective perceptual signal strength, thereby providing cleaner subjective measures for the study of visual consciousness.

62.23, 11:30 am **Dynamics of Motion Induced Position Shifts Revealed by Continuous Tracking** Lawrence Cormack[1,2,3](cormack@mail.utexas.edu); [1]Department of Psychology, The University of Texas at Austin, [2]Institute for Neuroscience, The University of Texas at Austin, [3]Center for Perceptual Systems, The University of Texas at Austin

When a Gabor with a drifting carrier is viewed peripherally, the entire Gabor patch appears to move – a compelling phenomenon called the motion induced position shift (MIPS). Indeed, an entire global form composed of many such Gabors appears to move despite remaining fixed (see the 2016 illusion-of-the-year winner "Motion Integration Unleashed").Here, subjects attempted to keep a global form (a large circle comprising 16 Gabor patches) centered on a fixation mark using a trackpad while an unseen force attempted to drive it in a random walk.The first main stimulus condition was "zebra motion," in which each Gabor had a fixed phase and the entire circle of Gabors was driven in a 2D random walk.The second was the MIPS-inducing "cuttlefish motion," in which the carriers were driven in a random phase walk while each envelope and hence the global circle was driven in a 1D walk in the orthogonal direction.For zebra motion, subjects responded to the motion components in both directions, but the responses parallel to the carrier stripes were slower than the orthogonal responses (as one might expect based on the direction of contrast energy). For cuttlefish motion, subjects responded likewise to the motion parallel to the stripes but, crucially, they also responded to the phase walk as if it were motion of the global form (i.e., they manually "nulled" their MIPS percepts by pushing the Gabor positions in the opposite direction).Moreover, the response latencies to MIPS were shorter than for the orthogonal "real" motion, and very similar to those for the fast component of the response to zebra motion. Hence, MIPSs are tracked as though they are real global motion, and a continuous tracking paradigm (or the nulling variant used here), can be used to parametrically explore and (quickly) quantify the MIPS percept.

Acknowledgement: NIH RO1 EY020592

62.24, 11:45 am **Octopuses perceive second order motion: Evidence for convergent evolution of visual systems** Marvin R Maechler[1](Marvin.R.Maechler.GR@Dartmouth.edu), Marie-Luise Kieseler[1], Jade E Smith[1], Shae K Wolfe[1], Mark A Taylor[1], Matthew D Goff[1], Jean Fang[1], David B Edelman[1], Peter U Tse[1]; [1]Psychological and Brain Sciences, Dartmouth College

The ability to detect camouflaged prey and predators is important for survival. One plausible candidate mechanism for counteracting camouflage in the environment is second-order motion perception, which requires different, more sophisticated neural circuitry than first-order motion perception. Using an operant conditioning paradigm, we trained octopuses (octopus bimaculoides) to approach the side of a screen containing a second-order motion stimulus: the silhouette of a crab filled with visual noise that moved over a background of similar visual noise. The other side of the screen had only static visual noise. Stimuli were presented on a special wall in the tank that served as a screen for projection. Two halves of the screen were separated by another wall orthogonal to the screen, splitting a small part of the tank into two compartments of equal size, inside one of which the target stimulus was presented. After conditioning, the animals would select the target by entering the correct compartment almost perfectly. Octopuses are an animal model of special interest because they are thought to be endowed with complex cognitive functions, while also having over 500 million years of evolutionary history that is unshared with humans. Cephalopod and mammalian visual systems have evolved largely independently, with their last common ancestor possessing only very rudimentary light sensing organs and visual processing faculties. Convergent evolution of such systems strongly suggests that the trait in question – second-order motion perception – is an optimal solution for a common problem faced by our two species.

62.25, 12:00 pm **Global motion identification is incredibly precise, but lowering coherence increases the probability of total identification failures** Marshall L Green[1](mg2057@msstate.edu), Michael S Pratte[1]; [1]Mississippi State University

Although much is known about how we perceive a moving object, such as a single leaf, a great deal of ongoing research explores how local motion is combined to perceive global motion, such as the leaves on a swaying tree. Much of this research utilizes random-dot kinematograms, in which many moving dots are shown. Some dots move in one coherent direction (signal) while the others move in random directions (noise), allowing the proportion of signal to noise (coherence) to be manipulated. Most behavioral and computational modeling research using such stimuli is rooted in a framework whereby the brain first determines the motion direction of each dot, and then combines these estimates (e.g. by averaging) to compute the global motion direction. Here, however, we test a novel prediction of this framework. Participants identified global motion directions, and a mixture model analysis was used to measure 1) how often the correct direction was identified, and 2) the precision of responses when they were correct. Under the standard framework the precision of responses should decrease with decreasing coherence. However, decreasing coherence lowered the probability that the correct global motion direction was identified, but the precision of correct responses was nearly invariant. Likewise, increasing the stimulus duration changed the probability of identification, but had very little effect on precision. These results are not in line with the standard framework, and instead suggest a two-stage model by which some subset of dots are first selected, and then the direction of those dots is precisely determined. This new model requires re-thinking previous behavioral results, and a revision of models rooted in the standard framework.

62.26, 12:15 pm **Additivity of attractive and repulsive sequential effects in motion direction estimation** Jongmin Moon[1](jmoon@unist.ac.kr), Oh-Sang Kwon[1]; [1]Department of Human Factors Engineering, Ulsan National Institute of Science and Technology

Perceptual estimation of a stimulus is often attracted toward the previous stimulus (Fischer & Whitney, 2014). The pattern of this attraction largely follows derivative-of-Gaussian (DoG) shape, exerting strong bias when consecutive stimuli are similar. Contrarily, repulsive sequential bias was also reported when different features were asked (Taubert et al., 2016) or time delay between stimulus and response was zero (Bliss et al., 2017). It still remains unclear how these two opposite effects interact. Existing studies using linear regression (DeCarlo & Cross, 1990; Kashiwakura & Motoyoshi, VSS 2018) to disentangle the effects of stimulus and response could not capture the DoG shape of the biases. Here, we empirically demonstrate that observers' perceptual estimates in sequential tasks result from additive effects of attractive and repulsive sequential biases. Subjects reported the direction of a random-dot motion stimulus whose direction randomly varied from the direction of previous trial following uniform distribution (range: ±20, 40, 80, or 180°). As expected, subjects' responses were biased toward the motion direction of previous trial. Importantly, when the biases were represented in a 2D surface as a function of both previous stimulus and response directions, it became apparent that the bias on current trial was systematically repelled away from the stimulus direction of previous trial and strongly attracted toward the response direction of previous trial. Moreover, we found that a summation of two DoG curves representing stimulus repulsion and response attraction fits the data closely, which does not systematically differ from the fitting by 2D Gaussian process regression. Magnitudes of extracted attraction and repulsion biases were considerably larger than magnitudes of observed biases in earlier reports. Our results provide direct evidence that both repulsion from previous stimulus and attraction to previous response concurrently occur even in a general sequence of trials, and effects of two biases on current response are largely additive.

Acknowledgement: UNIST Grant 2.180426.01

62.27, 12:30 pm **Adaptive center-surround mechanisms in non-retinotopic processes** Boris I Penaloza[1](b.penaloza.rojas@gmail.com), Michael H Herzog[2], Haluk Ogmen[1]; [1]Department of Electrical & Computer Engineering, University of Denver, [2]Laboratory of Psychophysics, Ecole Polytechnique Federale de Lausanne (EPFL)

The early visual system is organized retinotopically. However, motion perception occurs in non-retinotopic coordinates. Even though many perceptual studies revealed the central role of non-retinotopic processes, little is known about their neural correlates and mechanisms. Tadin and colleagues (2003) found that increasing the spatial size of a high-contrast drifting-Gabor deteriorates motion-direction discrimination whereas the opposite occurs with a low-contrast stimulus. This is proposed to reflect a perceptual correlate of an adaptive center-surround antagonism, whereby at low-contrast excitatory center dominates whereas at high-contrast suppressive-surround mechanisms become more effective. We tested the hypothesis that the non-retinotopic system also processes motion information by means of an adaptive center-surround mechanism. We used the Ternus-Pikler display, a paradigm that pits against each other retinotopic and non-retinotopic representations. The Ternus-Pikler display contained three Gabor-patches. Depending on ISI (133ms vs. 0ms), either group- or element-motion is perceived, i.e., either all Gabors moved back and forth in tandem or the utmost Gabors jumped alternating left-right. One of the Gabors in the display contained a fixed phase-shift that created the perception of coherent drift in either retinotopic or non-retinotopic coordinates. Observers were instructed to attend to one of the Gabors in the display and report its drift direction. We measured phase-shift thresholds for motion-direction discrimination while varying the size and contrast of the stimulus. Our results show a statistically significant interaction of size and contrast in both retinotopic and non-retinotopic tasks. We observed increases in thresholds as a function of size at high-contrast values and threshold decreases as a function of size at weak contrast values, thereby generalizing Tadin et al.'s results to non-retinotopic processing. Our results suggest that the non-retinotopic process may also be mediated by an adaptive center-surround mechanism where at low-contrast spatial summation prevails and then shifts to surround suppression as the input contrast increases.

WEDNESDAY MORNING POSTERS

Color and Light: Adaptation, constancy, cognition, models

Wednesday, May 22, 8:30 am - 12:30 pm, Banyan Breezeway

63.301 **Colour constancy measured by achromatic adjustment in immersive illumination** Anya C Hurlbert[1](anya.hurlbert@ncl.ac.uk), Gaurav Gupta[1], Naomi Gross[1], Ruben Pastilha[1]; [1]Institute of Neuroscience, Newcastle University

The achromatic point (surface chromaticity perceived as neutral) serves as a measure of both chromatic adaptation and colour constancy. Larger deviations of the achromatic point from the chromaticity of the adapting illumination indicate worse colour constancy and less complete adaptation. Previously reported deviations vary with adapting illumination chromaticity and experimental method (see e.g. Foster 2012). Here we obtain achromatic settings for a large range of adapting chromaticities in an immersive illumination setup. Participants sat in an (2 m3) enclosure with white walls, illuminated by four tuneable twelve-channel LED lamps, viewing a smartphone OLED display (visible size approx. 8 degrees) embedded in a neutral cardboard frame and recessed to minimise incident illumination. Participants adjusted the display to appear neutral using four joystick button inputs, corresponding to the four cardinal colour directions in CIELAB (roughly blue, yellow, red, and green). Test illumination irradiance and display luminance were held at a constant mean level. An interstimulus mask of 30 seconds of equal-energy-white light preceded each 120 second test illumination adaptation period; during the following 5 trials, lasting approximately 240 seconds, the test illumination remained unchanged. At the start of each trial, the display was set to a random chromaticity within its gamut. Test lights were generated as smooth spectra, matching chromaticities in three sets: (1) even samples of the hue circle equidistant from D65 at 40 deltaEuv (6); (2) daylight locus values ranging from 2000K to 10000K (9); (3) extreme chromaticities (6). Results: Mean colour constancy indices ranged from ~0.3 to ~0.9 depending on test illumination chromaticity and individual participant, with lower values for more extreme chromaticities. Deviations in achromatic settings pointed towards the daylight locus for off-locus test lights, and towards neutral for on-locus lights. The results suggest a systematic bias towards the daylight locus in chromatic adaptation and colour constancy.

Acknowledgement: Supported by Huawei Device (Dongguan) Co., Ltd. and EC H2020-MSCA-ITN (DyViTo)

63.302 **Color and Brightness constancies as functions of test saturation** Adam Reeves[1](reeves@neu.edu), Kinjiro Amano[2]; [1]Dept. of Psychology, 125NI, Northeastern University, Boston MA 02115, USA, [2]School of Electrical and Electronic Engineering, University of Manchester, Manchester M13 9PL, UK

The perceptual constancies, of brightness, shape, color, and size, are thought to be critical for object recognition; objects should in some sense 'look the same', even when the conditions of lighting and viewing are altered. Yet the constancies are imperfect, their extent differing over individuals, tasks, and situations from around 5% to around 80% of ideal. Is this variation just random, or is there a principled reason? Based on the underlying physics, Reeves (Color Research & Application, 8, 1-3, 2018) argued that as the color of a sample becomes purer, color constancy should decline, whereas brightness constancy should improve. Extensive raw data exists for the 20 observers of Foster, Amano & Nascimento (Vision Research, 41, 285–293, 2001), who made both simultaneous and successive matches of central squares presented in simulated Mondrian displays illuminated at 20,000K and 6,500K. Regressions of constancy indexes against sample saturation support the color constancy prediction for 16 observers and the brightness constancy prediction for 19 observers.Accounts of constancy should also consider saturation.

63.303 **Blue-yellow asymmetries in the perception of illuminant vs. surface color** Ivana Ilic[1](ivanailic@nevada.unr.edu), Jiale Yang[2], Masami K Yamaguchi[2], Katsumi Watanabe[3], Yoko Mizokami[4], Michael A Webster[1]; [1]University of Nevada, Reno, [2]Chuo University, [3]Waseda University, [4]Chiba University

A number of recent studies have pointed to asymmetries in color constancy for blue vs. yellow illuminants, including weaker sensitivity for detecting changes in blue illuminants and a tendency for blue tints to appear more achromatic. We compared how blue and yellow percepts are parsed between lighting and surfaces in scenes. Stimuli were uncalibrated images sampled from the internet of outdoor or indoor scenes or objects with a dominant yellow to orange or blue to blue-green hue. For each, chromatic contrast was rescaled or inverted to create a range of images varying along the complementary bluish to yellowish axis. Observers were shown each image and asked to identify the dominant color of the lighting and surface, and also the "known" color of the object. In scenes with strong blue tints (e.g. because of artificial lighting, shadows, or water) there is a strong bias to attribute the hue to the lighting while the objects appear achromatic. Conversely, in the same scenes with yellow tints, the hue is instead more likely to be attributed to the surface color, with the lighting perceived as more achromatic. For example, a room might appear white in blue light while yellow in white light, and translucent water might change to chocolate. These differences may partly reflect specific knowledge of object color (e.g. skin tones), but were also evident for objects which could be associated with any hue (e.g. clothing), or which are more likely to have neutral reflectances (e.g. interiors). Thus, they may reflect more general priors for a blue bias for lighting and shadows, while a yellow bias for surfaces, and may be consistent with recent evidence that objects are defined by predominantly warmer colors (e.g. Rosenthal et al., JOV 2018).

Acknowledgement: EY010834

63.304 **Cross-Media Colour Matching under Chromatic Lights** Jan Kučera[1](j.kucera1@ncl.ac.uk), Gaurav Gupta[2], James Scott[3], Anya Hurlbert[2]; [1]Open Lab, Newcastle University, [2]Institute of Neuroscience, Newcastle University, [3]Microsoft Research Cambridge

How does bright, chromatic illumination affect people's ability to discriminate and name colours? Participants (n=22) viewed an IPS LCD screen next to a white RAL 000 90 00 sheet, each occupying 10° viewing angle, in an enclosed achromatic booth illuminated by tuneable multi-channel LED lamps (www.hi-led.eu). The display was surrounded by a hood to prevent light from the lamps falling on it. Following an initial 2-min adaptation period and training under D65 illumination, participants viewed on each trial: top-up D65 adaptation illumination (10 seconds); test illumination, under which they adjusted the chromaticity and luminance ofthe LCD screen to match that of the white sheet, using joystick buttons to navigate in CIELAB space; 11-point rating scale for confidence of their match; and a 12-choice colour naming question to describe the sheet colour. Matching durations on each trial were recorded but not constrained. In total, 6 saturated test illuminations with equal illuminance levels (red, green, blue, cyan, magenta, yellow) ranging from 67 ΔEab to 103 ΔEab from D65 and 3 daylight illuminations ("CCT") (2650K daylight yellow, D65 white, 10000K daylight blue) were presented five times each inrandomized order. Results:Performance decreased with increasing saturation of the test illumination, from an average of 8.4 ΔEab chromaticity match (var 8.46) under D65 to 18.4 ΔEab (var 65.8) under the saturated blue illumination. On average, matches under saturated illuminations were 3 ΔEab worse than matches under CCT illuminations, although confidence ratings were higher for the former. Under CCT illuminations, the proportion of "white" sheet colour names increased with match duration. Under saturated blue, cyan and yellow illuminations, "white" colour names occurred on average after 102 seconds. White paper tends not to appear white under minutes-long exposure to coloured light, but people are able to match its colour.

63.305 **Speed limits on seeing temporal changes in daylight** Ruben C Pastilha[1](rubenpastilha@gmail.com), Gaurav Gupta[1], Anya Hurlbert[1]; [1]Institute of Neuroscience Newcastle University

Natural illumination changes smoothly in chromaticity and illuminance through the day, yet we are largely unaware of all but the most rapid changes, at dawn and dusk. Previously, we have shown that discrimination of abrupt temporal changes in illumination chromaticity depends on the chro-

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maticity of the reference (adapting) illumination; for more extreme chromaticities, changes towards neutral chromaticities are less easily discriminated than changes away from neutral (Aston et al., submitted).Here we examined discrimination of smooth temporal changes in illumination chromaticity along the daylight locus. We aimed to determine the minimum detectable velocity of chromaticity change in daylight metamers in an immersive illumination setting. Participants sat in a 2 m3 enclosure with matte white walls, illuminated by spectrally tunable LED lamps (Ledmotive; www.hi-led.eu). In each session, the participant first adapted for 2 minutes to the reference chromaticity (with correlated colour temperature (CCT) of 2000 K, 6500 K or 14000 K). Each trial began with 5 seconds of chromatic noise illumination, followed by a smooth change in illumination chromaticity away from the reference point along the daylight locus; the amount of change varied across trials while the duration was held fixed, or vice versa.Pilot results (n=4 participants) show that smooth change detection thresholds for bluish changes along the daylight locus are higher at 2000K than at 6500K and 14000K, consistent with the suggestion that illumination changes towards neutral are less easily detected than changes away from neutral.

Acknowledgement: EC H2020-MSCA-ITN (DyViTo)

63.306 **Large enhancement of simultaneous color contrast by surrounding white gap, but not by black gap** Tama Kanematsu[1](t131304@edu.tut.ac.jp), Kowa Koida[1,2]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, Toyohashi, Japan, [2]Electronics-Inspired Interdisciplinary Research Institute (EIIRIS), Toyohashi University of Technology Department of Computer Science and Engineering, Toyohashi, Japan

We found an illusion of which thin (0.031 deg) gray lines on a cyan background appeared red when the lines were surrounded by thin (0.031 deg) white gaps. This effect was known as simultaneous color contrast, however, the magnitude of the effect was greatly enhanced than the line without gaps. The effects were quantified by a color-matching experiment, and matched colors were significantly shifted toward a complementary hue than no gap conditions ($p < 0.05$, permutation test). Generally the appearance of gray lines on a color background reflects either simultaneous color assimilation or contrast depending on its luminance, whereas gray lines with white gaps always showed simultaneous color contrast regardless of gray luminance levels. Moreover, almost no simultaneous contrast nor assimilation was observed if the gap was black. This indicates any explanation based on spatial frequency or proximity would be difficult. The illusion occurred regardless of hues if the appropriate thickness of gray lines and gaps were used; preferred thickness was larger for blue and yellow (S cone axis) background than cyan and pink background (L-M cone axis). The illusion was prominent for thin lines and dots, however optical blur and chromatic aberration were not major factors. It might reflect the interaction between color and luminance in early vision stages which have small receptive fields. This phenomenon may be considered as an inference of color of small or thin objects which exceeds spatial resolution of color by remaining luminance pattern, and it help to recognize thin objects which have the specular reflection on the side edge, such as thin branches of a tree on the sky background.

63.307 **Neurocomputational model explains the lightness scaling of illuminated simultaneous contrast, staircase-Gelb, and scrambled Gelb displays** Michael E. Rudd[1](mrudd@uw.edu); [1]Department of Physiology and Biophysics, University of Washington

Rudd (2013, 2017) proposed a cortical model of lightness computation in which luminance transitions at edges and within gradients are encoded by separate populations of ON- and OFF-cells. OFF cells respond linearly, while ON-cell responses obey a Naka-Rushton function with an exponent of 1/3 that saturates for high input. The ON and OFF responses are log-transformed and spatially combined in cortex to compute lightness. Previous work showed how this model explains lightness judgments for simple computer-generated stimuli. Here, I demonstrate first that the model accounts for quantitative failures of lightness constancy in experiments with illuminated simultaneous lightness contrast (SLC) displays (Davagno et al., 2018). In applying the model to the SLC data, I assume that neural responses at the edges of the SLC targets and at the outer edge of the display are spatially integrated by the visual system to compute the target lightness (edge integration). I then use the model to account for lightness matches from a second experiment (Davagno et al., 2004) in which grayscale papers viewed in a spotlight were arranged either from lowest to highest reflectance (staircase-Gelb) or in a spatially scrambled order. These data are modeled by assuming that the lightness of each paper is computed by integrating the neurally-transformed steps in log luminance around the paper's border. Incremental steps between neighboring papers are assumed to be encoded by non-saturated ON-cells; decremental steps by linear OFF-cells; and the incremental outer edges of the Gelb series by saturated ON-cells. The model accounts for the lightness dynamic range compression exhibited in the staircase-Gelb paradigm, and for releases from this compression that occur when the papers are spatially scrambled. The model assumptions are supported by neural data and are fundamentally different from those of lightness anchoring theory--previously, the dominant theoretical approach to interpreting such phenomena.

63.308 **Predicting Human Perception of Glossy Highlights using Neural Networks** Konrad E Prokott[1](eugenprokott@hotmail.com), Roland W Fleming[1]; [1]Justus-Liebig-Universität Giessen

Human observers easily distinguish glossy from matte materials. Glossy materials reflect their surroundings, and exhibit distinctive specular highlights. The importance of highlights for gloss perception has been demonstrated by their use for centuries in the visual arts, and by the observation that removing highlights from photographs leads to a matte surface appearance. However, the visual computations underlying gloss perception remain largely unsolved. Here, we investigated how the visual system identifies specular highlights in images. This is challenging, because a given bright spot in the image could be a surface texture marking, light source, caustic, or many other physical events. Somehow the visual system has to identify that the bright spot is due to specular reflection, and then propagate this interpretation to surface regions where there is no local evidence that the surface is glossy. To test participants' ability of identifying highlights we showed them computer renderings of glossy textured surfaces. Participants were asked to judge whether a given location in the image was a highlight or a texture marking. The results indicate that participants are excellent at this task, but that there are occasional consistent errors. We then compared the observers' judgements to several models, ranging from a simple intensity threshold to more complex neural networks trained to give pixel-wise output maps of the specular reflectance component of an image. Our results show that human responses can be well matched by a relatively shallow feed-forward convolution neural network. We then compared model predictions to human responses on more challenging images in which the highlights are shown in the wrong locations and orientations relative to the matte components. Investigating the internal representations of the best models reveals a number of image measurements that could be the basis of human judgments.

Acknowledgement: This work was funded by the DFG-funded Collaborative Research Center on "Cardinal Mechanisms of Perception" (SFB-TRR-135) and an ERC Consolidator Award (ERC-2015-CoG-682859: "SHAPE")

63.309 **Understanding Information Processing Mechanisms for Estimating Material Properties of Cloth in Deep Neural Networks** Wenyan Bi[1](wb1918a@student.american.edu), Gaurav Kumar[2], Hendrikje Nienborg[3], Bei Xiao[1]; [1]Department of Computer Science, American University, [2]Samsung R&D Institute India-Bangalore, [3]University of Tuebingen, Werner Reichardt Centre for Integrative Neuroscience

Two decades of research in material perception shows that humans can estimate material properties in diverse scenes. However, it still lacks a computational framework that explains these perceptual data. Deep neural network trained on large data has succeeded in object recognition and classification. Will it succeed in estimating material properties of objects in dynamic scenes? One challenge is that it is difficult to obtain clear-cut labels for material properties. In addition, there is no simple relationship between perceived material attributes with the physical measurements. Here we use physics-based cloth simulations as our database and train neural networks with a variety of architectures to understand the computational mechanism of estimating mechanical properties of cloth. We hypothesize that network architectures that matches best with human performance would likely to be adapted by the human visual system. The dataset contain 1764 animations containing moving clothes rendered with 7 bending stiffness values, 6 mass values, 6 textures and in 3 dynamic scenes. First, we finetune a pre-trained ResNET (CNN) to extract features for static frames of maximum deformations with ground-truth parameters as labels. Second, we connect a long-short-term memory network (LSTM) in series with the CNN to train videos with the same labels. Thirdly, we use MDS method to obtain perceptual clusters of these stimuli and used these clusters as labels to train the videos with the same architecture (CNN + LSTM). Finally, we built a two-stage network where the first network performs unsupervised learning to cluster data to get the labels, and the second network uses those labels and learns a discriminative model to classify the videos. We use fisher vectors generated

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from dense trajectories of videos to represent the data in the first network. We find that the two-stage network outperforms the other architectures and the results are closest to human perception.

63.310 **Color Constancy in Deep Neural Networks** Alban C Flachot[1](flachot.alban@gmail.com), Heiko H Schuett[2], Roland W Fleming[1], Felix Wichmann[3], Karl R Gegenfurtner[1]; [1]Departement of Experimental Psychologie, Giessen University, [2]Center for Neural Science, New York University, [3]Neural Information Processing, Tuebingen University

Color constancy contributes to our visual system's ability to recognize objects. Here, we explored whether and how Deep Neural Networks can learn to identify the colours of objects across varying illuminations. We devised a 6-layer feedforward network (3 convolutional layers, 2 fully connected layers, one classification layer). The network was trained to classify the reflectances of objects. Stimuli consisted of the cone absorptions in rendered images of 3D objects, generated using 2115 different 3D-models, the reflectancies of 330 different Munsell chips, 265 different natural illuminations. One model, Deep65, was trained under a fixed daylight D65 illumination, while DeepCC, was trained under varying illuminations. Both networks were capable of learning the task, reaching 69% and 82% accuracy for DeepCC and Deep65 respectively on their validation sets (chance performance is 0.3%). In cross validation, however, Deep65 fails when tested on inputs with varying illuminations. This is the case even when chromatic noise is added during training, mimicking some of the effects of the varying illumination. DeepCC, on the other hand, performs at 73% when tested on a fixed D65 illumination. Importantly, color categorization errors were systematic, reflecting distances in color space. We then removed some cues for color constancy from the input images. DeepCC was slightly affected when hiding a panel of colorful patches, which had constant reflectance across all input images. Removing the complete image background deteriorated performance to nearly the level of Deep65. A multidimensional scaling analysis of both networks showed that they represent Munsell space quite accurately, but more robustly in DeepCC. Our results show that DNNs can be trained on color constancy, and that they use similar cues as observed in humans (e.g., Kraft & Brainard, PNAS 1999). Our approach allows to quickly test the effect of image manipulations on constancy performance.

Acknowledgement: Deutsche Forschungsgemeinschaft Cardinal Mechanism of Perception, SFB/TRR-135

63.311 **A probabilistic graphical model of lightness and lighting** Richard F Murray[1](rfm@yorku.ca); [1]Department of Psychology and Centre for Vision Research, York University

Many lightness experiments and illusions suggest that mid-level features such as lighting boundaries and reflectance edges play an important role in lightness perception.However, there has been relatively little work on developing complete computational models of lightness that incorporate mid-level factors, compared to the extensive work on developing low-level computational models. Here I use probabilistic graphical models and their well-developed inference methods to formulate a mid-level computational model of human perception of lightness and lighting. To simplify a first approach, I model lightness perception on a 16 x 16 pixel grid.Within this domain one can create many lightness illusions (e.g., the argyle illusion) and phenomena (e.g., assimilation) that challenge current models. The model makes simple probabilistic assumptions about local properties of lighting and reflectance:(1) reflectance spans the range 3% to 90%, (2) reflectance tends to change slowly from place to place, (3) incident illuminance spans the range 0 to 100,000 lux, (4) illuminance edges are less common than reflectance edges, (5) illuminance edges tend to be straighter than reflectance edges, (6) reflectance and illuminance edges usually occur at image image luminance edges, and (7) measured image luminance is contaminated by a small amount of noise.The model uses these local assumptions along with belief propagation methods to infer globally optimal estimates of reflectance and illuminance in 16 x 16 pixel stimulus images. The model arrives at human-like interpretations of several lightness illusions that have been problematic for previous models, including the argyle illusion, snake illusion, Koffka ring, and their control conditions.The model also reproduces several important lightness phenomena, including contrast and assimilation effects. Thus a probabilistic graphical model that incorporates simple assumptions about reflectance and lighting provides a strong mid-level computational account of lightness perception over a wide range of stimulus conditions.

Acknowledgement: NSERC, NVIDIA

63.312 **A Comparison of Two Methods of Hue Scaling** Courtney Matera[1](cmatera@nevada.unr.edu), Kara J Emery[1], Vicki J Volbrecht[2], Kavita Vemuri[3], Paul Kay[4], Michael A Webster[1]; [1]University of Nevada, Reno, [2]Colorado State University, [3]International Institute of Information Technology, Hyderabad, [4]International Computer Science Institute, Berkeley

Opponent process theory assumes that all colors can be described as different mixtures of the underlying opponent primaries red vs. green or blue vs. yellow. Hue scaling is widely used as a method for estimating the underlying opponent response functions by asking observers to explicitly decompose each hue into the percentage contributed by the different primaries. However, this decomposition can be nonintuitive and there are inherent problems in estimating and analyzing proportions. We developed an alternative hue scaling task based on a compass with the text labels "R", "B", "G", and "Y" placed along the cardinal axes. Observers judged each hue by setting the compass needle to reflect the perceived distance from these landmarks. The hue percentages could then be estimated from these similarity judgments. We tested 30 students on both the compass angle and primary percentage task, repeating each task twice in a counterbalanced order. The stimuli consisted of 36 chromatic angles at 10-deg intervals and constant contrast in a scaled MacLeod-Boynton space. Settings were analyzed in terms of both the mean responses and the variability. Our results indicate that the two techniques are similar with comparable variance, with between-subject differences larger than within-subject. The estimated chromatic response functions were also similar for the two tasks. Both showed weak categorical biases where there were tendencies to give greater weight to the perceptually closer primary or axis. Factor analyses of the variations across observers also showed for both tasks that these differences reflected multiple factors narrowly tuned for different hue angles, and thus both were inconsistent with variations arising from the putative underlying opponent dimensions. The similarities between the tasks suggest that the resulting chromatic response functions are not strongly shaped by the specific nature of the task and thus may reflect the properties of the perceptual encoding of color.

Acknowledgement: EY10834

63.313 **Developing a peripheral color tolerance model for gaze-contingent rendering** Lili Zhang[1](zhanglili9292@gmail.com), Rachel Albert[2], Joohwan Kim[2], David Luebke[2]; [1]Rochester Institute of Technology, [2]NVIDIA Research

Gaze-contingent rendering (also called foveated rendering) is a technique for increasing rendering efficiency by displaying reduced-fidelity content outside the fixation region. It has the potential to lower computational costs as well as reduce bandwidth and latency for cloud-based rendering. Color discrimination is known to be degraded in the periphery due to photoreceptor distribution (Curcio & Allen, 1990) and cortical magnification (Abramov et al., 1991), suggesting a potential for significant savings. However, an eccentricity-dependent color discrimination model is required to reduce peripheral color accuracy without detection. We built a model describing peripheral color difference tolerances, adapted from the CIEDE2000 color difference model. We used eccentricity-dependent parameters for hue and chroma based on measured peripheral chromatic discrimination thresholds from Hansen et al., 2009. We conducted two experiments to test our model. First, we compared the predicted versus actual thresholds by testing multiple levels of CIELAB chroma and direction (increased or decreased chroma) on three image types (simple, vector, and natural). Second, we validated the utility of the model as a visual difference predictor (VDP) for per-channel bit reduction of natural images (peripheral images were rendered at lower bit depth). In both experiments, subjects were asked to freely view high-resolution static images with real-time eye tracking and peripheral color degradation, responding whether they noticed any artifacts. Results indicate the model slightly overestimates color difference thresholds for some subjects and image types. There is a strong trend of content dependency, with more complex images producing higher and more consistent thresholds across subjects. No difference was found between chroma directions. Our simple model shows some predictive power as a VDP for gaze-contingent color degradation. However, additional perceptual effects such as chromatic crowding and peripheral spatial frequency characteristics would likely produce more accurate results. Further study is required for practical applications.

Acknowledgement: NVIDIA Research

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63.314 **What color are cantaloupes? The role of relative color-concept associations on interpretations of information visualizations**
Zachary T Leggon[1,2](zleggon@wisc.edu), Ragini Rathore[2,3], Laurent Lessard[2,4], Karen B Schloss[2,5]; [1]Department of Biology, University of Wisconsin-Madison, [2]Wisconsin Institute of Discovery, University of Wisconsin-Madison, [3]Department of Computer Science, University of Wisconsin-Madison, [4]Department of Electrical and Computer Engineering, University of Wisconsin-Madison, [5]Department of Psychology, University of Wisconsin-Madison

To interpret information visualizations, people infer how visual features map onto concepts. Evidence suggests this inference process is analogous to solving an assignment problem in optimization. People infer optimal mappings between colors and concepts, even if that requires assigning a concept to its most weakly associated color (Schloss, Lessard, Walmsley, & Foley, 2018). We developed and began testing a process model for how assignment inference works, asking how assignment inference is influenced by the relative association strength between two candidate colors with a target concept and a non-target concept. We selected the colors and concepts using data from an initial experiment in which participants rated the association strength between each of 58 colors (sampled uniformly over CIELAB space) and twelve fruits. We selected two fruits (cantaloupe and strawberry) and eight colors that varied systematically in association with each fruit. In the main experiment, participants interpreted bar graphs depicting fictitious fruit preference data. Each trial contained a graph with two unlabeled colored bars representing preferences for cantaloupes and strawberries and a target fruit name (cantaloupe/strawberry) above. Participants reported which color represented the target concept. Graphs were constructed from all 56 pairwise combinations of eight colors (left/right balanced) x 2 possible taller bars (left/right) x 2 target concepts (cantaloupe/strawberry) x 3 repetitions (total of 672 trials). Multiple linear regression demonstrated that 83% of the variance in response times was predicted by the association strength between the correct color and the target (70%) and the non-target (+13%). For accuracy, 79% of the variance was predicted by association strengths between the correct color and the target (41%), the incorrect, competitor color with the target (+28%), and between the correct color and the non-target (+10%). These results help refine our assignment inference process model and can be used to help design optimal visual encoding systems.

Acknowledgement: Office of the Vice Chancellor for Research and Graduate Education

63.315 **Building color-concept association distributions from statistical learning**
Melissa A Schoenlein[1,2](schoenlein@wisc.edu), Karen B Schloss[1,2]; [1]Department of Psychology, University of Wisconsin-Madison, [2]Wisconsin Institute for Discovery, University of Wisconsin-Madison

Knowledge about the properties of objects is continually updated with experience. The Color Inference Framework proposes that this is the process by which color-concept associations are formed--people update color-concept association distributions with every co-occurrence between colors and concepts (Schloss, 2018). We tested whether these distributions can be formed through statistical learning using two tasks (1) category learning, and (2) color-concept association ratings. In the category task, participants saw aliens from two species: Filks and Slubs. Body shape (pointy vs. round) was perfectly diagnostic of species, whereas color distribution (warm vs. cool) was partially diagnostic. The aliens appeared in eight saturated hues with different color distributions between species. One species' color distribution was warm-biased (20-red, 25-orange, 20-yellow, 15-chartreuse, 10-green, 5-cyan, 10-blue, and 15-purple aliens). The other species was cool-biased (opposite frequencies). On each trial, an alien appeared below the species' names and participants indicated the species to which the alien belonged. There was immediate feedback. In the association task, participants rated the association strength between each species name with each of 32 colors: the eight saturated hues, plus light, muted, and dark versions of each hue. After, participants reported their categorization strategy. Most reported only using shape, with only one-third of participants noticing color patterns between species. Results indicate that participants learned color distributions, regardless of noticing patterns. Color frequencies during category learning predicted color-concept associations for the saturated colors (mixed-effect linear regression: $p < .001$), with strong correlations between exposure frequencies and average color-concept associations for the Filk-warm/Slub-cool group ($r = 0.78$, $p < .001$) and Filk-cool/Slub-warm group ($r = 0.57$, $p < .05$). Learned associations tended to generalize to the same hues with different saturation/lightness levels for each group ($r = 0.40$, $p < .01$; $r = 0.26$, $p = .07$). This study demonstrates that people can form new color-concept associations through statistical learning.

Acknowledgement: Wisconsin Alumni Research Foundation

63.316 **The trajectories of conceptual change: mouse-tracking prevalence-induced concept change**
Michael Dieciuc[1](MichaelD180@gmail.com), Walter R Boot[1]; [1]Department of Psychology, College of Arts and Sciences, FSU

Changes in prevalence can induce changes in conceptual boundaries (Levari et al., 2018). For instance, if participants see fewer and fewer blue colored dots, their conceptual boundaries for what counts as blue expands. Effectively this means that more non-blue dots are categorized as being blue. While this change in conceptual boundaries is remarkably robust and generalizes to a number of different stimuli, little is known about how the decision unfolds within a trial and across trials. One possibility is that prevalence shifts the criteria for what counts as blue but the decision process remains the same. Another possibility is that prevalence changes the decision process itself. In order to differentiate between these two possibilities, we presented participants with a spectrum of blue and purple dots and used computer mouse-tracking to examine the dynamics of their responses and how they may (or may not) change over time. In the experimental condition, the prevalence of blue dots steadily decreased over time. In the control condition, the prevalence of blue dots remained stable over time. Replicating the original finding, we found that the criteria for what counts as blue shifted over time for participants in the decreased prevalence condition. Importantly, we also found a trend in the mouse-tracking trajectories, $b = 152.2$, $SE = 92.2$, $t = 1.654$, $p = 0.098$. Visual inspection of the trajectories suggests that ambiguous colors near the middle of the blue-purple spectrum were more confidently categorized as blue in the decreasing condition than in the stable condition. This suggests that prevalence does not just change our conceptual criteria, it also changes the process by which we evaluate stimuli.

63.317 **The role of spatial organization for interpreting colormap data visualizations**
Shannon C Sibrel[1,2](sibrel@wisc.edu), Ragini Rathore[2,3], Laurent Lessard[2,4], Karen B Schloss[1,2]; [1]Department of Psychology, University of Wisconsin-Madison, [2]Wisconsin Institute for Discovery, University of Wisconsin-Madison, [3]Department of Computer Science, University of Wisconsin-Madison, [4]Department of Electrical and Computer Engineering, University of Wisconsin-Madison

To interpret colormaps, people determine how dimensions of color map onto quantities. Colormaps are easier to interpret when encoded mappings match people's predicted mappings, but to harness this principle it is necessary to understand predicted mappings. Previous work demonstrated evidence for dark-is-more and opaque-is-more biases for grid colormaps—faster response times for interpreting colormaps when darker, more opaque colors mapped to larger quantities (Schloss, et al, 2019). However, it is unknown whether such biases persist when spatial configurations cue which regions represent larger quantities (e.g., hotspots in concentric configurations) (Schott, 2010). We investigated how the dark-is-more bias is influenced by spatial organization by comparing people's interpretations of grid and concentric colormaps. Colormaps displayed fictitious data on animal sightings across geographical regions and participants reported whether there were more sightings on the left/right. One side was always darker (left/right balanced), and the legend either encoded dark-more or light-more mapping. The design included 2 spatial configurations (grid/concentric) x 2 color scales (hot/viridis) x 2 hotspot lightnesses (dark/light) x 2 encoded mappings (dark-more/light-more) x 2 legend text positions (greater-high/greater-low) x 20 repetitions (different underlying datasets). Trials were blocked by spatial configuration (order counterbalanced). Overall, response times were faster for dark-more encodings, indicating a dark-is-more bias ($p < .01$), but this depended on spatial configuration and block order. Comparing "pure" grid and concentric conditions (each in block 1), a mapping x spatial configuration interaction ($p < .05$) indicated that the dark-is-more bias for grids ($p < .001$) was reduced for concentric configurations. However, exposure to spatial configuration in block 1 influenced responses in block 2. The dark-is-more bias for grids in the grid-first condition transferred to concentric configurations ($p < .01$), and the reduced dark-is-more bias for concentric configurations in the concentric-first condition transferred to grids. Therefore, spatial organization does affect interpretations of colormaps, as do contextual colormap configurations.

Acknowledgement: Wisconsin Alumni Research Foundation (WARF)

Multisensory Processing: Tactile, vestibular

Wednesday, May 22, 8:30 am - 12:30 pm, Banyan Breezeway

63.318 **Spatiotemporal mechanisms of multisensory integration** Majed J Samad[1](majed.samad@gmail.com), Cesare V Parise[1]; [1]Facebook Reality Labs

Multisensory integration is fundamentally a problem of redundancy exploitation in which the brain combines correspondent information from different senses to get faster and more reliable perceptual estimates. To achieve that, the brain must solve the correspondence problem, that is to continuously monitor the senses to infer which signals contain redundant (i.e., correlated) information that should be integrated. Over the last few years, several psychophysical studies have demonstrated the fundamental role of temporal correlation in the integration and temporal processing of visual and acoustic stimuli. However, it is still an open question whether the same principles operate across other pairs of modalities and whether the detection of spatial correlation is also necessary for integration. To answer this question, we used state-of-the-art virtual reality and hand tracking technology to deliver visual and tactile stimuli on the palm of the hand. On each trial the stimuli– composed of a train of four white spheres and four vibrotactile bursts– were randomly delivered in different spatial positions and with random timing, and different seeds were used to generate the visual and tactile streams. Participants observed the stimuli and reported whether the two modalities appeared to share a common cause or not. Reverse correlation analyses were then performed on the spatiotemporal cross-correlation of the visuotactile stimuli. Results clearly demonstrated that participants indeed relied on spatiotemporal correlation to perform the causality judgment task: only stimuli with high correlation at near-zero spatial and temporal offset were consistently judged as sharing a common cause. These results are consistent with the behavior of a population of biologically-plausible multisensory correlation detectors, whose architecture closely resembles the Hassenstein-Reichardt detector originally proposed for motion vision. Taken together, this study supports the view that correlation detection is indeed the canonical computation for multisensory integration, and that it operates across modalities in both time and space.

63.319 **Everyday haptic experiences influence visual perception of material roughness** Karina Kangur[1](r02kk17@abdn.ac.uk), Michal Toth[2], Julie Harris[3], Constanze Hesse[1]; [1]School of Psychology, University of Aberdeen, UK, [2]School of Psychology, Queen's University Belfast, UK, [3]School of Psychology & Neuroscience, University of St Andrews, UK

Humans have shown to effectively estimate material roughness using both vision and/or touch. If both modalities receive conflicting information (i.e., sensory conflict), the perceptual system tends to use a weighted combination of the available cues depending on their reliability. While previous studies have primarily focussed on participants' roughness perception in manual exploration tasks, we examined whether and how experiencing visuohaptic conflicts change roughness estimation during more natural object interactions (i.e., grasping). For stimuli selection, participants rated the visual and haptic roughness of a range of stimuli on a continuous rating scale (i.e., 0-100%). Based on these ratings, we identified three roughness levels (i.e., rough/medium/smooth) for three material categories (Wood, Sandpaper, Natural). In the main experiment, we dissociated the visual and haptic experience in three participant groups by using different sets of those stimuli and presenting them in a mirror setup.That is, all participants viewed the same three medium stimuli visually (placed in front of the mirror), but grasped either the same, the smoother, or the rougher version of the same object category (placed behind the mirror). Participants rated the perceived roughness of the stimuli, separately for visual and haptic sensation, on the same rating scale before and after the grasping task. Our findings (N=18) showed that participants exposed to rougher haptic experiences rated medium visual stimuli as looking rougher after grasping. Similarly, participants who touched smoother stimuli during grasping perceived medium stimuli as looking smoother. In contrast, we observed no visual bias on the haptic estimations of roughness. The findings suggest that visual perception of material properties can be biased by the haptic experience of everyday manual interactions.

Acknowledgement: Eastbio BBSRC [BB/M010996/1]

63.320 **Haptic discrimination of 3D-printed patterns based on natural visual textures** Scinob Kuroki[1](scinob@gmail.com), Masataka Sawayama[1], Shin'ya Nishida[1]; [1]NTT Communication Science Laboratories, NTT Corporation

We perceive spatial textures mainly through eyes and hands. In contrast to visual texture perception, computational mechanisms of haptic texture perception remain poorly understood. Here we measured haptic texture discrimination ability of 3D printed surfaces transcribed by visual images of five natural textures (stones, leaves etc.). For each texture image, the intensity map was converted into the 3D surface height modulation of a 40x40mm plate. The textures look sufficiently different and the maximum modulation depth (2mm) was well above the haptic detection threshold. Nevertheless, observers (n=10) could not accurately discriminate some texture pairs. In the main experiment, the observer passively touched the plate swept on their stabilized index finger (passive scan mode), but even when we tested other touching modes, the performance was improved only slightly (active scan), or not at all (static touch, vibration only). Since the amplitude spectra of natural visual textures are similar to each other (fall by a factor of f-a), we hypothesized that haptic texture discrimination may rely solely on the difference in amplitude spectra, or on the spatial-frequency/orientation subband histograms. In agreement with this, the discrimination performance we obtained could be explained by a multivariate linear regression based on the amplitude difference between the paired textures. In an additional experiment, we directly tested this hypothesis by matching the subband histogram of each texture using a texture synthesis algorithm (Heeger & Bergen, 1995). Haptic discrimination of these textures was found to be nearly impossible, although visual discrimination remains feasible due to differences in higher-order statistics (joint subband statistics to which V2 neurons are sensitive, or more complex phase information detectable by attentive foveal vision). These findings suggest that haptic texture processing may be qualitatively different from visual texture processing in that it simply relies on lower-order image statistics.

Acknowledgement: This work was supported by Grant-in-Aid for Scientific Research on Innovative Areas (No. 15H05915) from MEXT, Japan.

63.321 **Unimodal and Cross-Modal Shape Recognition** Ashley E Peterson[1](ashley.peterson141@topper.wku.edu), Farley Norman[1], Hannah K Shapiro[2], Matthew D Hall[1]; [1]Department of Psychological Sciences, Ogden College of Science and Engineering, Western Kentucky University, [2]Carol Martin Gatton Academy of Mathematics and Science

Thirty-two younger adults (mean age was 20.8 years) participated in a solid shape recognition task. In an initial study phase, participants were either visually or haptically familiarized with either 4 (or 6) randomly chosen replicas of naturally-shaped objects (bell peppers, Capsicum annuum). In this familiarization phase, the study objects were presented 4 separate times for 15 seconds each time. Following familiarization, 8 (or 12) bell peppers were presented to either the same or opposite modality. The participants' task for each object was to indicate whether it was "old" (presented during the familiarization phase) or "new" (not previously presented). For the condition where the participants were familiarized with 6 objects (and tested with 12), the participants' unimodal visual recognition performance was significantly higher than both unimodal haptic (34.5 percent higher) and cross-modal recognition performance (38.1 percent higher). When the memory demand was reduced (participants only needed to remember 4 study objects), however, performance for unimodal vision and unimodal haptics became much more comparable (87.5 versus 81.3 percent correct, respectively). In this later condition (4 study objects), an asymmetry emerged between haptic-visual and visual-haptic shape recognition, such that visual-haptic performance was superior. The current results demonstrate that visual shape memory capacity is higher than that of haptics. When the number of objects to be remembered does not exceed either modality's storage capacity, however, human participants' visual and haptic shape recognition performance is comparable. When recognizing the shape of objects across the sensory modalities of vision and touch, accurate performance only occurs when the objects are familiarized using vision and the resulting object recognition is tested haptically.

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63.322 **Visual-vestibular conflict detection is best during active head movement with scene-fixed fixation** Savannah J Halow[1](savvyhalow@gmail.com), Jax D Skye[1], James Lui[2], Paul R Macneilage[1]; [1]Department of Psychology, Cognitive and Brain Sciences, University of Nevada, Reno, [2]Department of Computer Science, University of Nevada, Reno

Head movement relative to the stationary environment gives rise to congruent vestibular and visual optic flow signals. The resulting percept of a stationary visual environment depends on mechanisms that compare visual and vestibular signals to evaluate their congruence. Here we investigate the efficiency of these mechanisms and how it depends on fixation behavior as well as on the active versus passive nature of the head movement. Sensitivity to conflict was measured by modifying the gain on visual motion relative to head movement on individual trials and asking subjects to report whether the gain was too low or too high. Low and high gains result in percepts of the environment moving with or against head movement, respectively. Fitting a psychometric function to the resulting data yields the range of gains that are compatible with perception of a stationary visual environment, referred to by Wallach as the Range of Immobility. Experiments were conducted using a head-mounted display capable of rendering visual scene motion contingent on head motion, with fixation behavior monitored by an embedded eye tracker. The experimental design included combinations of active or passive head movement together with head-fixed or scene-fixed fixation. During active conditions, subjects rotated their heads in yaw ~15 degs over ~1 sec. Each subject's movements were recorded and played back via rotating chair during the passive condition. During head-fixed and scene-fixed fixation the target moved with the head or scene, respectively. Performance was better during active than passive head movement, likely due to increased precision on the head movement estimate arising from motor prediction and neck proprioception. Performance was also better during scene-fixed than head-fixed fixation, perhaps due to decreased velocity of retinal image motion and increased precision on the estimate of retinal image motion under these conditions.

Acknowledgement: Research was supported by NIGMS of NIH under grant number P20 GM103650.

63.323 **Impossible integration of size and weight** Isabel Won[1](i-won1@jhu.edu), Steven Gross[1,2,3], Chaz Firestone[1,2,3]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University, [2]Department of Cognitive Science, Johns Hopkins University, [3]Department of Philosophy, Johns Hopkins University

Some of the most striking phenomena in visual perception are "impossible figures"—objects or scenes that could never exist in real life, such as a staircase that ascends in every direction, or a triangle with three 90° sides. How pervasive are such experiences in the mind? Specifically, could there be impossible multisensory experiences? Here, we explore one such example that is both (i) phenomenologically striking, and (ii) theoretically significant for notions of perception as rational Bayesian inference. In the Size-Weight Illusion, a smaller object is perceived as heavier than an objectively-equally-weighted larger object. This illusion, though not "impossible", is puzzling: typically, our interpretation of new data is attracted towards our priors, but the size-weight illusion instead seems to involve repulsion from our priors; faced with ambiguous sensory evidence (i.e., two equally massive objects), we experience the object we expected to be lighter as heavier. Can the insight from this illusion be used to create an impossible perceptual experience? In three experiments, subjects were shown three visually identical boxes in a stack, and were asked to compare the weight of all three boxes lifted together vs. the top box lifted alone. Unbeknownst to them, the top box contained 250g of copper, while the other two boxes were empty. Which felt heavier? As in the classic size-weight illusion, the single top box felt heavier than all three combined—no matter whether the subjects hefted the boxes themselves (Exp.1), had them placed on their hands (Exp.2), or lifted them with strings rather than grasping the boxes directly (Exp.3). However, this outcome is impossible: A subset (box A alone) could never weigh more than its superset (boxes A, B, and C together). Evidently, the mind tolerates not only improbable, but also impossible, integration of information across modalities—and in a way one can feel for oneself.

Acknowledgement: JHU Science of Learning Institute

63.324 **Perceived timing of passive self-motion relative to auditory stimuli with and without vision** William Chung[1](w-8chung@uwaterloo.ca), Michael Barnett-Cowan[1,2]; [1]Department of Kinesiology, University of Waterloo, [2]Games Institute, University of Waterloo

Past research shows that the perceived onset of vestibular cues to self-motion are delayed compared to other senses. However, most research has been conducted with closed eyes, omitting visual information which is also an important self-motion cue. Previously we found that the perceived onset of active head movement paired with sound does not change when visual cues to self-motion are available (Chung & Barnett-Cowan, Exp Brain Res 235. 3069-79). Here we extend this work by investigating whether the perceived timing of passive self-motion paired with sound changes when visual cues to self-motion are available. Participants performed a temporal order judgement task between passive whole-body rotation and an auditory tone at various stimulus onset synchronies (-600 to 600 ms). Rotations were presented on a motion platform (raised-cosine trajectory; 0.5 Hz and 1 Hz; 20 deg/s peak velocity). A virtual forest environment was created in Unreal Engine (version 4.6) and presented using the Oculus Rift CV1 head mounted display (HMD). As a secondary goal of the study, the rotational gain of the visual scene relative to the rotation of the HMD was manipulated (+0.5, +1, + 2, -1). Preliminary results from six participants replicates previous reports that vestibular stimuli must occur before an auditory stimulus in order to be perceived as occurring simultaneously, where a greater delay is found when passively rotated at 0.5 Hz compared to 1 Hz. We found a significant main effect of the visual gain manipulation at 0.5 Hz but not 1 Hz and a significant interaction between movement frequency and the rotational gain of the visual scene. While the results suggest that the presence of visual feedback may have a modulating effect on the perceived timing of passive whole-body rotation, the presence of visual cues to self-motion do not reduce the perceived delay for the onset of self-motion.

Acknowledgement: We gratefully acknowledge the support of NVIDIA Corporation with the donation of the Titan Xp GPU used for this research and support from Ontario Research Fund and Canadian Foundation for Innovation (#32618), NSERC (RGPIN-05435-2014), and Oculus Research grants to Michael Barnett-Cowan. William Chung was supported by the Queen Elizabeth II Graduate Scholarship in Science and Technology.

63.325 **A virtual reality approach identifies flexible inhibition of motion aftereffects induced by head rotation** Xin He[1,5](steven.hsin.ho@gmail.com), Jianying Bai[1,2,3], Min Bao[1,4,5], Tao Zhang[4,5], Yi Jiang[4,5,6]; [1]Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, China, [2]Xinjiang Astronomical Observatory, Chinese Academy of Sciences, Urumuqi, China, [3]University of Chinese Academy of Sciences, Beijing, China, [4]State Key Laboratory of Brain and Cognitive Science, Beijing, China, [5]Department of Psychology, University of Chinese Academy of Sciences, Beijing, China, [6]Center for Excellence in Brain Science and Intelligence Technology, Chinese Academy of Sciences, Shanghai, China

As we move in space, retinae receive motion signals from two causes: those resulting from motion in the world, and those resulting from self-motion. Mounting evidence has shown that vestibular signals interact with visual motion processing profoundly. However, most contemporary methods are lacking portability, generality, and incapable of measurements during locomotion. Here we developed a virtual reality approach, combining a 3-space sensor (TSS-WL Sensor, YEI technology, U.S.A.) with head-mounted display (Sony HMZ-T3, 50°×28° visual angle, 1280×720 pixel resolution at 60Hz), to quantitatively manipulate the causality between retinal motion and head rotations in the yaw plane. Using this system, we explored how self-motion affected visual motion perception, particularly the motion aftereffect (MAE). Subjects watched full-contrast gratings presented on a head-mounted display. The spatial frequency of the gratings was 0.13 cpd. Each subtended 24.7°×6.79°. The gratings drifted at the same velocity as head rotations, with the drifting directions either identical, opposite, or perpendicular to the directions of head rotations. We found that MAE lasted significantly shorter ($t(10) = 4.71$, $p < 0.001$, Cohen's $d = 1.42$, Experiment 1) when subjects' heads rotated (11.36 s, Experiment 1) than when their heads kept still (19.93 s, Experiment 1). This effect was present regardless of the drifting direction of the gratings, and was also observed during passive head rotations. These findings suggest that the adaptation to retinal motion is suppressed by head rotations. Because the suppression was also found during passive head movements, it should result from visual-vestibular interactions rather than efference copy signals. Such visual-vestibular interactions are more flexible than previously thought, since the suppression could be observed even when the retinal motion direction was perpendicular to head rotations. Our work suggests that virtual reality approach can be used to produce a wide range of applications for studying multisensory integration and interaction.

Keywords: motion aftereffect, vestibular, multisensory

63.326 **Updating the position of eccentric targets during visually-induced lateral motion** Jong-Jin Kim[1](johnk84@yorku.ca), Laurence R Harris[1]; [1]Department of Psychology, York University

INTRODUCTION: Updating egocentric positions of objects of interest during self-motion is fundamental to our daily navigation. Past studies show we make systematic errors in the direction of the movement when updating these positions after lateral self-motion. However, the source of these errors is still largely unknown. To distinguish between the errors due to our perception of target position and errors in updating during movement, the present study measured errors in remembered target position with and without visually-simulated movements. METHODS: We used an Oculus Rift (CV1) to present targets (lateral positions: ±.75m, ±.5m, ±.25m, or 0m; simulated viewing distance 2m) briefly (0.5s) on a simulated projector screen while participants fixated a cross. After an idle period (7s) or a visually-induced lateral movement (left or right at ~0.14 m/s for 7s), they positioned a dot at the remembered target positions by pointing a hand-held controller. RESULTS: Participants underestimated target eccentricity when remembering target positions, with greater errors for more eccentric targets. After visually-induced lateral motion, errors were reduced for targets within the range of motion and increased for targets outside the range of motion. CONCLUSION: Our ability to update a remembered target's position is affected by both its initial and final eccentricity and the perceived magnitude of the movement. People may be more accurate in updating the positions of targets within the perceived range of motion. Future experiments will extend these studies using physical motion and real targets.

Acknowledgement: VISTA, CVR

63.327 **Underwater virtual reality for spatial orientation research.** Christian B Sinnott[1](csinnott@nevada.unr.edu), James Liu[2], Courtney Matera[1], Savannah Halow[1], Ann E Jones[1], Matthew Moroz[1], Jeff Mulligan[3], Michael Crognale[1], Eelke Folmer[2], Paul MacNeilage[1]; [1]Department of Psychology, University of Nevada, Reno, [2]Computer Science and Engineering, University of Nevada, Reno, [3]Human Systems Integration Division, NASA Ames Research Center

Spatial orientation is the sense of self-motion and orientation relative to the environment. Perception of spatial orientation depends most strongly on information from the visual and vestibular systems, but somatosensory and proprioceptive modalities also contribute. Like the vestibular system, these modalities transduce linear and angular accelerations acting on the body which allow reconstructing how the body is supported and moved. Because these systems typically respond to the same stimuli, methods are needed to distinguish how perception is driven by vestibular versus somatosensory and proprioceptive modalities. We therefore developed a system for conducting psychophysical experiments underwater, where somatosensory and proprioceptive cues to body orientation are rendered largely uninformative. The system consists of a full-face dive mask that has been modified to accommodate a smartphone and lenses, turning it into an underwater head-mounted display (HMD). The phone is connected to a wired, waterproofed Xbox controller for input. To demonstrate usability of the system, we conducted an experiment in which participants were trained to use jetpack locomotion to navigate a series of gates in the simulated zero-gravity environment outside the international space station. Simulated locomotion was visual only. Safety and neutral buoyancy of the participants was constantly monitored by a companion diver. Nine participants (3F) completed the experiment, both while seated in a chair above water (familiarization), and while neutrally buoyant underwater. Participants also completed simulator sickness questionnaires before and after each of these periods. Participants showed a significant decrease in time taken to complete the virtual locomotion task while underwater. Simulator sickness reports did not differ significantly between the underwater and familiarization phases. We discuss strengths and limitations of the underwater VR system as well as future research that could be facilitated by this technology.

Acknowledgement: Research was supported by the Nevada-NASA Space Grant Consortium, under NASA NNX15AI02H.

Eye Movements: Pursuit, vergence

Wednesday, May 22, 8:30 am - 12:30 pm, Banyan Breezeway

63.328 **Earth Gravity-Congruent Motion Benefits Pursuit Gain for Parabolic Trajectories** Björn Jörges[1](bjoern_joerges@hotmail.de), Joan López-Moliner[1]; [1]Institut de Neurociències, Universitat de Barcelona

It has been suggested that humans rely on an internal representation of earth gravity ($9.81 m/s^2$) for a series of tasks such as catching. Furthermore, eye-movements seem to be partially guided by predictions about observed motion. Thus, the question arises whether knowledge about gravity is also used to guide eye-movements: If humans rely on a representation of earth gravity for the control of eye movements, earth-gravity-congruent motion should lead to improved visual pursuit. In a pre-registered experiment, we presented participants (n=6) with parabolic motion governed by six different gravities (-1/0.7/0.85/1/1.15/1.3g), two initial vertical velocities and two initial horizontal velocities in an immersive 3D environment. Participants were instructed to follow the target with their eyes. We tracked their gaze and computed the visual gain (velocity of the eyes divided by velocity of the target) as proxy for the quality of pursuit. An LMM analysis with gravity condition as fixed effect that allowed intercepts to vary per subject showed that the gain was lower for -1g than for 1g (by -0.134, SE = 0.068). This model was significantly better than a null model without gravity as fixed effect (p< 0.001), supporting our hypothesis. A comparison of 1g and the remaining gravity conditions revealed that 1.15g (by -0.028,SE=0.009) and 1.3g (by -0.039, SE=0.009) were associated with lower gains, while 0.7g (by 0.016, SE=0.009) and 0.85g (by 0.008, SE=0.009) were associated with higher gains. This model was again significantly better than a null model (p< 0.001), contradicting our hypothesis. Contrasting 1g with 0.7/0.85/1.15/1.3g is, however, a less specific test of our hypothesis because it adds possible confounds such as differences in curvature. This is largely circumvented in the -1g condition, which we therefore consider the stronger test of our hypothesis. Our data thus supports the hypothesis that internalized knowledge about earth gravity guides eye movements.

63.329 **Microsaccades, Pursuit and Drift Modulations During Smooth Pursuit** Inbal Ziv[1](inbalz86@gmail.com), Yoram S Bonneh[1]; [1]Faculty of Life Sciences, School of Optometry and Vision Science, Ramat-Gan, Israel

background: Our eyes are always in motion, even during fixation, but tend to "freeze" in response to stimulus onset. This phenomenon is known as "oculomotor inhibition" (OMI) and its time-course and magnitude depend on stimulus parameters, attention and expectation. It applies to microsaccades and eye-blinks in strict fixation, with some evidence for OMI in drift. In previous experiments, we found that a flashed Gabor patch during smooth pursuit induced a velocity slowdown ("pursuit-inhibition") followed by acceleration, as well as inhibition of catch-up saccades (< 2°), with stronger inhibition and faster release for more salient stimuli, demonstrating that OMI applies to smooth pursuit. The purpose of the current study was to re-examine ocular drift inhibition and its generalization to conditions of smooth pursuit. Methods: In two experiments, observers (N=18) followed a small circle surrounded by a bright circular envelope, which moved back and forth horizontally at 6.2°/sec. While tracking, a Gabor patch was briefly flashed (100ms) at 0.5Hz rate, at the display center with varied spatial-frequency and contrast. We computed drift velocity and drift "box-counting" across time, after filtering out all saccade traces and the pursuit movement itself. Results: Drift during pursuit, like microsaccades and the pursuit itself, showed initial slowdown flowed by increase in amplitude and speed depending on the stimulus parameters. This occurred even when all saccades and the pursuit movement were carefully filtered out. Furthermore, we found no correlation between pupil size and the filtered horizontal trace, and the results persisted even in one case of artificially dilated pupil, evidence against a pupil-drift artifact of the eye-tracker. Finally, we obtained a similar drift inhibition for a static target in comparison. Conclusion: The OMI phenomenon applies to drift during pursuit as well as during fixation. This may indicate a general mechanism to attenuate incoming information while processing previous stimuli.

 See page 3 for Abstract Numbering System

63.330 **The Quantification of Smooth Pursuit Eye Movements**
Inge L Wilms[1](inge.wilms@psy.ku.dk); [1]Dept. of Psychology, The University of Copenhagen

Smooth pursuit eye movements (SPEM) are continuous eye movements which occur in response to a moving target. SPEM can be observed as a slow rotation of the eyes keeping the object of pursuit in fovea. SPEM occur in response to following moving objects and cannot be initiated voluntarily [1]. To maintain smooth pursuit, the brain must predict and calculate appropriate eye movements based on observed speed and direction of a target to ensure a stable image. SPEM cannot be maintained if the speed of the target exceeds 30 degrees/s [1, 2]. As the speed of the object increases, the smooth movements will be interrupted by catch up punctuated by saccades [1]. Smooth pursuit are quantified by the gain (how well the eyes follow the target in speed) and phase (distance to the target during pursuit)[3]. Testing of SPEM ability is often included in visual exams and thought to provide information on sudden or developmental damage to the oculomotor system or the controlling functions such as attention. However, very little normative data exists and assessment guidelines on execution, scoring and interpretation of SPEM are almost non-existing. This study targeted three challenges in relation to this: 1) that hand-held movement of an object may be too fast, unsteady or unpredictable for activating SPEM, 2) the lack of normative data and 3) improved quantification of activities during a SPEM task. 96 children were tested three times in our smooth pursuit paradigm. Software to capture, quantify and analyze the data was developed. Apart from gain and phase, the quantification includes data on backup, catchup and distractor saccades, eye dominance as well as dividing period of smooth pursuit into pursuit on and off target. The quantification parameters has been tested subsequently and been shown to correlate nicely with appropriate measures of visual attention.

Acknowledgement: The Synoptik-foundation and the Rockwell Foundation

63.331 **Smooth pursuit of two-dimensional target motion: Pursuit speed varies with turning angle for predictable and unpredictable motion paths**
Jie Wang[1](jie.zy.wang@rutgers.edu), Morgan T. M. McCabe[1], Renee J. Tournoux[1], Eileen Kowler[1]; [1]Department of Psychology, Rutgers University

Smooth pursuit is highly accurate for two-dimensional target motions whose tangential speed decreases with increasing curvature according to the two-thirds power law, a characteristic shared with many biological motor actions (de'Sperati and Viviani, 1997). Nevertheless, the effect of changes in target direction on pursuit of constant velocity motions has been controversial.Subjects pursued a target that moved at constant speed (8 deg/s) starting from one of 8 positions along an imaginary circle, moving toward center, and returning to one of the 8 positions.Turning angles at the center ranged from 0 to180 deg.Start and end positions were selected randomly. On half the trials (predictable paths) a line marking the path was displayed. Turning angle had large effects. Pursuit speed began to decrease 500 ms before the turn, in anticipation of the change in direction. For predictable paths pursuit speed decreased steadily, reaching a minimum by 50-100 ms after the turn.Pursuit speed decreased at a slower rate for unpredictable paths until 100 ms after the turn when speed decreased sharply. Minimum pursuit speed was reached 100 ms after the turn for predictable, and 200 ms after for unpredictable paths.Minimum pursuit speed for both predictable and unpredictable paths varied linearly with turning angle, with the lowest value, 20% of target speed, found for the sharpest turns.These results show that pursuit of two-dimensional motions depends on the geometry of the motion path, with marked reductions in speed accompanying sharp changes in direction.Cues that disclosed the amount of direction change caused smooth pursuit to reduce speed earlier and more gradually.These results may reflect changes in the neural representation of direction over time, and serve to make properties of pursuit compatible with the naturally-occurring motions that are pursued during real-world tasks.

63.332 **Effect of priors on smooth pursuit of clear and noisy random dot kinematograms**
Jason F Rubinstein[1](j.rubinstein@rutgers.edu), Manish Singh[1], Eileen Kowler[1]; [1]Department of Psychology, Rutgers University

Smooth pursuit anticipates the direction of future target motion.Once target motion begins, pursuit undergos a transition between dependence on anticipation (priors) and dependence on immediate sensory motion.Principles of optimal cue combination suggest that the relative contribution of sensory motion may be smaller, or take longer to develop, the noisier the motion. Subjects pursued random dot kinematograms (200 dots; 1.6 dots/deg2). Mean direction of dot motion on each trial was chosen from a Gaussian prior with mean=45 deg (up and to the right), SD 10 deg. Direction of motion of individual dots was chosen from a Gaussian likelihood with SD 0 (clear) or 45° (noisy). Dot displacement/frame was larger for the noisy motions to equate stimulus speeds (6 deg/s). Perceptual testing using brief (150 ms) durations confirmed that judgments of motion direction were more variable with the noisier RDKs.Correlations between mean dot direction and pursuit direction increased over time reaching a maximum of ~.75 by 250ms after the start of motion for clear, and .7 by 350 ms for the noisy target motions. The contribution of the immediate sensory motion to pursuit was shown by slopes of the functions relating mean dot direction on each trial to mean pursuit direction for different epochs of time following the onset of target motion.Slopes increased over time reaching asymptotic values near 1 by ~250 ms after motion onset for clear, and ~350 ms for noisy motion. The evolution of slopes over time shows that pursuit assigned greater weight to the current sensory information at a rate that depended on motion noise. These results show that effects of motion priors persist for a longer time after target motion onset when sensory motion is noisier, a result that may be consistent with principles of optimal cue combination.

63.333 **Pre-saccadic attention to motion initiates predictive ocular following**
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Ocular following eye movements are involuntarily responses to wide field motion, with a preferential bias to weight motion near the fovea (Quaia et al, 2012; Mukherjee et al, 2017). Previously, we found that saccades to peripheral apertures containing dot motion drive smooth eye movements immediately following saccade landing. These movements persisted even when the motion aperture disappeared in saccade flight, indicating that pre-saccadic motion selection initiates these responses. Here, we examined whether the smooth eye movements in our paradigm were more consistent with voluntary pursuit or with ocular following of motion at the saccade target. If they reflected ocular following, it would suggest that the weighting of motion in the visual field can be dynamically biased by pre-saccadic attention. While classical pursuit eye movements are voluntary and have a linear dependence on the target velocity, ocular following has a log-linear dependence. Thus we varied the velocity of motion in the target aperture to determine how it influenced post-saccadic following responses. As we increased the target velocity, we found the post-saccadic following velocity scaled more consistently with a log-linear dependence and had a low gain, consistent with ocular following. Analysis of secondary eye movements after saccades into the aperture also supported that the responses were involuntary. First, corrective saccades within 200ms of the primary saccade into the aperture were directed towards the aperture's center, rather than along the target motion. Second, on those trials where the primary saccade deviated along the axis of target motion, following responses were smaller or opposite of the target motion, reflecting eye movements back to the aperture center rather than pursuit. Taken together, these findings support that the smooth movements we observed were consistent with involuntary ocular following. Moreover, pre-saccadic attention to motion information can bias the spatial weighting of motion integration that drives these responses.

63.334 **Smooth Pursuit Eye Movements in Patients with Schizophrenia and Bipolar Disorder**
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Patients with psychotic disorders are found to have deficits in pursuit eye movements. However, the ocular motility of some of these patients is within the normative range (Nkam et al., 2010). The aim of the present study was to evaluate smooth pursuit eye movements in schizophrenia and bipolar disorders patients and analyze the association with severity of symptoms and executive functions. Participants were thirty-seven patients with schizophrenia, fifty-eight with bipolar disorder (age range 18-55 years) and twenty-two age-matched controls. The patients were recruited from a psychiatric hospital and diagnosed according to DSM-V criteria. Symptoms severity was measured using the Brief Psychiatric Rating Scale (BPRS). Executive functions were assessed with Wisconsin Card Sorting Test (WCST). Smooth pursuit eye movements were recorded using the Eye Tribe infrared system and elicited using computer-based stimuli. The gain and the latency were used to measure the pursuit efficiency. The gain was calculated as the ratio of eye velocity to target velocity. The latency was calculated as the differ-

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ence between the phase of the eye fitting curve and that of the stimulus fitting curve. From the generalized linear model, both schizophrenic and bipolar disorder patients showed significantly impaired smooth pursuit with higher latency and lower gain as compared to controls, indicating a general difficulty in following a moving target. No differences were found between schizophrenic and bipolar disorder patients for gain and latency. Moreover, the ocular motility deficit was correlated with WCST score and not with BPRS score, confirming that the patients' efficiency in smooth pursuit was linked to executive functions and not merely to symptoms severity. These findings are in accordance with previous studies and they specify that the deficit in pursuit eye movements in psychotic patients is associated with impairment in executive functions.

63.335 **Following Forrest Gump: Smooth pursuit related brain activation during free movie viewing** Ioannis Agtzidis[1](ioannis.agtzidis@tum.de), Inga Meyhoefer[2], Michael Dorr[1], Rebekka Lencer[2]; [1]Technical University of Munich, [2]University of Muenster

Most fMRI studies investigating smooth pursuit (SP) related brain activity, i.e. BOLD-responses, have used simple synthetic stimuli such as a sinusoidally moving dot. However, real-life situations are much more complex and SP does not occur in isolation but within sequences of saccades and fixations. This raises the question whether brain networks for SP, which have been identified under laboratory conditions, are similarly activated when following moving objects in a movie. Here, we analyzed studyforrest data providing 3T fMRI recordings along with eye tracking data from 15 subjects while watching the Forrest Gump movie (Hanke et al., 2016). Automated eye movement classification across subjects (Agtzidis et al., 2016) resulted in 50.7% (+/- 18.2%) of viewing time spent on fixations, 8.4% (+/- 3.5%) on saccades, and 14.4% (+/- 4.8%) on SP tracking. In order to maintain high specificity, the rest of the samples were left unlabeled or labeled as noise. For fMRI analysis we used an event-related design (SPM 12) modelling saccades and SP as regressors. Contrasts of interest in whole-brain analyses were BOLD-response differences during SP compared to saccades. A threshold of pcorrected < 0.05 FWE was applied for cluster level findings. By this, we identified higher BOLD-response during SP than saccades in V5 bilaterally (right: kE=175, left: kE=93), in middle cingulate extending to precuneus (kE=519), and in an area in the right superior temporal gyrus (kE=86). Higher BOLD-response during saccades than pursuit was observed in V1 (right: kE=112). This is the first report about brain activity specifically related to the most prominent eye movements such as SP and saccades in complex naturalistic situations. Most importantly, we were able to show that bilateral activation of V5, which is the core motion processing area, was related to SP but not saccades.

Acknowledgement: Elite Network Bavaria

63.336 **A covered eye does not always follow objects moving smoothly in depth** Stephen Heinen[1](heinen@ski.org), Scott NJ Watamaniuk[1,2], T. R Candy[3], Jeremy B Badler[1], Arvind Chandna[1]; [1]Smith-Kettlewell, [2]Wright State University, [3]Indiana University

The vergence system is thought to rotate the eyes through equal but opposite angles for gaze shifts in depth. A conjugate system also exists to rotate the eyes through equal, but the same angles. These systems are assumed to move the eyes appropriately for a given target motion, i.e., the eyes should rotate oppositely when a target moves only in depth, and conjugately when there is no depth component. It might be that the conjugate system is turned off when only vergence is required. Alternatively, vergence modulates a conjugate system that is always engaged. Observers pursued a physical target (small letter "E") moving in depth on a motorized track on the midline. The target moved with a periodic profile between 33.3 cm (3.0 dpt) and 66.7 cm (1.5 dpt), with a peak velocity of 30 cm/s and acceleration of 50 cm/s2. Viewing was either binocular, or monocular with either eye viewing. Eye movements and accommodation were measured from both eyes with a PlusOptix photorefractor, and in separate sessions, eye movements only with an EyeLink 1000. We found typical vergence in binocular viewing. However, when one eye was covered, it surprisingly did not always rotate inward to follow the target in depth. Instead, the covered eye usually moved in the opposite direction, often nearly conjugate with the viewing eye despite the presence of other monocular depth cues. The covered movements were also frequently different between the eyes of a subject. In all cases accommodation was symmetric and unaffected by viewing condition. The results suggest that a conjugate drive remains active during pursuit of objects moving in depth, which can be overridden by binocular input to produce vergence.

63.337 **When intercepting an approaching ball in flight, only some individuals compensate for its acceleration through head-centered spherical space.** Gabriel J Diaz[1](gabriel.diaz@rit.edu), Catherine A Fromm[1]; [1]Chester F. Carlson Center for Imaging Science

An attempt to catch a ball must be preceded by accurate visual tracking while, as a result of the ball's changing depth, it accelerates through the head-centered, spherical frame of reference (described in degrees azimuth/elevation). However, studies of smooth pursuit of 2D fronto-parallel motion demonstrate a perceptual insensitivity to acceleration. This predicts that gaze will lag behind an accelerating target. In the natural context, one might couple rotation of the gaze-vector to a visual source of information that covaries with changes in depth. This study tests the potential role of information related to angular size. Subjects were immersed in a virtual reality ball catching simulation, and gaze was monitored using an integrated eye tracker. The ball travelled to one of three lateral distances from the subject's head. Arrival height was randomized. A gain was applied to the ball's natural looming rate resulting in inflation/deflation of the approaching virtual ball. Subjects performed 10 repetitions at gain values of 0.5, 0.75, 1 (normal looming rate), 1.25, and 1.5.Ten repetitions of each gain/distance combination yielded 150 trials per subject. Although the preliminary analysis presented at VSS2018 supported the role of looming rate in compensation for the ball's acceleration, a new, more sensitive analysis casts doubt on these findings. On each trial, tracking behavior was compared to ball movement during a windowed portion of the ball's trajectory through head-centered spherical space, just prior to the attempted catch, during which the trajectory was linear and subject to acceleration. Comparison between the location of gaze at the end of the window to 1) the actual ball location at the end of the window and 2) the location predicted by a constant-velocity model of ball movement revealed two distinct classes of participant – those that partially compensated for acceleration, and those who did not.

63.338 **Blink adaptation for vergence eye movements** Arnab Biswas[1](arnab.biswas93@gmail.com), Gerrit W. Maus[1]; [1]Psychology, School of Social Sciences, Nanyang Technological University, Singapore

To maintain gaze stability, the oculomotor system needs to correct fixational errors that may emerge subsequent to an eye blink. It has been shown that artificially induced fixation errors, when a target is displaced by a consistent amount during an eye blink, lead to an automatic correction of gaze during the blink, a process termed 'blink adaptation' (Lau & Maus 2018; Maus et al. 2017).In this experiment, we check if a similar corrective mechanism occurs for errors induced by displacing the target in depth during an eye blink. Participants were asked to fixate on a dot, viewed stereoscopically through 3D shutter glasses. After each blink, the binocular disparity of the dot was either increased or decreased, in separate blocks, by 0.5 degrees. Blink-induced fixation error was measured separately for each eye as the difference between the last stable gaze position prior to blink onset and the first stable gaze position after the blink, using an EyeLink 1000+ eye tracker. Fixation errors for the adaptation phase were compared to baseline measurements, where the target remained unchanged across a blink. We found that participants recalibrated their gaze for both conditions, with more automatic vergence eye movements occurring during the blink in the direction required to correct for the dichoptic step of the target. This corrective effect was generally larger for the condition with increasing disparity as compared to decreasing disparity. These results are consistent with earlier findings by Lau & Maus (2018), who showed that blink adaptation more effectively corrects errors requiring temporal as compared to nasal eye movements across eye blinks. This points to a common mechanism underlying blink adaptation for conjugate as well as dichoptic target steps.

63.339 **Measuring the Vergence Horopter** Ashleigh L Harrold[1](ashleigh.harrold@uqconnect.edu.au), Philip M Grove[2]; [1]School of Psychology, The University of Queensland, [2]School of Psychology, The University of Queensland

The horopter, is theoretically defined as the location of points in space, from which images are projected onto corresponding points in the two eyes. Typically, the horopter consists of two elements, the horizontal horopter which is an arc intersecting the fixation point and the nodal points of the two eyes in the horizontal plane of regard, and the vertical horopter which a vertical line intersecting the fixation point. Empirically, when participants identify locations in space that stimulate corresponding points, they differ from the theoretical predictions. Furthermore, the empirical horopter differs based on the criterion used to measure it. These include but are not limited to the locus of fused images in space, the locus of zero dichoptic motion, the equal distance criterion, the apparent fronto-parallel plane and the region of maximal stereoacuity. A suggested criterion is also the location of points that do not elicit vergence movements, though no data based on this criterion have been reported. Measuring the horopter using the criterion of zero vergence is the main focus of this study. In two experiments measuring the vergence horopter on the horizontal plane (Exp 1) and the vertical plane (Exp 2), using the nonius alignment procedure, participants indicated whether a texture patch presented at a range of disparities (+/- 3 to 15 min arc) and eccentricities (1-10°) elicited a vergence response as indicated by a change in alignment of two nonius lines.. Results from both experiments support the criterion of zero vergence movements, with a small range of disparities (~5-6 min arc) reliably not eliciting vergence movements, which remains relatively constant across eccentricities.

Acknowledgement: RTP Stipend

63.340 **Factors Influencing Webcam Eye-tracking** Brooke Bullek[1](btbullek@geisinger.edu), Vanessa Troiani[1], Evan Peck[2], Brian King[2]; [1]Geisinger's Autism & Developmental Medicine Institute, [2]Bucknell University, Department of Computer Science

Eye-tracking methods, traditionally, have been limited in scope and scale. Confined to powerful infrared (IR) technology administered on expensive equipment in laboratory settings, the poor accessibility of eye-tracking has diminished some of its potential. Recent consideration of these constraints has led to the development of cost-effective eye-tracking software that operates from consumer-grade webcams. WebGazer is one such software library that has gained traction for its ability to predict eye-gaze from inexpensive webcams—vital for deploying large-scale online eye-tracking studies. However, an inevitable tradeoff exists wherein greater affordability garners less accurate inferences of eye-gaze. To this effect, we built upon WebGazer's toolkit to explore the fidelity of webcam eye-tracking using six alternative calibration techniques. Additionally, we explore how environmental factors (eye color; vision correction) influence the efficacy of gaze estimation with webcams. Participants (n=20; data collection ongoing) each completed a within-subject design with six conditions that manipulated the stimulus type (static or pursuit) and interaction type (passive watching or active clicking). For the interactive condition, we also included a placebo variant in which participant clicks were discarded in the model; this was included to assess how clicking impacted human attention and engagement apart from prediction. Results from the calibration manipulation indicate that pursuit with clicking stimulus appears to yield optimal results (467.03 ± 177.9 pixels). Preliminary analysis also suggests that increased visual acuity improves accuracy (normal or corrected to normal vision, 660.14 ± 381.73; uncorrected, 780.76 ± 447.15 pixels). Further, blue-eyed participants yielded the best results (566.87 ± 249.74 pixels) while those with brown eyes yielded the worst (763.45 ± 458.42 pixels). Overall, preliminary findings here may stimulate the development of adaptive webcam eye-tracking technology going forward that incorporates various calibration methods and accounts for differences among users.

Acknowledgement: Bucknell-Geisinger Research Initiative

Eye Movements: Models, neural mechanisms

Wednesday, May 22, 8:30 am - 12:30 pm, Banyan Breezeway

63.341 **Behavioural evidence for the existence of a spatiotopic free-viewing saliency map** Matthias Kümmerer[1](matthias.kuemmerer@bethgelab.org), Thomas S.A. Wallis[1,2], Matthias Bethge[1,3]; [1]Centre for Integrative Neuroscience, University of Tübingen, [2]Bernstein Center for Computational Neuroscience, University of Tübingen, [3]Physics Department, University of Tübingen

Humans gather high-resolution visual information only in the fovea, therefore they must make eye movements to explore the visual world. Inspired by results in attention research (Treisman 1980), it has been proposed that free-viewing fixations are driven by a spatial priority or "saliency" map. Whether this is the case has been debated for decades in neuroscience and psychology. One hypothesis states that priority values are assigned locally to image locations, independent of saccade history, and are only later combined with saccade history and other constraints to select the next fixation location. A second hypothesis is that there are interactions between saccade history and image content that cannot be summarised by a single value. For example, if after long saccades different content drives the next fixation than after short saccades, then it is impossible to assign a single saliency value to image locations. Here we discriminate between these possibilities in a data-driven manner. We extend the DeepGaze II model (Kümmerer et al., 2017) to a new model of scanpath prediction. First, we extract features from the VGG deep neural network that are used in a small "readout network" to predict one or multiple saliency maps. These saliency maps are then processed in a second readout network together with information on the scanpath history to predict upcoming saccade landing positions. We train the model using human free-viewing scan path data and achieve state-of-the-art performance compared to previous scanpath models. We find that using multiple saliency maps gives no advantage in scanpath prediction compared to a single saliency map. Since the number of saliency maps the network can use imposes strong qualitative constraints on what the model is able to predict, this suggests that for free-viewing a single saliency map may exist that does not depend on either current or previous gaze locations.

Acknowledgement: German Science Foundation (DFG Collaborative Research Centre 1233), German Excellency Initiative (EXC307)

63.342 **Microsaccade inhibition inhibited upon visual transients in the fovea** Katharina Rifai[1,2](katharina.rifai@medizin.uni-tuebingen.de), Denitsa Dragneva[1], Siegfried Wahl[1,2]; [1]Institute for Ophthalmic Research, University of Tuebingen, [2]Carl Zeiss Vision International GmbH, Aalen

Microsaccade inhibition has been researched extensively as indicator for the employment of attention to an eccentric target location. But, it has been found that microsaccade inhibition occurs in response to task-unrelated visual transients as well, indicating a rather low level origin of the microsaccade rate reduction. The current study evaluates microsaccade inhibition in response to periodically occurring short-term visual transients of a fixational target. 13 subjects fixated a target for a duration of 300 seconds. Short target-off phases were applied as visual transients in sequences within defined time-intervals. After 10 seconds of steady target presentation, target-off phases of 10 ms were applied within a 3 second time interval. This sequence was applied repeatedly, summing up to an extended fixation of 300 seconds. Three different conditions were measured, in which target-off phases were applied to the fixation target at different repetition rates. In the first two conditions, target-off phases occurred regularly with repetition rates of 50 Hz and 5 Hz, respectively. In the third condition, target-off phases were applied repeatedly with random delays. After each target-off phase micro-saccade rate has been analyzed as a measure of microsaccade inhibition. Microsaccade rates dropped in response to the first visual transient but did not in the following visual transients. Only after an extended period of time, microsaccade inhibition occurred again in response to a visual transient. Differential effects were found depending on the repetition rate of the target-off phases. After microsaccade rate inhibition occurring to an initial visual transient in the fovea, microsaccade rate was "blind" to visual transients for an extended period of time, indicating higher level processing in response to exogenous visual transients at the target location.

63.343 **Applying linear additive models to isolate component processes in task-evoked pupil responses** Steven M Thurman[1](steven.matthew.thurman@gmail.com), Russell A Cohen Hoffing[1], Nina Lauharatanahirum[1,2], Daniel E Forster[1], Kanika Bansal[1,3], Scott T Grafton[4], Barry Giesbrecht[4], Jean M Vettel[1,4,5]; [1]Human Research and Engineering Directorate, US Army Research Laboratory, [2]Annenberg School of Communication, University of Pennsylvania, [3]Department of Biomedical Engineering, Columbia University, [4]Department of Psychological and Brain Sciences, University of California, Santa Barbara, [5]Department of Biomedical Engineering, University of Pennsylvania

The diameter of the eye's pupil is constantly in flux. Decades of research have established a strong relationship between modulations of pupil diameter and internal mental processes. One of the major challenges in applied pupillometry research has been delineating the various factors that influence pupil diameter and isolating distinct mappings between mental processes and time-varying features of the task-evoked pupil response (TEPR). Here we applied a linear additive modeling (LAM) framework that posits the TEPR as a temporal sequence of transitions in arousal state reflecting task-dependent changes in attention and cognitive processes. We evaluated and compared LAM models on a longitudinal repeated-measures data set in which 26 subjects performed a 10-min psychomotor vigilance task (PVT) biweekly for 16 weeks (8 sessions per subject). PVT performance was captured by mean response time (rt) and lapse rate (proportion of rt's>0.5 sec). The mean TEPR had a biphasic shape that was well-described by a LAM consisting of an early response (peaking between 0.5-1.0 sec post-stimulus-onset) and a broader late response (peaking between 1.25-3.0 sec), likely reflecting rapid orienting of attention followed by allocation of attentional resources to support decision making, respectively. There was, however, substantial variability in TEPR shape from subject-to-subject and session-to-session.

We used multilevel linear models to examine the relationship between model-fitted TEPRs and performance measures at multiple levels including the group-level, subject-level, and individual-trial-level. We discovered two parameters of the fitted LAMs that explained unique variance in performance across all three levels including 1) peak amplitude of the early (orienting) response and 2) latency of the later (executive arousal) response. These two components represent a scale-invariant signature of performance. This work highlights the value of applying LAMs to identify component processes in TEPRs, and we explore applicability to other task domains.

63.344 Modeling and removal of eye signals does not abolish visual cortex resting state correlation structure

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Enhanced correlation in BOLD fMRI signals under rest conditions has been found between visual areas with hierarchical (e.g., V1d -> V2d) and homotopic (V3v -> V3d) relations. Separately, saccades, blinks, and changes in pupil diameter are associated with visual cortex activity. Here we tested if between visual area resting state correlations are explained by shared eye-related signals. We collected 22 minutes of rest-state data in total darkness from 20 subjects at 3T. Infrared eye tracking was performed. Following preprocessing with the HCP pipeline, the median time series was extracted from each of six visual regions of interest per hemisphere (V1-V3, dorsal and ventral). We removed variance related to head motion, respiration, heartbeat, and ventricular and white matter signal. We created covariates that modeled pupil radius, change in eye position, and blinks. These were convolved with a hemodynamic response function. We modeled and removed these signals (and their first derivatives) using linear regression from the cleaned time series. Across visual areas, covariates derived from eye signals accounted for 15.6% of variation in the BOLD fMRI signal (±1.3% SEM by bootstrap), as compared to 10.0% (±0.7%) when the subject pairing between eye and BOLD signals were permuted. Prior to removing eye-related variance from the BOLD fMRI time-series, the correlation between hierarchical and homotopic visual area pairings was greater than that observed for other (background) pairings (z' of 0.756 vs 0.562), recapitulating prior work. Removal of eye signals from the BOLD data slightly reduced hierarchical and homotopic correlations as compared to background pairings (z' of 0.722 vs 0.550). Eye signals appeared to explain different variance components in striate and extrastriate regions. BOLD fMRI signals in V1 and extrastriate cortex reflect eye and pupil dynamics. These signals are not entirely responsible for the correlation in spontaneous activity across visual areas.

Acknowledgement: U01EY025864, R01EY024681

63.345 Estimation of pupillary responses to rapid events

Rachel Denison[1](rachel.denison@nyu.edu), Jacob Parker[1,2], Marisa Carrasco[1]; [1]Department of Psychology and Center for Neural Science, New York University, [2]National Institutes of Health

Goal: Pupil size is an easily accessible, noninvasive online indicator of various cognitive processes. Pupil measurements can reveal continuous processing dynamics throughout an experimental trial, including anticipatory responses. However, the relatively sluggish (~1 s) response dynamics of pupil dilation makes it challenging to connect changes in pupil size to events occurring close together in time. Researchers have begun to use models to link changes in pupil size to specific trial events, but such methods have not been systematically evaluated. Here we developed and evaluated a model-based procedure that estimates pupillary responses to multiple events within an experimental trial. Methods: The mean pupil area timeseries across trials was modeled as a linear combination of pupil dilations to each trial event (general linear model). We evaluated the model using a sample dataset in which multiple sequential stimuli –precue, two sequential grating stimuli, and response cue– were presented within 2-s trials. We compared alternative models to determine model parameters, performed parameter recovery to validate fitting procedures, and used bootstrapping to determine the reliability of parameter estimates for our sample dataset. Results: We found that the best model provided robust estimates of pupil response amplitude and latency even for trial events separated by only 250 ms. Importantly, two timing parameters not previously modeled –pupil response latency and time-to-peak– improved fits. Estimated response latencies indicated anticipatory pupil responses to predictable trial events. Pupil response dynamics varied substantially across observers but were consistent for a given observer. Conclusions: A general linear model with specific parameters can estimate separate pupil responses to events in a rapid sequence for each individual. We provide our pupil modeling pipeline as a freely available software package (Pupil Response Estimation Toolbox, PRET) to facilitate the estimation of pupil responses and the evaluation of the estimates in other datasets.

Acknowledgement: NIH NEI R01 EY019693, F32 EY025533, T32 EY007136

63.346 I see what you did there: Deep learning algorithms can classify cognitive tasks from images of eye tracking data

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Since Yarbus (1967) wrote the book on examining eye movements, researchers have tracked eye movements associated with various tasks and mindsets. This line of research has consistently shown that eye movements can be indicative of the task at hand (Einhauser et al., 2008; Yarbus, 1967). Recently, theoretically informed computational models have been able to categorize eye movements at levels significantly above chance (e.g., MacInnes et al., 2018). The purpose of the present study was to design a neural network alternative to the previously implemented eye tracking models by categorizing eye movements using a simple deep learning model that was not guided by theoretical assumptions. In the current study, participants were presented with color images of scenes (interior and exterior locations, no images of people) while performing either a search task, a memory task, or an image preference task. Each image was viewed for several seconds, during which an eye tracker sampling at 1000 Hz was used to record eye movements. During data processing, each trial was converted into an image that represented the full path of the eye movements throughout the trial, but without any explicit notation of saccades, fixations, dwell times, or other traditional eye tracking variables. The DeLINEATE deep learning toolbox (http://delineate.it) was used to classify these images. The classifier consisted of a convolutional neural network that decoded the image into search, memory, or preference tasks. The deep learning model classified the eye movement images with accuracy that was well above chance, commensurate to contemporary results using explicit cognitive models. This suggests that deep learning models are capable of extracting a surprising amount of useful information out of nearly-raw eye tracking data with minimal human guidance as to what the relevant features are in the data.

Acknowledgement: Supported by NSF/EPSCoR grant #1632849 to MRJ, MD, and colleagues.

63.347 Cortical microcircuitry of gaze monitoring in supplementary eye field

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Previous research has demonstrated a role of the supplementary eye field (SEF) in detecting errors, registering success, and exerting pro-active control on saccade production. The cortical circuitry accomplishing these computations is unknown. We present neurophysiological data from two monkeys collected using a linear electrode array during a visually-guided saccade countermanding task. Monkeys were rewarded for making a saccade to a visual target unless, in infrequent random trials, a stop signal appeared which instructed the subject to cancel this pre-planned saccade. Analysis of performance using a race model provides the duration of a covert STOP process. From 16 perpendicular penetrations, we isolated 293 neurons across all layers. Here, we report the laminar organization of three types of neurons that were modulated most prominently after the STOP process terminated to cancel the planned saccade. Two populations of neurons generated complementary reduction and elevation of discharge rates after the STOP process, resembling movement and fixation neurons found in ocular motor structures. However, because this modulation arose too late to exert reactive control over saccade initiation, we interpret the neurons as enabling and disabling task goals. Enable neurons were dense in L2/3 and upper L5 and commonly had broad spikes. Disable neurons were restricted to L2/3, commonly had narrow spikes, and modulated before Enable neurons. A third population of neurons exhibited pronounced, transient modulation after the STOP process that scaled with the magnitude of conflict inferred between competing gaze-holding and gaze-shifting neuron populations. Conflict neurons were found in L2/3 and L6 and were a mixture of broad and narrow spikes. The conflict signal arose earliest in L2/3 and later in L6. These findings further delineate the mechanisms of medial frontal cortex in response monitoring, constrain circuit-level models of executive control, and guide inverse modelling solutions of visual performance event-related potentials.

Acknowledgement: This work was supported by R01-MH55806, P30-EY08126, and by Robin and Richard Patton through the E. Bronson Ingram Chair in Neuroscience.

63.348 **Topographic maps of visual space in the human cerebellum** Tomas Knapen[1,2](tknapen@gmail.com), Wietske Van Der Zwaag[2,1], Daan Van Es[1]; [1]Vrije Universiteit Amsterdam, [2]Spinoza Centre for Neuroimaging Amsterdam

While the cerebellum is instrumental for motor control, it is not traditionally implicated in vision. We used the HCP retinotopy dataset to identify 5 ipsilateral visual field maps in the human cerebellum. These maps are located within the oculomotor vermis and cerebellar nodes of the dorsal attention and visual networks. These findings imply that the cerebellum is closely involved in visuospatial cognition, and that its contributions are anchored in sensory coordinates.

Acknowledgement: NWO

63.349 **Identifying Scanpath Trends using a Frequent Trajectory Pattern Mining Approach** Brian R King[1](brian.king@bucknell.edu), Vanessa Troiani[2]; [1]Department of Computer Science, Bucknell University, [2]Geisinger Autism and Developmental Medicine Institute (ADMI), Geisinger Health System

Eye tracking systems have a large number of methods available to identify and visualize fixations, saccades, and scanpaths from individual participants in a study. However, methods to extract meaningful, statistically-significant group-level eye movement behaviors from a large cohort of subjects from multiple trials in a study are limited. Heat maps aggregate multiple trials over time, providing the means to visually identify fixations most common among multiple participants. However, heatmap methods discard the temporal view of the data, making it difficult to identify common patterns and trends in eye gaze behavior within subject groups, and even more challenging to compare gaze behavior between groups observing the same stimulus. We present a new method to extract frequent, significant trends in scanpaths from a cohort of participants observing static images. Our method is based on techniques used in the fields of sequential pattern mining and trajectory data mining, which are regularly used in mapping and navigation systems. Similar to how these systems analyze trends from large quantities of geospatial / global positioning system (GPS) data, our method analyzes eye tracking data from multiple subjects to identify frequently occurring scanpath trends. Identified trends are tested for statistical significance using bootstrap sampling. Scanpath trends are visualized, with p-values indicated, providing an easily interpretable plot for establishing the most significant trends among the cohort being evaluated. To validate the method, we implemented preliminary software in Python and evaluated eye tracking data collected from 60 participants observing a 2D static stimulus used in previous studies to characterize the visual attention of children exploring social objects [1]. All data were analyzed and trends plotted, revealing that the most significant scanpaths were those strongly trending toward social stimuli. [Figure 1, Supp]. Our method provides a useful tool for eye tracking researchers working with multiple participants observing identical stimuli.

Visual Search: Eye movements, features, scenes

Wednesday, May 22, 8:30 am - 12:30 pm, Pavilion

63.401 **Eye Tracking During Search for Two Unique Targets to Investigate Categorical Effects in Subsequent Search Misses** Mark W. Becker[1](becker54@msu.edu), Kaitlyn Anderson[1]; [1]Department of Psychology, College of Social Science, Michigan State University

When searching displays that can have more than one target, the detection of a second target is reduced relative to detection of the same target in a single target trial (Subsequent Search Misses).In addition, the second target deficit is magnified when the two targets are different objects.In order to explain this categorical effect, it has been suggested that detection of the first target activates that item's search template in working memory, while the other target's template become temporality deactivated.To test this theory, we eye tracked participants while they search for Ts and Os among L and Q distractors.The theory suggests that finding a T should produce a subsequent bias to fixate Ls (since they are similar to the T), while finding an O should bias subsequent fixations towards Qs.Our results failed to find such a bias. In addition, when we calculated second target detection rates using the conditional probability method that has been suggested for this type of work, we observed a significant second target deficit. However, this method neglects the fact that trials with two targets provide two opportunities for one of the targets to be a "difficult target".We propose an alternative, and more appropriate, method for calculating the expected detection rate for the second target.When applied to our data, the apparent reduction in second target detection disappears. In short, the "second target deficit" we observed can be explained by simple probability theory, and thus does not require a cognitive explanation. This probability issue may not explain all prior findings of a second target deficit, but it may account for some of the findings, and may artificially increase the effect sizes when there are indeed effects.Researchers investigating multiple target searches should be aware of this issue.

63.402 **Does the relationship between incidental fixations and distractor recognition depend on target consistency across visual search trials?** David F Alonso[1](davidalonsoq53@gmail.com), Steffi Y Falla[1], Anna Vaskevich[2], Roy Luria[2], Trafton Drew[1]; [1]University of Utah, [2]Tel Aviv University

Prior work has suggested that information about distractors is encoded from incidental fixations during visual search (Hout & Goldinger, 2001; Williams, Henderson & Zack, 2005). This work has shown that there is better memory for the distractor object identities that are more frequently fixated. All this prior work, however, is based on experiments where targets change on each trial. Does this effect replicate when the target remains the same on each trial? In a different context, evidence from event-related potentials has suggested that the role of working memory decreases when a visual target is repeated across trials (Carlisle et al., 2011). One possibility is that recognition memory for incidental fixations is driven by working memory (WM). If this is the case, we should expect dwell time to be less predictive of later recognition for distractors if a target is repeated because a repeated target will engage long-term memory rather than WM. To test whether a repeated target decreases the benefit in memory gained by incidental fixations we compared two experiments. In Experiment One, participants searched for the same target on every trial. In Experiment Two, targets changed on every trial. Consistent with prior work, we found that greater dwell time on distractors led to increased recognition during a surprise memory test. However, contrary to our predictions, increased dwell time lead to improved recognition memory even when the same target repeated 400 times in row. Even more striking, recognition memory was equivalent across both experiments despite far greater dwell time on distractors when participants searched for a new target on each trial. Overall, we find that the nature of the search does not appear to influence the small, but reliable relationship between incidental fixations and later recognition.

Acknowledgement: DOD: W911NF-07-2-0055 BSF: #2015301

63.403 **Target-distractor similarity and distractor heterogeneity affect the number of fixations, refixations, and dwell times in visual search** Daniel Ernst[1](daniel.ernst@uni-bielefeld.de), Gernot Horstmann [1]; [1]Neurocognitive Psychology & CITEC, Bielefeld University

Models of visual search often assume constant revisiting rates and dwell times– irrespective of search difficulty. Previous studies showed, however, that both gaze dwell times and the number of refixations on stimuli covary with target-distractor similarity. Moreover, dwell times and refixations appear to determine search times in target absent trials even more strongly than the number of fixated stimuli. However, these results were obtained in studies including searches for naturalistic faces which had higher complexity than stimuli that are usually used for visual search experiments. In the present study, it was tested whether such findings generalize to simple search stimuli, where participants search for a closed ring among rings with a gap. Results showed that, compared to experiments with complex stimuli, the relative contribution of the number of fixated stimuli increased, whereas the effects of dwelling and revisiting were still substantial. Crucially, all three gaze parameters covaried both with target-distractor similarity and distractor-distractor similarity, which were manipulated in a parametrical and orthogonal fashion. Implications for current visual search models are discussed.

Acknowledgement: The work was supported by the Cluster of Excellence – Cognitive Interaction Technology

63.404 **Temporal integration negates pop-out and reveals attentive blank stares**
Tess White[1](tesswhite55@yahoo.com), David Sheinberg[2], Vanessa Godina[1], Gideon P Caplovitz[1]; [1]Department of Psychology, University of Nevada Reno, [2]Department of Neuroscience, Brown University

It is trivial to find a target line segment in an array of distractors that are oriented orthogonal to the target, even when the display is presented for a very brief duration. Here we investigated the effect of temporal integration on this pop-out effect. Specifically, we presented observers with alternating line-segment pop-out arrays that changed in luminance contrast (i.e. black to white) with a fixed change in orientation. Participants were asked to identify the location of the pop-out target while freely moving their eyes. Using eyetracking, we measured accuracy, reaction-time and the time to the first fixation of the target as a function of flicker rate (3.125Hz, 4.16Hz, 6.25Hz, 12.5Hz, 25Hz and 50Hz).This corresponds to individual array presentations of 160ms, 120ms, 80ms, 40ms, 20ms, and 10ms. At the highest rates, the displays take on the appearance of flickering Xs. We found that increasing the flicker rate led to a monotonic decrease in accuracy and monotonic increases in reaction time. Similar to manual reaction times, latency to the first target fixation increased with flicker rate, with the first statistically-significant effect occurring between 120ms and 80ms (4.16Hz, 6.25Hz).Moreover, across all flicker rates (more so at higher rates), observers occasionally fixated the target without detecting it and instead continued their search. On some of these 'attentive blank stare' trials, the observer eventually did detect the target, demonstrating that the target was in fact detectable, whereas on others of these these trials, their search timed out in vain. Conclusions: The results provide evidence for a temporal integration window of ~100ms during which the presentation of multiple stimuli can interfere with attentional pop-out. In addition, we find evidence that goal-directed overt attention is not necessarily sufficient to allow the detection of a detectable fixated target.

Acknowledgement: NSF 1632738 and NSF 1632849

63.405 **Explicit Sequence Learning in Hybrid Visual Search in Younger and Older Age**
Erica Westenberg[1](ewesten15@gmail.com), Jeremy M Wolfe[2], Iris Wiegand[2,3]; [1]Department of Neuro-Cognitive Psychology, Ludwig-Maximilians-Universität, Munich, [2]Brigham and Women's Hospital and Harvard University, Cambridge, MA, [3]Max Planck UCL Centre for Computational Psychiatry and Ageing Research, Berlin

In "hybrid search", observers search visual displays for memorized target items. Studies have found that reaction times (RTs) in these tasks grow linearly with the number of items in the visual display and logarithmically with the memory set size. In a recent study, we demonstrated that if target items appeared in a predictable sequence that was not explicitly mentioned, a subset of younger adults was able to learn the sequence. These "learners" had faster RTs and shallower RT x memory set size slopes in sequence conditions compared to when items appeared in random order. Post-experimental tests showed that observers whose performance improved in sequence conditions acquired explicit knowledge about the sequence. This suggests that learners used explicit sequence knowledge to improve search. However, none of our older adult observers learned the sequences. In a second study, we told observers about the sequence prior to the search task to examine if explicit knowledge would allow all observers to facilitate hybrid search. 12 participants aged 18-35 and 9 participants aged 65-85 completed four blocks of a target localization task. After memorizing 4 or 16 target items, they searched for the targets among 3 or 15 distractors. They were informed when targets would appear in either a fixed sequence over trials or in random order. Younger participants showed significantly faster RTs in sequence blocks than random blocks, particularly with memory sets of 16. Older participants also showed significantly faster RTs in sequence blocks, but only in blocks with 4 memorized targets. Post-experimental testing proved that participants had explicit knowledge of the sequence. This indicates that explicit sequence knowledge allows younger people to predict the next target and restrict their effective memory set size, especially when memory load is high, but that older adults may only benefit with smaller target sets.

63.406 **Contextual Cueing in a Comparative Visual Search task.**
M Pilar Aivar[1](mariapilar.aivar@uam.es), Sandra Miguel[1], Elena Sanz[1]; [1]Experimental Psychology, Facultad de Psicología, Universidad Autónoma de Madrid

In simple visual search tasks repetition of spatial context reduces RTs when the context is predictive of target location (Chun & Jiang, 1998, Cognitive Psychology, 36, 28-71). To analyze how far cueing effects can be generalized to other tasks, in this study we tried to reproduce contextual cuing in a different kind of visual search: comparative search. In each trial, the screen was divided in two halves and an identical random configuration of eight elements (red and green squares and circles) was presented in each. Both halves differed either on one element's color or shape. In each trial participants had to find the element that was different and indicate the differential feature. Four configurations were repeated 14 times along the experiment, intermixed with newly generated configurations. For each of the repeated configurations the critical item always appeared at the same location, but the differential feature varied across repetitions. Eye movements and RTs were recorded during the task. Results showed no differences on average RTs between repeated and new configurations. However, since RTs in these tasks are clearly affected by the cognitive processes involved in confirming the mismatch, we performed a more detailed analysis of eye fixations. Following the methods described by Pomplun (Pomplun et al, 2001, Cognitive Science, 25, 3-36) trials were divided in two phases: Search and Verification, and all fixations detected in each trial were categorized in one of these groups. The effect of repetition was calculated separately for the average fixation count for each phase. Results showed that Verification fixations decreased significantly more in number over epochs for repeated configurations. Search fixations, however, did not vary between repeated and new configurations. This suggests that, in comparative visual search, contextual cueing effects do not facilitate search, but optimize the verification process prior to response.

Acknowledgement: Research supported by grant PSI2013-43742.

63.407 **Search termination when target is absent: the prevalence of coarse processing and its inter-trial influence**
Jieun Cho[1](m.jieuncho@gmail.com), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

According to the coarse-to-fine framework of visual search (e.g., Over et al., 2007), eye movements are initially rapid and distributed for scanning the coarse information of a scene, but as search progresses, they become slower and local for processing detailed information. Previous studies, however, examined the transition towards fine-scale processing when the target was present, leaving the transition in target-absent trials unclarified. The current study investigated how visual processing changes when people terminate target-absent visual search. We hypothesized that towards the end of search, target-absent trials should involve coarse processing as many distractors are simultaneously rejected compared to target-present trials where target selection would involve fine processing. In Experiment 1, while participants were searching for a uniquely oriented target among heterogeneous distractors, their eye movements were tracked. Here, distractor heterogeneity was manipulated into two conditions to vary ease of distractor rejection. Results showed that at the search onset, there was an increase in saccadic amplitudes along with short fixation durations which indicate coarse processing. The increasing trend of saccadic amplitudes was stronger when the distractors were less heterogeneous. Towards search termination, regardless of the extent of distractor heterogeneity, target-absent trials showed larger, increasing pattern of saccadic amplitudes with shorter fixation durations, compared to target-present trials. This suggests that the coarse processing remained until the end when no target was found. This termination effect was further investigated with reaction time in Experiment 2. We found that search duration of the current trial was shorter when preceded by a correct target-absent trial than by a correct target-present trial. This implies that target-absent trials benefit subsequent searches because of the maintained coarse processing mode which can be used when both terminating target-absent trials and starting new trials. Altogether, the current study indicates that rejecting multiple distractors brings coarse-scale processing when terminating target-absent trials.

Acknowledgement: This work was supported by National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (NRF-2016R1A2B4016171).

63.408 **The effects of information integration on categorical visual search**
Clay D Killingsworth[1](ckillingsworth@knights.ucf.edu), Ashley Ercolino[1], Schmidt Joseph[1], Mark Neider[1], Corey Bohil[1]; [1]University of Central Florida

Most categorical visual search work has used natural pre-existing categories (e.g., fish, cars; Schmidt, & Zelinsky, 2009). Many categorization studies, however, use simple perceptual stimuli to explore the idea that category learning is mediated by separate, competing brain systems. Rule-based (RB) category learning relies on explicit, verbalizable rules (and working memory), whereas information-integration (II) categorization relies on associative learning and dopaminergic reinforcement (Ashby, et al. 2008). Natural categories almost certainly utilize both systems, making it difficult to disentangle

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their separate contributions. Recent work found that categorical search performance for RB is faster and more accurate relative to II categories (Helie, Turner, & Cousineau, 2018). However, decades of search work shows that low-level visual features can impact search performance, suggesting that search differences may arise simply because RB and II differ in their low-level visual features. We explored this by utilizing one set of stimuli and simply changing the decision bound separating categories to create RB and II conditions. Participants learned four categories using either an RB or II decision rule, followed by visual search trials prompted by either a pictorial or categorical target cue. Observers searched for the target among the three other categories presented as distractors. Importantly, we found that pictorially-previewed search results did not vary significantly across RB and II structures on any metrics, suggesting that low-level visual features of the categories did not impact performance. However, contrary to earlier reports using a categorical cue, II-categories produced faster search, more efficient guidance of attention to the target, and faster target recognition (all p< .016). This suggests that, after controlling for low-level visual features, categories separated by an information-integration rule (which relies on gradual associative learning) produce stronger search performance than categories separated by an explicit, verbalizable rule (which relies on working memory).

Acknowledgement: Acknowledgements: Research reported in this work was supported by the National Eye Institute of the National Institutes of Health under Award Number R15EY029511. This work is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

63.409 **Changes in target-distractor similarity space with experience in complex visual search** Patrick H Cox[1](patrickcox@gwu.edu), Stephen R Mitroff[1], Dwight J Kravitz[1]; [1]Psychology, The George Washington University

Studies of visual search—looking for targets among distractors—typically focus on quantifying the impact of general factors (e.g., number of distractors) on search performance. However, search efficiency, particularly in complex environments, is undoubtedly a function of the particular similarity relationships between the specific target(s) and distractors. Further, the visual system represents many different dimensions (color, location, category) that can be flexibly weighted according to current goals, implying that different similarity relationships may be important in distinct contexts. In the current study we examined the impact of similarity in complex visual search by using "big data" from the mobile app Airport Scanner, where the player serves as an airport security officer searching bags for a diverse set of prohibited items among a large heterogeneous set of potential distractors. This large variability in possible targets and distractors, combined with the volume of data (~3.6 billion trials, ~14.8 million users), provide a means to explore the impact of target-distractor similarity on search. The game also includes levels that players advance through in sequence, enabling an investigation of the effect of experience. The data were used to calculate the impact of every distractor on every target at each level, and the resulting behavioral matrices were then compared to a number of different similarity metrics derived from image statistics (e.g., color, pixelwise) and biologically-inspired models of vision (e.g., HMAX). The analyses revealed that experience shaped the impact of distractors, with lower-level metrics dominant early and higher-level features becoming increasingly important as target and distractor familiarity increased. The detailed understanding of search revealed by these analyses provides key insights for generating a detailed model of real-world search difficulty.

Acknowledgement: Army Research Office

63.410 **Are conjunctions of motion and orientation special? Evidence from singleton interference effects** Kevin Dent[1](k-dent@essex.ac.uk); [1]Department of Psychology, University of Essex

Four experiments explored the mechanisms by which participants achieve efficient conjunction search, by measuring the interference caused by the presence of an irrelevant singleton, unique in either motion direction, colour, or orientation. Experiments 1 (moving vertical target amongst moving horizontal and stationary vertical distractors) and 2 (static vertical target amongst static horizontal and moving vertical distractors) investigated conjunctions of motion and orientation. Experiments 3 and 4 investigated conjunctions of colour and orientation (e.g. red vertical target amongst green vertical and red horizontal distractors). In Experiment 3 all items moved, whereas in Experiment 4 all items (except the motion singleton when present) were stationary. Participants judged whether the target was present or absent. Across all experiments orientation singletons (an item with unique orientation) caused large and robust interference. This orientation interference was strongly modulated by the singleton's task relevant motion or colour, such that interference was much larger when the singleton shared the target's motion or colour. The interfering effect of colour was much smaller and was not always statistically significant. Motion singletons interfered very little when the target was defined by colour but created substantial interference when the target was defined by motion. Of particular interest when searching for a stationary target amongst moving and stationary distractors, in Experiment 2, a motion singleton (an item moving in a different direction to all other items) caused substantial interference, even when it had no task relevant features. The results provide evidence for very imprecise control of search by orientation coupled with the selection of subsets of elements based on common colour or motion; sub-set search. However, motion is special in providing very strong bottom-up constraints on search such that distinctive elements within a moving group continue to cause substantial distraction even when they have no target features at all.

63.411 **Examining the Utility of Negative Search Cues with Real-World Object Categories** Samantha D Lopez[1](samanthalopez@knights.ucf.edu), Ashley M Ercolino[1], Joseph Schmidt[1]; [1]Psychology, College of Sciences, University of Central Florida

Decades of research has demonstrated that increased target knowledge improves search performance. However, most work has used pictorial or text cues that reference target features (i.e., positive target cues). More recently, work has examined the role of negative cues (Beck, Hollingsworth, & Luck, 2018), in which the distractor features you should avoid are cued, but the target can be determined from the given information. Previous work on negative cues have used simple stimuli and pictorial cues or specific text cues. We build on that work by comparing positive and negative cues (cue type) for pictorial cues and categorical text cues (cue specificity), using real-world objects. We predict that pictorial negative cues will prime the visual system and result in a cost to search performance relative to negative categorical cues or positive cue conditions.Search displays contained a target, a lure from the target category (which was cued on negative trials and uncued on positive trials), and four categorically unrelated distractors. Consistent with prior literature, we found two main effects indicating positive cues relative to negative cues, and pictorial cues relative to categorical cues, produce superior search performance across multiple eye movement and manual response measures (% trials target or lure is fixated first; target verification time; reaction time; and accuracy; all p< .001). We also observed an interaction of cue type and cue specificity (all measures p< .001), in which the benefit of pictorial cues was present, but greatly reduced on negative cue trials. Contrary to our hypothesis, we observed a pictorial benefit even on negative cue trials. This suggests that the target matching details of a pictorial negative cue are better at overcoming the capture of attention by a lure than a categorical negative cue.

63.412 **Comparing Search Strategies of Humans and Machines in Clutter** Claudio Michaelis[1](claudio.michaelis@uni-tuebingen.de), Marlene Weller[1], Christina Funke[1], Alexander S. Ecker[1,3], Thomas S.A. Wallis[1], Matthias Bethge[1,2,3]; [1]Centre for Integrative Neuroscience, University of Tuebingen, Germany, [2]Max Planck Institute for Biological Cybernetics, Tuebingen, Germany, [3]Center for Neuroscience and Artificial Intelligence, Baylor College of Medicine, Houston, TX, USA

While many perceptual tasks become more difficult in the presence of clutter, in general the human visual system has evolved tolerance to cluttered environments. In contrast, current machine learning approaches struggle in the presence of clutter. We compare human observers and CNNs on two target localization tasks with cluttered images created from characters or rendered objects. Each task sample consists of such a cluttered image as well as a separate image of one object which has to be localized. Human observers are asked to identify wether the object lies in the left or right half of the image and accuracy, reaction time and eye movements are recorded. CNNs are trained to segment the object and the position of the center of mass of the segmentation mask is then used to predict the position. Clutter levels are defined by the set-size ranging from 2 to 256 objects per image. We find that for humans processing times increase with the amount of clutter while for machine learning models accuracy drops. This points to a critical difference in human and machine processing: humans search serially whereas current machine learning models typically process a whole image in one pass. Following this line of thought we show that machine learning models with two iterations of processing perform significantly better than the purely feed-forward CNNs dominating in current object recognition applications. This finding suggests that confronted with challenging scenes iterative processing might be just as important for machines as it is for humans.

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63.413 **Metacognitive estimates predict detection accuracy in low prevalence search** Michael T Miuccio[1](mikemiuccio@knights.ucf.edu), Joseph Schmidt[1]; [1]University of Central Florida

Low prevalence search targets such as tumors in radiographs, result in disturbingly high miss rates relative to high prevalence targets (Wolfe, Horowitz, & Kenner, 2005). This suggests that a method to mitigate low prevalence misses could literally save lives. Recent work (Peltier & Becker, 2017), has suggested several individual difference measures that predict low prevalence miss rates. Building on this work, we examined metacognition's contribution to target detection.Metacognition is the ability to introspect about one's own thoughts, perceptions, and performance (Maniscalco, McCurdy, Odegaard, & Lau, 2017). We hypothesized that individuals with higher metacognitive estimates should more effectively monitoring their search performance, producing fewer low prevalence misses. Twenty-four participants completed a task designed to estimate metacognition (meta d'; Maniscalco & Lau, 2012), and a visual search task that manipulated target prevalence. To estimate metacognition, participants indicated which of two successive screens contained a tilted target gabor and rated their confidence.Performance was titrated to 75% accuracy. Participants then searched arrays of 24 pseudo-randomly placed objects and located targets from six potential target categories; distractors were drawn from 47 non-target categories. Overall target prevalence was held at 50% to control for motor errors. High (45%) and low (5%) prevalence trials were interleaved by manipulating the prevalence of individual target categories (counterbalanced across observers). Detection accuracy was predicted using hierarchical linear mixed effect models with metacognitive estimates, and target prevalence conditions as predictors, and with participant, trial, and target category as random effects.As hypothesized, higher metacognitive estimates result in higher low-prevalence detection accuracy (p=.008).This suggests that individuals with higher metacognitive estimates are less affected by low target prevalence, likely due to an improved ability to monitor and regulate their task performance. Futhermore, metacognitive estimates may serve as an effective way to prescreen searchers to minimize low prevalence misses.

63.414 **The gist in prostate volumetric imaging** Melissa Trevino[1](melissa.trevino@nih.gov), Todd S Horowitz[1], Marcin Czarniecki[2], Ismail B Turkbey[2], Peter L Choyke[2]; [1]Basic Biobehavioral and Psychological Sciences Branch, National Cancer Institute, [2]Molecular Imaging Program, National Cancer Institute

Radiologists can identify the gist of a radiograph (i.e., abnormal vs. normal) better than chance in breast, lung, and prostate images presented for half a second. However, this rapid perceptual gist processing has only been demonstrated in static two-dimensional images. Standard practice in radiology is moving to three-dimensional (3D) "volumetric" modalities. In volumetric imaging, such as multiparametric MRI (mpMRI), used in prostate screening, a single case consists of a series of image slices through the body that are assembled into a virtual stack. Radiologists can acquire a 3D representation of organ structures by scrolling through stacks. Can radiologists extract perceptual gist from this more complex imaging modality? We tested 14 radiologists with prostate mpMRI experience on 56 cases, each comprising a stack of 26 T2-weighted prostate mpMRI slices. Lesions (Gleason scores 6-9) were present in 50% of cases. A trial consisted of a single movie of the stack. After each case, participants localized the cancerous lesion on a prostate sector map, then indicated whether a cancerous lesion was presented, and gave a confidence rating. Presentation duration was varied between groups. Radiologists were divided into three groups who viewed cases presented at either 48 ms/slice (20.8 Hz, n = 5), 96 ms/slice (10.4 Hz, n = 5), or 144 ms/slice (6.9 Hz, n = 4). Performance declined as slice duration increased (d' [95% CI]: 48 ms = 0.77 [-.08 – 1.6]; 96 ms = 0.71 [0.17 – 1.24]; 144 ms = 0.47 [0.25 – 0.69]), though gist perception was not statistically significant for the 48 ms group. Localization accuracy (chance ~= 0.08) was 0.40, 0.47, and 0.48, respectively. Our data indicate that radiologists do develop gist perception for 3D modalities. Furthermore, slower presentation rates did not improve performance; there may be an optimal framerate for processing this type of 3D information.

63.415 **The effect of spatial organization in the design of visual supports for adults with communicative disorders** Yiming Qian[1](yxq5055@psu.edu), Krista Wilkinson[2], Rick Gilmore [1]; [1]Department of Psychology, Pennsylvania State University, [2]Department of Communication Sciences and Disorders, Pennsylvania State University

Visual supports are commonly used to enhance communication in individuals with developmental disorders, including Down syndrome (DS). Augmentative and Alternative Communication (AAC) supports display customized symbols designed to facilitate communication. Until recently, little research has focused on what properties of the symbols or their arrangement facilitates the use of AAC tools. This study used eye-tracking to investigate how different layouts of symbol icons altered the visual search process. Five participants with DS and 25 typically developing young adults participated. In each trial of the experiment, observers were cued to search for a target symbol in a 16-symbol display (19.2 deg x 14.2 deg at the viewing distance of 65 cm).Four different symbol layouts were evaluated, with 8 trials per layout. Eye position data was collected at 60 Hz and fixations on the symbols or the background were calculated using standard algorithms. The results showed that the participants with DS made significantly more eye movements than typically developing participants before making a decision about the position of the cued target. Among the 4 layouts, both groups of participants made significantly fewer eye fixations to the annular arrangement with emotions clustered in the middle (Clock condition, see Figure 1 in the supplementary material) than when presented with a grid arrangement based on the standard of care (SOC condition). Additionally, once participants fixated the target symbol in the Clock condition, they were less likely to look toward distractors than in the SOC condition. These results provide evidence that altering the size and arrangement of visual symbols in AAC-like displays can effectively alter visual search behavior.Understanding how people search for visual information may help optimize the utility of visual communication supports for individuals with special needs.

Acknowledgement: NICHD 1R01HD083381

Visual Memory: Attention, cues, search

Wednesday, May 22, 8:30 am - 12:30 pm, Pavilion

63.416 **Too little too late: No flexible control of memory by retro-cues** Blaire Dube[1](bdube@uoguelph.ca), Stephanie Rak[1], Liana Iannucci[1], Naseem Al-Aidroos[1]; [1]Department of Psychology, University of Guelph

Visual working memory (VWM) is severely capacity limited. As such, the ability to use it flexibly is important in ensuring that it effectively supports behavior. Cueing the relative priorities of items in the environment before they are encoded, for instance, will result in the flexible distribution of VWM resources such that the most relevant information is also best remembered. Similarly, using a cue after encoding to retrospectively indicate which representation is most relevant will result in enhanced performance on tests of the cued representation relative to the non-cued representations, known as the retro-cue benefit. How flexible is this retro-cue benefit? Across three experiments, we manipulated the predictive validity assigned to a single retro-cue (E1), and to two consecutive (E2) or simultaneous (E3) retro-cues, and assessed whether cue validity affected the precision of color responses in a subsequent memory test. Despite observing a reliable retro-cue benefit (i.e., better performance on tests of the cued, relative to the non-cued, representations), we observed no evidence that the size of this benefit varied as a function of cue validity across trials (E1). Further, we observed no evidence that participants were able to prioritize multiple cued representations relative to each other within a given trial (E2 and E3). That is, the cue(s) prompted participants to effectively prioritize the cued representation(s), but this process is all-or-none, and resources cannot be re-distributed flexibly. As such, we conclude that the benefit that a retro-cue incurs to memory performance is inflexible, highlighting an important limitation to the re-focusing of internal attention that is not observed when assessing attention at encoding.

63.417 **More than a button response: How saccades and fixations can inform our interpretation of VWM quantification** Bret T Eschman[1](beschma1@vols.utk.edu), Shannon Ross-Sheehy[1]; [1]University of Tennessee, Knoxville

Visual working memory (WM), is a capacity limited system used for the short-term storage and manipulation of visual information (Baddeley & Hitch, 1974). WM capacity is typically assessed using a "change-detection" task, and capacity for each participant is estimated based on behavioral accuracy across different set sizes. Given the relation between capacity and academic achievement (Alloway & Passolunghi, 2011; Bull et al., 2008), WM may be a useful marker of general cognitive development in infants. Although infants cannot make explicit behavioral responses as adults do, previous eyetracking work with adults (Ross-Sheehy and Eschman, under review) suggests that adults make significantly more saccades and have significantly longer fixations for incorrect trials than for correct trials. Thus, in an attempt to further quantify the saccade/fixation correlates of accuracy in adults, we present here results from three adult studies. Seventy-two adult participants (24 in each task) completed a change-detection task while their eye gaze was recorded with an Eyelink 1000 + eyetracking system. Button responses (e.g. same/different) were also collected. Experiment 1 examined visual

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dynamics during a replication of Luck and Vogel (1997), Experiment 2 was a modified version of Experiment 1 with larger total eccentricity and larger array items, and Experiment 3 replicated Experiment 2 only with increased encoding time (1000ms vs. 100ms in Exps 1-2). Across all three experiments, results were highly consistent: Adults made significantly more saccades for incorrect trials [Exp 1, $F(1,12)=9.919$, $p=.008$, $h2p=.453$, Exp 2, $F(1,10)=6.694$, $p=.027$, $h2p=.401$, and Exp 3, $F(1,19)=8.954$, $p=.007$, $h2p=.320$, and had significantly longer run counts for incorrect trials [Exp 2, $F(1,10)=9.087$, $p=.013$, $h2p=.476$ and Exp3, $F(1,19)=4.588$, $p=.045$, $h2p=.195$]. Taken together these results suggest: 1) Saccades and fixations may be useful new indexes of WM efficiency, and 2) visualdynamics may be an index of WM maintenance, and 3) encoding time, total eccentricity and element size did not influence WM performance, suggesting that adopting infant parameters does not fundamentally change the task.

63.418 **The precision of attentional selection is far worse than the precision of the underlying memory representation** Dirk Kerzel[1](dirk.kerzel@unige.ch); [1]Faculté de Psychologie et des Sciences de l'Education, Université de Genève

Voluntary attentional selection requires the match of sensory input to a stored representation of the target features. We compared the precision of attentional selection to the precision of the underlying memory representation of the target. To measure the precision of attentional selection, we used a cue-target paradigm where participants searched for a colored target. Typically, RTs are shorter at the cued compared to uncued locations when the cue has the same color as the target. In contrast, cueing effects are absent or even inverted when cue and target colors are dissimilar. By systematically varying the difference between cue and target color, we calculated a function relating cue color to cueing effects. The width of this function reflects the precision of attentional selection and was compared to the precision of judgments of the target color on a color wheel. The precision of the memory representation was far better than the precision of attentional selection. When the task was made more difficult by increasing the similarity between the target and the nontarget stimuli in the target display, the precision of attentional selection increased, but was still worse than the precision of memory. When the search task was made more difficult, we also observed that for dissimilar cue colors, RTs were slower at cued than at uncued locations (i.e., same location costs), suggesting that improvements in attentional selectivity were achieved by suppressing non-target colors.

Acknowledgement: Grant No. 100019_182146 from the Swiss National Foundation

63.419 **Shifts of Attention in Working Memory Space Differ from Those in Perceptual Space: Evidence from Memory Search** Garry Kong[1](kong.garry@nyu.edu), Daryl Fougnie[1]; [1]Department of Psychology, New York University Abu Dhabi

Just as we can use attention to select relevant information in our environment, we can also selectively attend to information held in working memory. Here we consider whether shifts in attention differ between perception and memory. When shifting attention in visual perception, the duration of shift depends on distance (Tsal, 1983), consistent with the movement of an attentional "spotlight" (Posner, Snyder & Davidson, 1980). When attention moves within a representation held in the mind, will similar distance effects emerge? We had participants memorize the identity and location of 4 objects on a 4x4 grid. During memory maintenance, participants were instructed to update the spatial position of one of the objects, before being instructed to update a second. The updating process was self-paced, with the time between each step indicating the time required to shift to and access the relevant item within memory. Importantly, we manipulated displays such that the second target was either close to or far from, and either shared one or no features with the first target. Updating the second target was faster when the targets shared a feature, $F(1,17) = 14.06$, $p = .002$, but the distance between targets did not matter, $F(1,17) = 1.33$, $p = .265$. While participants showed clear evidence of remembering location, location had ceased to affect updating times, unlike featural overlap. In contrast, in a visual search task using the same displays, participants were faster at finding the second target when it shared a feature with, $F(1,17) = 34.45$, $p < .000$, and when it was closer to, $F(1,17) = 39.28$, $p < .001$, the first target. This suggests that accessing a new position in memory does not require traversing spatiotopic distance as appears to happen during visual attention and raises questions about how spatial information changes between perception and memory.

63.420 **Visual working memory representations are shifted toward irrelevant features of distractors in intervening visual search tasks** Zachary A Lively[1](zlively2@illinois.edu), Gavin JP Ng[1], Simona Buetti[1], Alejandro Lleras[1]; [1]University of Illinois

The question of whether visual working memory (VWM) and visual attention share the same representations has been investigated for a long time. Many studies have shown that attention is captured by items that are similar to items currently held in VWM. In such studies, observers are typically first tasked to remember a color. They then perform a visual search task. On some trials, one of the distractors has a unique color. Interestingly, when this distractor is a memory-similar color, search times are slower than when the distractor is a memory-dissimilar color. This capture of visual attention is interpreted as evidence for the view that VWM and visual attention share the same representations. While the bulk of these studies have focused on the effects of VWM representations on visual search performance, the reverse has largely been ignored. Here, we asked whether the reverse is true as well: does the nature of the visual search task affect the quality of the VWM representation? On each trial, observers were tasked to memorize a single color followed by either a retention interval or a search task. The search task could be efficient (easy) or inefficient (hard) and the color of the search items was irrelevant to the search task. There were four possible search conditions: 1) easy search using a memory-similar color or 2) a memory-dissimilar color, 3) hard search using a memory-similar color or 4) a memory-dissimilar color. After each trial, participants reported the color in memory. The results showed that VWM representations were shifted towards the irrelevant color of the search items in the memory-similar condition, and this effect was larger in inefficient search. The results provide further evidence that VWM and visual attention share the same representations and that the interaction between the two systems is bi-directional.

63.421 **Time-dependent saccadic selection in analogue and categorical visual short-term memory tasks** Sven Ohl[1](sven.ohl@bccn-berlin.de), Martin Rolfs[1]; [1]Department of Psychology, Humboldt-Universität zu Berlin

Saccades to locations at which stimuli have just disappeared manifest the encoding of these stimuli in visual short-term memory (VSTM). This saccadic selection effect is robust to visual interference but vanishes within 1 s of stimulus disappearance. As previous studies have used categorical stimulus reports, we speculated that memory representations transition from analogue to categorical formats and that only the former is susceptible to saccadic selection. Here, we examined the time course of saccadic selection in VSTM using analogue reports to understand its consequences for VSTM representations. Participants reported the orientation of a memorized stimulus either relative to vertical (clockwise vs counterclockwise; categorical trials) or by reproducing the orientation using a rotation knob (analogue trials), in separate and randomly interleaved blocks. On each trial, we flashed two randomly selected orientations at two of eight equally eccentric locations for 100 ms. Following a delay of 100, 400, or 1600 ms, a movement cue prompted a saccade to one of the two locations. Finally, a response cue probed either location, asking participants to report the corresponding orientation. In both categorical and analogue trials, we replicated the saccadic selection effect, yet contrary to previous findings, congruency with the saccade target affected memory performance across all movement-cue delays. We modeled analogue orientation reports as a combination of previously reported influences on orientation memory. The best fitting model featured the proportion and precision of target reports, an oblique effect, and a cardinal-orientation bias. The model parameters suggest that saccades increased the proportion of guesses at incongruent locations. This detrimental influence decreased with increasing movement-cue delays. These findings demonstrate that saccades cause an immediate forgetting of stimuli at saccade-incongruent locations. The similar time course in categorical and analogue trials suggests that memory representations undergo similar transitions during memory consolidation irrespective of the report type.

Acknowledgement: DFG research grant to S.O. and M.R. (OH 274/2-1 and RO 3579/6-1).

63.422 **Attention for feature-context binding in working memory** Frida AB Printzlau[1,2](frida.printzlau@biodtp.ox.ac.uk), Nicholas E Myers[1,2], Sanjay G Manohar[1,3], Mark G Stokes[1,2]; [1]Department of Experimental Psychology, University of Oxford, [2]Oxford Centre for Human Brain Activity, Wellcome Centre for Integrative Neuroimaging, University of Oxford, [3]Nuffield Department of Clinical Neurosciences, University of Oxford

Working memory (WM) is the ability to hold information in mind over a few seconds and use it flexibly for behaviour. Not all items are represented equally in WM. Attention can be allocated to privilege certain information, perhaps by strengthening the trace between items and their context (i.e. "binding"). The aim of this project was to explore the role of attentional selection for feature-binding in WM. We conducted one behavioural and one EEG experiment to test the hypothesis that selecting one feature in memory automatically brings associated, but redundant, features into a privileged state. For both experiments, participants completed a precision WM task that asked them to recall the angle of one of three oriented, coloured bars after a delay. During the delay, an orthogonal 'incidental task' cued a feature of one item (behaviour: colour or location cues, EEG: colour cues only) for a match/non-match judgement. On congruent trials, the item that was incidentally cued was probed during memory recall; on incongruent trials, an uncued item was probed. 21 participants completed the behavioural experiment and 30 participants completed the EEG experiment. Behavioural results from both experiments showed improved performance (precision and response times) for congruent relative to incongruent trials. We propose that attentional selection of an item-feature in WM privileges associated, but currently redundant, features. Neurally, following the incidental cue we found greater contra- than ipsilateral alpha suppression and improved neural decoding of the location where the cued item, relative to uncued items, was originally presented. Bringing the cued colour into the focus of attention may involve auto-associative retrieval of the cued-item location, thereby strengthening the feature-context binding and improving behavioural performance. This is consistent with computational models of WM that retrieve features by pattern completion as well as 'feature-map' models where location is an obligatory component of feature-binding.

Acknowledgement: Biotechnology and Biological Sciences Research Council

63.423 **Directing retrospective attention in visual working memory in a graded manner** Timothy C Sheehan[1](timothysheehanc@gmail.com), John T Serences[1,2]; [1]Neurosciences Graduate Program, University of California, San Diego, La Jolla, California, [2]Department of Psychology, University of California, San Diego, La Jolla, California

Visual working memory capacity is limited (Luck, 1997) so prioritizing the most behaviorally relevant items is important. Retrospective cues (retro-cues) presented during a retention interval when sensory information is no longer available have been shown to improve item recognition (Griffin 2003), with larger effects for high validity cues (Berryhill 2015, Gunseli, 2015, Gunseli, 2018). Importantly, however, studies have only used 1-2 levels of cue-validity so it is not clear if internal shifts of attention in response to retro-cues can be directed in a graded manner or if a single item is either in or out of the privileged 'Focus of Attention" (Cowan, 2011). Recent work (Lockhart, 2018) utilizing multiple 100% valid retro-cues found that attentional benefits did not exist when >1 item was cued, supporting the notion that retrospective attention is 'all-or-none.' To test if retrospective attention can be directed in a graded manner, we ran two delayed report experiments with variable validity retro-cues. In E1, using a between-subjects design, each subject (n=93) was assigned a cue validity (50-90%) and we found that mnemonic precision was higher on cued trials but did not increase with cue validity while precision on un-cued trials significantly decreased with validity. In E2, each subject (n=10) was presented with a colored arrow corresponding to 3 possible cue validities (50, 65, 80%). While recall precision was higher for the cued stimulus, there was no main effect or interaction between cue probability and whether the probed target was valid or invalidly cued. Taken together, these results suggest that while individuals may be able to take cues validity into account to set one level of relative priority, there is little evidence that a given individual can flexibly direct retrospective attention to memoranda in a graded manner.

63.424 **Facial Emotions Guide Attention to Task-Irrelevant Color Cues** Thaatsha Sivananthan[1](thaatsha.sivananthan@mq.edu.au), Steven B. Most[2], Kim M. Curby[1]; [1]Department of Psychology, Macquarie University, Australia, [2]School of Psychology, University of New South Wales, Australia

In what ways does emotion guide attention and affect perception? Do the associations people make between feelings and colors influence what they attend to and remember? We hypothesized that holding emotional faces (angry, happy, or neutral) in working memory (WM) would enhance attention to and memory for novel shapes presented in emotionally congruent, task-irrelevant colors. For example, we predicted better memory for red than green shapes after people were primed by an angry face. In Experiment 1, participants maintained in WM the identity and expression of a face presented for 500ms, during concurrent encoding of a 2500ms array of six shapes (three red & three green). Participants then indicated whether a subsequent achromatic shape had been present in the array, irrespective of its color. Experiment 1 initially seemed to suggest that the emotion of the face held in WM did not guide attention to congruently colored shapes. However, a post-hoc analysis revealed that those who reported mimicking the emotional expressions while attending to the shape array (rather than labeling them) exhibited the predicted WM advantage for shapes presented in the color congruent with the emotion mimicked. Experiment 2 provided confirmatory evidence: participants were randomly instructed to either mimic or label emotional face primes and, consistent with Experiment 1, mimicking (but not labeling) facial expressions resulted in a memory advantage for novel shapes in the emotion-congruent colors. These findings highlight how emotional associations can shape our attention and perception of the world around us.

Visual Search: Attention, memory, cues, windows

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63.425 **Visual Search Revisited in East Asia: Experience Matters** Yoshiyuki Ueda[1](ueda.yoshiyuki.3e@kyoto-u.ac.jp), Chia-Chun Tsai[2], Sung-En Chien[2], Su-Ling Yeh[2], Jun Saiki[3]; [1]Kokoro Research Center, Kyoto University, [2]Department of Psychology, National Taiwan University, [3]Graduate School of Human and Environmental Studies, Kyoto University

Compared to the well-known cultural differences in higher-level processes such as thinking and reasoning, there is no consensus on whether lower-level processes such as visual perception and attention can also be different among cultures. One of the reasons is that visual perception and attention tasks have been used in previous studies are more complicated, leading to accumulated errors and contamination of verbal instruction. Using a simple visual search task, Ueda et al. (2018) showed that there are cultural differences in visual search between Caucasians (in the United States and Canada) and East Asians (in Japan); Caucasians showed search asymmetry of shorter/longer line length, whereas East Asians did not. To examine whether this effect can also be observed for East Asians of a different culture, we conducted another series of experiments in Taiwan. East Asians in Taiwan were asked to search either the longer line among 3, 6, or 12 distractors of shorter lines, or vice versa, and judge whether the target was present or not (the same task as in Treisman & Gormican, 1988). The experiment was divided into two sub-sessions, and the target changed between them. The results showed that East Asians in Taiwan showed no difference in search slopes (changes in reaction times as a function of set size) between shorter and longer line search, suggesting that there is no search asymmetry for line length in East Asians in Taiwan, similar to the findings observed for those in Japan. Surprisingly, however, the search for shorter line was significantly faster than that for longer line. Taking the current and previous results together, the pooled-response model proposed by Treisman & Gormican (1988) explaining why search asymmetry is observed should be reconsidered, by taking into account the key component of culturally shaped experiences.

Acknowledgement: JSPS Grants-in-Aid for Scientific Research (#16H01727), SPIRITS program in Kyoto University

63.426 From the clinic to the lab and back: Fixing the problem of missed "incidental findings" Makaela S. Nartker[1](mnartker@bwh.harvard.edu), Jeremy M. Wolfe[1,2]; [1]Department of Surgery, Brigham & Women's Hospital, [2]Departments of Ophthalmology and Radiology, Harvard Medical School

For radiologists searching images, "incidental findings" are clinically significant targets that were not the original subject of search (e.g., search a lung for pneumonia, incidentally detect a broken rib). Incidental findings are missed more often than is desirable. How can we reduce those errors? The "mixed hybrid search task" is a model system to study the basis of these errors in the lab. In this task, non-expert observers memorize N specific photorealistic object targets (e.g., this specific cat). They also memorize N broader categorical target types (e.g., "fruit," "clothing"). In subsequent visual search, they report any specific or categorical targets. Observers show elevated (>30%) miss error rates for categorical targets – our stand-in for incidental findings. Our current goal is to reduce these categorical target miss errors in the hope that a method that works in the lab could be transferred to the clinic. Our first attempts were unsuccessful. Showing observers exemplars from a target category did not improve subsequent detection of other exemplars from that category. Prompting observers on each trial to search separately for specific and categorical targets also left miss errors above 30%. However, error rates dropped by more than 40% when we used a checklist procedure where observers had to confirm whether each target was present or absent on every trial. Unfortunately, this method increased time per trial too much to be desirable for the clinic. Interestingly, we found similar improvement in errors in a task where observers memorized three categorical (incidental) targets and then searched for novel specific targets on each trial. Observers were prompted to respond to all targets on each trial (analogous to "check this x-ray for broken ribs and the next for kidney disease AND look out for incidental findings"). However, even with this improvement, categorical errors remain stubbornly persistent.

Acknowledgement: NIH-NEI [DHHS] F32EY019819-01

63.427 Large attentional window produces contextual cueing effects on target absent trials Jeunghwan Choi[1](abcdef0518@naver.com), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

People search targets more efficiently in repeated displays than in novel displays (contextual cueing; Chun & Jiang, 1988). It is well known that target-distractor associations could guide attention to the target location. However, studies have found conflicting results on whether repeated displays without a target could produce contextual cueing effects (Beesley et al., 2015; Geyer et al., 2010) or not (Kunar & Wolfe, 2011; Schankin et al., 2011). We first tested three factors that might influence the strength of distractor-distractor associations which can enable the contextual cueing effect in the target absent condition (Experiments 1 & 2), and then investigated how it produced faster responses on repeated target absent trials using an eye-tracking method (Experiment 3). The first factor was a set size (8 or 16), the second one was the number of repeated displays (8 or 16), and the last one was the heterogeneity of distractors' properties (homogeneously or heterogeneously colored distractors). Experiment 1 varied the first two factors and the third factor was varied across Experiments 1 and 2. In all experiments, participants were asked to find a T shape (target) among L shapes (distractors). In Experiments 1 and 2, we found the consistent contextual cueing effect in the target present condition. However, only the heterogeneously colored distractors produced the contextual cueing effect in the target absent condition. In Experiment 3, we found that this contextual cueing effect in the target absent condition was due to lower number of fixations and larger mean saccadic amplitudes on repeated absent trials. Overall, these results suggest that the distractor-distractor associations formed and facilitated by the heterogeneity of distractors' properties induce a large attentional window. This makes it possible to reject more distractors at the same time such that people terminated a visual search faster on repeated target absent trials.

Acknowledgement: This research was supported by the Brain Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (NRF-2017M3C7A1029658).

63.428 Leveling the viewing field: The influence of target prevalence on the attentional window Juan D Guevara Pinto[1](jgueva3@lsu.edu), Megan H Papesh[1]; [1]Louisiana State University

Recent research suggests that, when search targets are difficult to discriminate from distractors, fewer items can be processed within a single fixation, reflecting a narrowing of the Functional Viewing Field (FVF, Young & Hulleman, 2013; Hulleman & Olivers, 2016). Discrimination difficulty is also at the core of the low-prevalence effect (LPE) in visual search (Wolfe & Van Wert, 2010): Observers often miss rare targets, despite directly fixating them (e.g., Hout et al., 2015; Peltier & Becker, 2016). Across three experiments, we examined the hypothesis that discrimination difficulty, induced by prevalence manipulations, should affect the size of the FVF. In Experiments 1 and 2, observers searched for simple stimuli presented in circular arrays at varying eccentricies off-center. Target frequency was manipulated across three "invisible" blocks in each experiment, appearing in 25%, 50%, or 75% of trials. We measured the probability of directing the first fixation (FF) to the target as an index of relative FVF size. In both experiments, the probability of FF decreased as arrays appeared further from central fixation. Unexpectedly, the probability of FF was more likely during LP, relative to high-prevalence, search, particularly when arrays were close to central fixation. In Experiment 3, we eliminated eye movements by presenting search items in Rapid Serial Visual Presentation (RSVP) search streams. Peripheral distractors appeared at varying eccentricities in 20% of the RSVP trials, allowing us to use detection and identification as an index of FVF size. Although a classic LPE emerged, observers were more likely to miss peripheral distractors during high-prevalence search, replicating the narrowed FVF observed in Experiments 1 and 2. Together, these results show that FVF size is reduced as target-prevalence increases, suggesting that top-down, preparatory attention mechanisms mediate the attentional window.

63.429 What are the features of shapes easy to remember in the visual search? Kazuki Konno[1](n185211f@yokohama-cu.ac.jp), Ruggero Micheletto[1]; [1]Graduate School of Nano bioscience, Yokohama City University, Japan

How do we find objects in scenes? When we recognize things in the outside world, we feel that we recognize shapes as one entire object, not an ensemble of inconsistent characteristics. In perception theory, it is thought that features are integrated in structures that define objects, but how these structures are maintained in the working memory remains unknown. Therefore submitting clear evidence of the features binding in the memory is the first goal of this study. In this experiment, firstly the target is displayed. Then a panel is shown with the target and some distractors. Firstly, we generated eight different individual targets in this experiment. We show the targets in different presentation patterns: for each target, the presentation time is 300ms or 600ms, and the number of distractors can be 15 and 23 for a total of four different trial combinations. We measured the correct answer rate and the reaction time in those four tasks. The targets are generated with the using Genetic Algorithm. The targets more easy to remember will have a lower reaction time and better correct answer rate. Using these results, the genetic algorithm produces next generation targets in order to be more easy to remember. As a result, the "correct answer" rate is 51% at stimulation time of 300ms, 61% at 600ms in the first generation, and it is 79% at 300ms, 73% at 600ms in the second generation. In addition, we found that in the second generation there is a clear reduction of reaction times. When the number of distractors increases we found that the reaction time gets longer and this is preserved in the second generation too. This behavior is in accord with the visual search "conjunction search" theory. We will describe our Genetic Algorithm model able to generate targets easy to remember.

63.430 Mere presence effects of entirely task-irrelevant but significant real objects on visual search performances Motohiro Ito[1,2](moto.1100525@gmail.com), Jun I Kawahara[1]; [1]Hokkaido University, Department of Psychology, [2]Japan Society for the Promotion of Science

Researches have shown that attentional selection can be distracted (i.e., attentional capture) momentarily by the presence of biologically, socially, or personally significant objects, such as human faces, emotional expressions, features related to monetary rewords, or calorie-dense foods. A large body of literature on attentional capture demonstrated that attentional capture effect is volatile and time-locked by the onset of distractors. However, recent studies found that a mere presence of a mobile communication device, such as a smartphone, even in no use during tasks, impairs social interactions and cognitive activities for an extended period of time for over 10 minutes when allocation of attention is required. The present study examined whether the mere presence effect of the mobile device can be extended for other significant objects (e.g., money bill) in everyday life during attentionally demanding visual search tasks. Specifically, participants identified a target letter among spatially distributed non-targets through a computer display with which money bills (or notepad as the control) were placed on the left side of the search display. Participants rated their mood before and after the visual search session. The result showed that reaction times under the money-bill presence were longer than those under the control condition, indicating the occurrence of the mere presence effect. The increase in arousal could not account for the results. Moreover, we found no such distraction effects when the money bill was visually concealed from observers by placing them in an envelope (however, participants knew the presence of the bills) and when a photographic image of the money bill was presented in the search display. These results suggest that the mere presence effect can be applicable to the presence of significant objects when the distractor is real and visually available, due to lingering attentional biases based on prior attentional deployments or learning.

63.431 **Concreteness Versus Complexity: Similarly Named Icon Features Elicit Dissimilar Performance During Visual Search** Jessica Nguyen[1](jessica.nguyen@knights.ucf.edu), Mark B Neider[1]; [1]Psychology, College of Sciences, University of Central Florida

Most modern devices include a user interface that employ symbolic icons to represent information to the user. Previous studies relating visual features of icons to response time (RT) differences in visual search have produced ambiguous findings (Arend, Muthig, & Wandmacher, 1987; Byrne, 1993). In the current study, our goal was to quantify concreteness and visual complexity of icons in a search task. We distinguished between concrete and abstract icons by creating our own set of icons meant to correspond to common applications encountered on an Apple iPad.Concrete icons were operationalized as an image of a real object (e.g., a camera); abstract icons were simple graphical depictions of the concrete icons. To validate our item categories, 52 participants rated each icon on several characteristics, including concreteness and complexity. In a separate study, 20 new participants performed a visual search-and-match task for a target icon among four different target/distractor arrays (concrete/concrete; abstract / abstract; concrete /abstract; abstract/concrete) on a background similar to an iPad screen. Eye movement data were also collected. Subjective ratings confirmed that observers considered concrete icons (x = 4.15) more concrete than abstract icons (x = 2.49). Accuracy in the search task was high (~ 98%) and did not differ significantly across conditions. Contrary to previous findings, we found that search RTs did not differ between concrete (2028 ms) and abstract icons (1969 ms). However, participants were significantly faster to locate the icon when the distractor category was different from the target category (215 ms and 173 ms, respectively). Interestingly, although RT in the concrete and abstract conditions did not differ, when factoring in complexity ratings we found that for abstract icons higher complexity led to longer RTs (~215 ms), suggesting that when icons are more ambiguous visual complexity plays a larger role in driving performance.

63.432 **Occlusion and object specific effects on visual search for complex objects** Rachel T Nguyen[1](rnguye@masonlive.gmu.edu), Matthew S Peterson[1]; [1]Department of Psychology, George Mason University

When an object is partially occluded, the process of amodal completion can perceptually fill in the occluded object to help guide attention (Rensink & Enns, 1998). However, amodal completion for an objects' guiding feature, such as orientation, can fail, causing search to be inefficient. (Wolfe et al., 2011). However, these tasks used orientation as the target-defining feature, and our question was whether we would see evidence for amodal completion when the task was to search through complex objects. To test this, we displayed objects that had different levels of internal complexity (Black bar, Hershey bar, and Remote Controller), yet had the same horizontal and vertical dimensions. The targets and distractors could be fully visible or partially occluded by a diagonal white bar or a gap. Distractors were either horizontal or vertical versions of those three stimuli. In the first experiment participants searched for a vertical. When there was no occlusion, the target popped-out, no matter the object type.However, when the target was occluded, search was more difficult when it was a black bar or Hershey bar compared to when it was the remote control.This object-specific effect might be due to surface features of the remote control interacting with the occluder to make detection of its vertical orientation easier.However, vertical is not an inherent feature of any of the objects, but instead a transient property. In the second experiments, participants searched for an object based on its identity. Occlusion had a larger effect on the complex objects compared to the simple bar, with search efficiency roughly 2.5x slower.In addition, the remote control failed to pop-out when there was no occlusion. Effects of occlusion on visual search are complex, object specific, and may depend on which surface features are occluded.

63.433 **Perceived rather than physical direction of the double-drift stimulus pops out in visual search** Mert Ozkan[1](mert.ozkan.gr@dartmouth.edu), Peter U Tse[1], Patrick Cavanagh[1,2,3]; [1]Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH, USA, [2]Department of Psychology, Glendon College, Toronto, ON, Canada, [3]Centre for Visual Research, York University, Toronto, ON, Canada

In the double-drift stimulus, a patch of 1/f noise moves in one direction while its internal texture drifts in the orthogonal direction and the result is that the perceived direction deviates dramatically from the physical path.Surprisingly, non-delayed saccades to the double-drift targets go to their physical not perceived locations (e.g. Lisi & Cavanagh, 2015). Using an oddball search paradigm, we examined whether visual attention operates over the perceived or physical direction of the double-drift stimulus. We presented either 4 or 8 moving patches, one of which differed in only its illusory direction from the others (each half of the items had matching physical directions) or only its physical direction from the others (all perceived directions were matched). Participants pressed a key once they localized the target, then another key to report target location. Results showed that the odd illusory direction produced a pop-out effect: the participants were able to report the target's location correctly on 96% of the trials, independently of set size. Reaction times also showed that the target popped out among the distractors: the response to the odd target was faster in the larger set (4 items, 1.43 s vs 8 items, 1.10 s). This improvement with increasing distractor set size is consistent with previous findings of the pop-out effect in visual search (e.g. Bravo & Nakayama, 1992). In contrast, when the odd target was defined by its physical direction, participants showed poorer performance and even worse performance at the larger set size (40% and 27% correct, respectively). Average reaction time was, overall, longer and increased with set size (3.18 s vs 4.18 s, respectively). We conclude that pop-out operates over perceived, not physical double-drift directions. Perceived double-drift directions are subject to parallel processing whereas physical double-drift directions require serial search.

Acknowledgement: NSF EPSCoR Award #1632738

63.434 **Grouping does not help you to guide conjunction visual search** Igor S. Utochkin[1](isutochkin@inbox.ru), Vladislav A Khvostov[1], Jeremy M Wolfe[2]; [1]National Research University Higher School of Economics, Russia, [2]Visual Attention Lab, Brigham & Women's Hospital & Harvard Medical School, United States

The knowledge of target features can be used to guide attention in many conjunction searches in a top-down manner. For example, in search for a red vertical line among blue vertical and red horizontal lines, observers can guide attention toward all red items and all vertical items. Items with both features would gain greater activation. It could be that attention is guided to the group of red items and the group of vertical items with items neatly divided into those with a target feature and those without. Alternatively, attention might be guided to any reddish and relatively vertical items, with no grouping. We tested whether clear, categorical groups were useful in guided search. Observers searched for color-orientation (Experiment 1) or length-orientation (Experiment 2) conjunction targets. Distractors could form two segmentable groups (e.g blue steep and red flat) or distractors could be "non-segmentable" varying from red to blue and steep to flat discouraging grouping and increasing overall heterogeneity. We found that, when the target was present, the searches were quite efficient in Experiment 1 (~9-14 ms/item) and more efficient in Experiment 2 (~0-6 ms/item). Target-present slopes were not affected by "segmentability" manipulations. However, target-absent slopes were less efficient if one of the dimensions was "non-segmentable" (especially in length-orientation conjunctions). In Experiment 3, we demonstrated that search in "non-segmentable" conjunction sets search no less and could be even more efficient than search in "non-segmentable" feature search. Our results suggest that attention is directly guided by the overlap between top-down activation signals corresponding to target features. The guidance mechanism bypasses grouping and segmentation cues that are very important in other tasks like scene parsing and object recognition.

Acknowledgement: Russian Science Foundation, grant 18-18-00334

63.435 **Useful Field of View shows why we miss the search target when we "look at" it** Chia-Chien Wu[1,2](cchienwu@gmail.com), Jeremy M Wolfe[1,2]; [1]Brigham and Women's Hospital, [2]Harvard Medical School

How much of the visual world do we process with each fixation? What is the "useful field of view" (UFOV). The answer to that question depends on the task. If the task is peripheral recognition, the answer is constrained by

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acuity and crowding. If the task is visual search, we need to know if an item in the periphery can attract the next fixation. To measure the UFOV for visual search, observers were asked to mouseclick on the target letter, T, among distractor, Ls, while their eye movements were recorded. Once the target letter was clicked, a new T would immediately appear at a random location and all other letters would rotate by a random angle to mask any pop-out of the new target. Os collected 500 targets in a session. The results show that saccade length distributions are identical except for the last saccade to the target. The positively skewed distribution has a peak at about 4 degrees and an average of 5.7 degrees. It is likely that observers forage for targets within region defined by that saccade spacing.Similar distributions were found when searching for conjunctions, ambiguous Ts and Ls, and a TvsL display of a different density. This suggests that Os adopted a scanning strategy with roughly constant saccade lengths to explore the search display until the target fell within their UFOV. The length of the last target-fixating saccade can be used to calculate an effective size of the search UFOV; 3.5 - 5 degrees for these stimuli. Twenty Hz serial deployments of attention within the UFOV can model the saccade length distribution and can explain why the target is sometimes missed even when it is within the UFOV. Our results help to distinguish between the UFOV for peripheral recognition and the UFOV for visual search.

Acknowledgement: NIH EY017001 / Army Research Office R00000000000588

63.436 **Probing the early attentional benefits of negative templates** Ziyao Zhang[1](ziz418@lehigh.edu), Nicholas Gaspelin[2], Nancy B. Carlisle[1]; [1]Psychology department, Lehigh University, [2]Psychology department, Binghamton University, State University of New York.

Previous research has revealed cuing distractor color can benefit search performance compared to uninformative cues (Arita, Carlisle, & Woodman, 2012). However, the benefits from negative cues are consistently smaller than benefits from positive cues (cuing target color), even when both cues mean participants only need to search through half of the array. This suggests that using a negative template is less effective than using a positive template. Here, we tested the early attentional effects of the negative template and compared it with positive template using the probe technique (Gaspelin, Leonard, & Luck, 2015). On most trials, participants performed a search task for a shape-defined target after receiving positive, negative or neutral color cue. On occasional trials, letters were briefly presented on top of search items, and participants were required to report these letters, providing a snapshot of attention to potential targets vs. distractors. In three experiments, we varied timing of probe letters (100 ms, 250 ms or 400 ms after search array onset). All three experiments replicated the RT benefits on search trials from previous results. Crucially, on probe trials, participants recalled more letters on target-colored locations than letters on distractor-colored locations following both positive and negative cues. Moreover, the benefits of these cues were larger at the later probe times than 100ms for both positive and negative cues (p's < .01), indicating both cues became more effective across time during search. These results suggest that the time course of negative template effectiveness during search is similar to that of positive template. However, negative template probe benefits were consistently not as potent as positive cues (p's < .001) in guiding attention toward target features. The probe results help explain the previously reported differences in RT benefit following positive and negative cues, and support the idea of early active attentional suppression.

63.437 **Learned Feature Variability Predicts Visual Search and Working Memory Precision** Phillip P Witkowski[1,2](pwitkowski@ucdavis.edu), Joy J Geng[1,2]; [1]Psychology, University of California, Davis, [2]Center for Mind and Brain, University of California, Davis

Previous research has established that attention operates by selectively enhancing sensory processing of task-relevant target features held in working memory. Much of this literature uses search displays in which the target is an exact match of cued features. However, real world visual search rarely involves targets that are identical to our memory representations. The ability to deal with cue-to-target variability is a critical, but understudied aspect of visual attention. In these studies, we test the hypothesis that top-down attentional biases are sensitive to the reliability of target feature dimensions over time. In two experiments, subjects completed a visual search task where they saw a target cue composed of a certain motion direction and color, followed by a visual search display with multiple distractors (S.1 Supplemental). The target features changed from the cue, with one dimension drawn from a distribution narrowly centered over the cued feature (reliable dimension), while the other was broad (unreliable dimension). The results demonstrate that subjects learned the distributions of cue-to-target variability for the two dimensions and used that information to bias working memory and attentional selection: Reaction times and first saccades were better predicted by the similarity of the consistent feature than the inconsistent feature and the precision of working memory probe responses was greater for the consistent dimension (S.2 Supplemental). Moreover, the working memory precision predicted individual variation in search performance. Our results suggest that observers are sensitive to the learned reliability of individual features within a target and use this information adaptively to weight mechanisms of attentional selection.

63.438 **How does the bzzzzzzzzzzzz influence search? - The effects of sound on memory and visual search** Caroline D. Seidel[1](caroline.seidel@stud.uni-frankfurt.de), Sage E.P. Boettcher[2], Dejan Draschkow[1], Melissa L.-H. Võ[1]; [1]Department of Psychology, Goethe University Frankfurt, [2]Brain and Cognition Lab, University of Oxford

Learned associations between objects and sounds influence how we search through our real world (e.g. sirens of an ambulance). Previous studies have demonstrated that non-spatial sounds facilitate visual search performance in artificial displays but not in scene search (Seidel, Draschkow & Võ, 2017). In two experiments, we tested how sounds facilitate search whereby the experimental setup mimicked prior hybrid search experiments (Wolfe, 2012). In Experiment 1, participants memorized eight objects along with their characteristic sound. Subsequently, participants searched for the target objects held in memory. Before the onset of the search display one of the four sound conditions – natural, distractor, scrambled, vs. no sound – was played. In the natural sound condition, observers heard the sound associated with the target, whereas in the distractor condition a sound associated with another item in memory that was not present in the display was presented. In the scrambled condition a distorted, unrecognizable sound was played, and in the no sound condition observers did not hear anything before beginning their search. In the second experiment, we varied the amount of items held in memory across blocks (4, 8,16) and the amount of objects presented during search across search trials (4, 8, 16). Results from both experiments showed that reaction times were faster for searches accompanied by natural sounds and slower for the distractor compared to the neutral condition. Experiment 2 demonstrated that this benefit could be attributed to a change in memory search efficiency – presumably due to a prioritization of the target. We found no change in visual search efficiency. Our results implicate that the involvement of several factors for auditory facilitation of visual search - such as stimulus material, task relevance, SOA, memorability, and number of objects held in memory or present in the search display - determines whether the bzzzzzzzz facilitates search.

Acknowledgement: This work was supported by DFG grant VO 1683/2-1 and by SFB/TRR 135 project C7 to MLV. We also want to thank Nina Jaeschke, Evelyn Richter, Charlotte Habers, Kim-Veronique Knöpfel, Sarah Peetz and Valerie Tanzberger for assistance in data acquisition.

63.439 **A secondary task stunts the development of contextual cueing** Lisa M Heisterberg[1](heisterberg.2@osu.edu), Andrew B Leber[1,2]; [1]The Ohio State Medical Scientist Training Program & Neuroscience Graduate Program, [2]The Ohio State Department of Psychology

Humans routinely encounter spatial regularities in their environment that can be exploited to improve visual search performance. A demonstration of such search facilitation in the lab is known as contextual cueing, an effect that results from implicit learning of repeated spatial arrangements. Despite countless studies, there remains uncertainty about the processes involved in the acquisition and expression of learned contextual information. Previous studies have found that taxing visual spatial working memory concurrently with the search task can impact the later development of a cueing effect. However, the time after the search task may also be important for the consolidation of learned spatial regularities. We hypothesized that a secondary task presented immediately after completion of the target search would retroactively disrupt the consolidation process, resulting in a diminished contextual cueing effect. To test this, we conducted an exploratory experiment and a pre-registered replication in which participants completed a variation of the contextual cueing procedure (Chun & Jiang, 1998). Subjects searched for a T among Ls in displays with repeating and random spatial arrangements of stimuli. There were 4 critical conditions: 1) standard repeated arrangement trials, 2) repeated arrangement trials during which the search task was followed by a secondary task of judging simple math problems, 3) repeated arrangement trials during which the search task was followed by a blank period of the same duration as the secondary task, and 4) random arrangement trials where the distractor locations did not predict the location of the target. Results showed that contextual cueing was diminished when

the search task was followed by a secondary task. Such findings demonstrate that learning of visual regularities is susceptible to interference by a secondary task that occurs during the consolidation period. In addition, results show that a non-working memory, non-spatial, non-concurrent secondary task can disrupt spatial implicit learning.

Acknowledgement: NSF BCS-1632296 to ABL

63.440 **An individual differences investigation of the relationship between visuospatial working memory capacity and inefficient search.** Kirk Ballew[1](kballew2@illinois.edu), Jing Xu[1], Alejandro Lleras[1], Simona Buetti[1]; [1]University of Illinois at Urbana-Champaign

Inefficient search is the process of locating a target among distractors whose features are highly similar to those of the target. Such search requires a serial process, in which one must foveate items one-by-one until the target is found. As such, mean response time increases for each additional distractor in the display. It has been shown that inefficient search uses visuospatial working memory (VWM). When an inefficient search was completed while participants were holding information in VWM, the search slope was greater than when the search task was run in isolation (Woodman & Luck, 2004). We therefore hypothesized that individual differences in VWM capacity might predict individual differences in search slopes. Toward that end, we developed four tasks to measure working memory capacity. In the Corsi blocks task, we asked participants to remember, and subsequently identify in order, sets of spatial locations presented serially within a grid. Set size increased across blocks. We also used three change detection tasks. In the first task, we asked participants to detect changes between pairs of displays containing twelve spatial locations arrayed within a grid. In the second task, we asked participants to detect changes between pairs of displays containing four dots arrayed along an invisible circle. The third task was a test of non-spatial working memory, which served as a control condition. We asked participants to detect changes between a probed color and a set of four colors presented previously. Finally, participants performed an inefficient search task with two difficulty conditions (difficult and very difficult) and two set sizes (5 and 8). We used individual differences in working memory capacity to predict individual differences in inefficient search slopes. The findings are discussed in terms of the different underlying memory constructs that contribute to performing inefficient search.

Visual Search: Models, neural mechanisms

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63.441 **Information processing architectures across the visual field: an EEG study** Gaojie Fan[1](gaojief@gmail.com), Gamble Heather[1], Robin Thomas[1]; [1]Psychology, Miami University

How people combine and utilize information from different sources during cognitive processing has always been an interesting topic in visual research. Frameworks such as Systems Factorial Technology (SFT) have been developed to study this process. By using a variety of non-parametric analyses such as mean interaction contrast and survivor interaction contrast, SFT can distinguish between types of information processing architectures (mainly parallel and serial) as well as stopping rules (mainly exhaustive and self-terminating). However, most of these frameworks utilize behavioral data for model building and psychophysiological activities underlying the models are not commonly examined. The present study aims at both extending SFT with similar visual stimuli presented in bilateral visual fields, and examining the brain activities by looking at ERPs and continuous EEG data. We expect to see we expect to see different patterns of architectures and stopping rules when the location of stimuli varies, and we also expect to see different patterns of psychophysiological activities from different conditions.

63.442 **Performance monitoring signals during visual priming** Jacob A Westerberg[1,2,3](jacob.a.westerberg@vanderbilt.edu), Geoffrey F Woodman[1,2,3], Alexander Maier[1,2,3], Jeffrey D Schall[1,2,3]; [1]Department of Psychology, Vanderbilt University, [2]Center for Integrative and Cognitive Neuroscience, Vanderbilt University, [3]Vanderbilt Vision Research Center, Vanderbilt University

Repetitive task performance can lead to faster, more accurate performance, a phenomenon known as priming. One example is priming of pop-out visual search. In this task, participants identify a conspicuous singleton in a search array by shifting gaze to the singleton. This singleton is defined by a pop-out feature such as color (e.g. red among green). With repetition of the singleton feature participants become faster and more accurate. We investigated further what neural processes could yield the observed behavioral effects. Performance monitoring signaling seems a likely neural contributor as priming occurs concurrently with improved performance. We hypothesized that the modulation of performance monitoring signals contributes to behavioral changes observed during visual priming. Earlier work has demonstrated that an area known as the Supplementary Eye Field (SEF), a medial frontal cortical area, contributes to performance monitoring in visual search. This intersection provides a neural location in which we can investigate priming of pop-out. To test our hypothesis, two monkeys performed a priming of pop-out search task. During task performance, microelectrodes recorded from SEF simultaneously with EEG recorded extracranially to monitor an index of performance monitoring known as the error related negativity (ERN). Bayesian analysis demonstrated that whereas spike rates show no modulation with visual priming, the ERN did modulate with visual priming. This is particularly interesting as it has been shown previously that spiking in SEF contributes to the generation of the ERN. It is not entirely unexpected, however. SEF spiking does not reliably represent ongoing visual search processing, such as discrimination of target and distractors. The absence of stimulus-specific and spatially distinct visual information may be important to priming. Based on the dissociation between SEF spiking and EEG, we conclude that performance monitoring does play a role in priming of pop-out, but the signal source is not localized to SEF.

Acknowledgement: R01EY019882, R01EY08890, R01EY027402, P30EY008126, T32EY007135, U54HD083211, E. Bronson Ingram Chair in Neuroscience

63.443 **Neural Evidence for Interference in Contextual Cueing** Anna Vaskevich[1](anna.vask@gmail.com), Roy Luria[1,2]; [1]The School of Psychological Sciences, Tel-Aviv University, [2]The Sagol School of Neuroscience, Tel-Aviv University

Previous studies have demonstrated that in a visual search task, observers are faster to locate targets when these are presented in repeated rather than random contexts, an effect termed contextual-cuing. However, we have recently shown that this effect reflects interference. In the present study, we used event related potentials (ERP) to investigate whether this interference is reflected in target selection processing and in visual working memory (VWM). Three groups of participants completed a visual search task while EEG was recorded. For the Consistent-only group, targets and distractors appeared in predefined spatial locations, for the Random-only group the task contained no regularity, and for the Mixed group the task contained both consistent and random conditions intermixed. Behaviorally, we replicated our previous results, such that performance in a random visual search, without any regularity, was better than performance in a mixed-design search that contained a beneficial regularity. This interference was reflected by an earlier N2pc component with higher amplitude in the Random-first group than in the Random-mixed condition, suggesting that the efficiency of target selection in a random search deteriorated when regularity was introduced into the task. More generally, we conclude that the interference to performance under mixed conditions begins during the search process itself, long before the response. Additionally, the ERP marker for VWM (the contralateral delay activity; CDA) was higher when the task contained regularity (Consistent-only group, Consistent-mixed condition) than during a random search (Random-only group, Random-mixed condition), presumably because search templates (i.e., context) were continuously held in VWM.

63.444 **Perceptual expectancy is revealed by pupillometry and correlates with autistic traits** Antonella Pome[1](antonella.pom@gmail.com), Paola Binda[2,3], Guido Marco Cicchini[3], David Charles Burr[1,3,4]; [1]Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence, Florence, Italy., [2]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, Pisa, Italy, [3]Institute of Neuroscience, National Research Council, Pisa, Italy., [4]School of Psychology, University of Sydney, Sydney, Australia

Priming refers to increased performance (usually measured by reaction times) on repetition of a perceptual feature. In Maljkovic and Nakayama's (1994) paradigm, three pseudo-diamond shapes are displayed each trial, two of one color and one of another, and participants identify rapidly the shape of the odd-colored (target) diamond. When target colors repeat, reaction times decrease, consistent with perceptual expectation for that target color. We replicated this study while monitoring pupil size, with 27 neurotypical participants for whom we had measured Autism-Spectrum Quotient (AQ). For participants with low AQ, pupil diameter increased more on trials where the target color swapped than when it repeated, consistent with a reaction to violated perceptual expectancy. The dependence of pupil dilation on previous

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trial color correlated strongly with AQ scores. This result is consistent with the suggestion that integration of prior information may be sub-optimal in individuals with high autistic traits (Pellicano and Burr, Trends Cogn Sci, 2012). However, neither the average pupil response nor the difference in reaction times were predicted by AQ. Overall the results show that pupil response can provide useful non-invasive measures of priming effects related to perceptual expectancy, and go on to show how this objective measure can vary with personality traits such as AQ.

Acknowledgement: ERC Grant Pupiltraits

63.445 **Collinear grouped items are more distracted for older adults: Behavior and neural imaging evidence on the collinear masking effect** Li Jingling[1](jlli@mail.cmu.edu.tw), Yi-Ping Chao[2], Shuo-Heng Li[3], Joshua O. S. Goh[4], Arthur C. Tsai[5], Su-Ling Yeh[3]; [1]Graduate Institute of Biomedical Sciences, China Medical University, [2] Graduate Institute of Electro-Optical Engineering, Chang Gung University, [3]Department of Psychology, National Taiwan University, [4]Graduate Institute of Brain and Mind Sciences, National Taiwan University, [5]Institute of Statistical Science, Academia Sinica

Aging is known to increase capture effect by salient distractors. Meanwhile, aging also declines the ability of perceptual grouping. Since well-grouped items can also capture attention, older adults may release from distraction if the distractor is well-grouped. This study evaluated this possibility by the collinear masking effect. The collinear masking effect refers to the condition that a collinear distractor can mask a local target in visual search. Thirty-two young adults and 26 normal older adults participated in this experiment. Results showed a larger collinear masking effect for older than young adults. BOLD signal revealed that young adults activated the left superior parietal area to suppress the collinear distractor, while older adults did not. Further, older adults additionally recruited frontal-parietal networks which implied that their attention was captured by the collinear distractor. The collinear masking effect also correlate to bilateral motor cortex and putamen activations in older adults, suggesting a heavy motor demands on older adults. Our data thus showed that older adults are more distracted by well-grouped distractors, which is due to more capture, less suppression, and more complex motor execution. Thus aging does not release older adults from distraction by well-grouped items.

Acknowledgement: MOST106-2420-H-039-002-MY3

63.446 **How do you know if you saw that? Electrophysiological correlates of searching through memory.** Trafton Drew[1](trafton.drew@psych.utah.edu), Lauren H. Williams[1], Jeremy M. Wolfe[2], Iris Wiegand[2, 3]; [1]University of Utah, [2]Brigham & Women's Hospital, [3]Max Planck UCL Centre for Computational Psychiatry and Ageing Research

People are remarkably adept at recognizing thousands of previously studied pictures or objects (Brady et al., 2008). Wolfe (2012) extended this finding to the visual search domain by asking subjects to search for any instance of up to 100 memorized objects presented in a visual search display ("Hybrid search"). By varying both the number of objects held in memory and in the visual search array, he found that increasing the number of objects in visual space led to linear increase in response time (RT), whereas increasing the number of items in memory led to a logarithmic increase in RT. Although we know a great deal about the electrophysiological correlates of visual search, we know much less about memory search. In the current study, we sought to identify the electrophysiological correlates of memory search in a modified hybrid search task. During the learning phase, subjects (n=32) memorized a set of 2, 4, 16, or 64 real world objects and completed a subsequent recognition test. Next, subjects searched for the items in a lateralized search display. In order to identify the ERP components specific to searching through memory, the visual set size was constrained to a single lateralized object with a lateralized distractor. ERP waveforms were time-locked to the onset of the two-item search array. To examine recognition memory, we subtracted Absent from Present trials. We found a large modulation of N400 amplitude and latency (measured using fractional area latency) as a function of memory set: Larger memory set sizes were associated with a significantly smaller, later N400 deflection. While much prior research has shown that the N400 is sensitive to recognition of previously observed stimuli (e.g., Kutas & Federmeier, 2011), the current work suggests it may also be acutely sensitive to searching through memory spaces of different sizes.

Acknowledgement: DOD: W911NF-07-2-0055 BSF: #2015301

63.447 **Local and global dynamics of fixation-related brain activity during visual search** Matias J Ison[1](Matias.Ison@nottingham.ac.uk), Juan E Kamienkowski[2,3], Alexander Varatharajah[4], Mariano Sigman[5]; [1]School of Psychology, University of Nottingham, UK, [2]Computer Science Institute, University of Buenos Aires, Argentina, [3]Physics Department, University of Buenos Aires, Argentina, [4]Department of Engineering, University of Leicester, UK, [5]Torcuato Di Tella University, Argentina

Effective visual search requires an orchestrated sequence of steps, sampling the environment, directing attention to one part of it, comparing what we see with what we are looking for and, if necessary, deciding where we should move our eyes next. Recent developments in our ability to co-register brain scalp potentials (EEG) during free eye movements has allowed investigating brain responses related to fixations (fixation-Related Potentials; fERPs), including the identification of sensory and cognitive local ERP components linked to individual fixations (e.g. Ossandon et al., 2010; Kamienkowski et al., 2012; Kaunitz et al., 2014). However, little is known about how local information across individual fixations is integrated globally to facilitate visual search. Given the links between low-frequency oscillations and integrative processes in fixed-gaze paradigms (e.g. Donner and Siegel, 2011; Bauer et al., 2014), we hypothesized that signatures of global integration of information along the task would be reflected in changes in low-frequency oscillations. Here, we performed an EEG and eye tracking co-registration experiment in which participants searched for a target face in natural images of crowds. We successfully obtained local fERPs, associated to the classical fixed-gaze ERP components (P1, N170/VPP, P3), and showed that changes in the frequency power indexed accumulation of evidence along the task, thus supporting our experimental hypothesis. Finally, we show how our findings lead to a data-driven integrative framework, including a role for occipital theta oscillations in visual attention and reduced alpha in expectancy, which can be a starting point to elucidate how complex mental processes are implemented in natural viewing.

63.448 **Ultrafast object detection in naturalistic vision relies on ultrafast distractor suppression** Clayton M Hickey[1,2](cmhickey@gmail.com), Daniele Pollicino[2], Giacomo Bertazzoli[2], Ludwig Barbaro[1,2]; [1]School of Psychology, University of Birmingham, [2]Center for Mind / Brain Sciences, University of Trento

People are quick to detect examples of real-world object categories in natural scenes, with evidence of target presence emerging in frontal event-related potentials (ERPs) as early as 150 ms after stimulus onset. This is far faster than predicted by classical attention theories, which suggest that naturalistic search should require the serial deployment of attention so that features characterizing objects can be bound together. Two proposals have been offered to solve this puzzle. One is that repeated experience might render the visual system sensitive to combinations of low-level features so that their combined presence can be detected without the need for spatial attention (eg. Evans & Treisman, 2006). This predicts that evidence of target detection might emerge in non-visual brain areas even before spatially-localized, attention-related mechanisms act on visual representations. The alternative is that naturalistic search relies on spatial mechanisms, but that global scene information constrains the search space and reduces the number of objects that need be resolved (eg. Wolfe et al., 2011). This predicts that spatially-localized object processing should be required for target detection, but that this may occur very quickly. Here we use ERPs to differentiate between these possibilities. In Experiment 1 we find that discrimination of a naturalistic target generates an early ERP effect associated with the suppression of salient distractors. In Experiment 2 we show that this early distractor positivity (Pd) is larger when participants must confirm that the scene does not contain a target. Critically, sensitivity to target presence in this spatial mechanism emerges 39 ms before evidence of target presence appears in frontal ERPs. Naturalistic search for heterogenous targets therefore appears to rely on spatial mechanisms, as predicted by classic attention theory, but these mechanisms act very quickly. This is consistent with the idea that global scene characteristics constrain the search space.

63.449 Flipped on its Head: Deep Learning-Based Saliency Finds Asymmetry in the Opposite Direction Expected for Singleton Search of Flipped and Canonical Targets
Calden Wloka[1,2](calden@cse.yorku.ca), John K Tsotsos[1,2]; [1]Electrical Engineering and Computer Science, Lassonde School of Engineering, York University, [2]Centre for Vision Research, York University

A search asymmetry occurs when it is faster for an observer to find some search target A amongst a set of distractors B than when searching for a target B amongst a set of A distractors. A number of search asymmetries are well-established in humans, but the phenomenon is less well studied by research into computational saliency models. Nevertheless, if these algorithsm are truly representing a component of early human visual attention, they should also be able to account for aspects of human attention beyond simply testing prediction performance on free-viewing fixation datasets (Bruce et al., 2015). Leveraging the recently developed Saliency Model Implementation Library for Experimental Research (SMILER), we devise a set of visual search arrays and test whether learned models of saliency exhibit an asymmetry of performance for targets with a novel flipped orientation over canonically oriented targets. Our findings show that the deep learning approach to computational saliency modelling which currently dominates the field consistently displays an asymmetric preference for canonically oriented stimuli. This asymmetry in performance runs counter to the behavioural performance patterns expected of human subjects, and suggests that the pattern-matching nature of deep learning is insufficient to fully account for human judgements of target salience.

Acknowledgement: The Canada Research Chairs Program, the Natural Sciences and Engineering Research Council of Canada, the Air Force Office of Scientific Research USA, the Office of Naval Research USA

63.450 Theory of Covert Search in Noise Backgrounds Correctly Predicts Asymmetrical Spatial Distributions of Misses and False Alarms
R Calen Walshe[1](calen.walshe@gmail.com), Wilson S. Geisler[2]; [1]Center for Perceptual Systems and Department of Psychology, The University of Texas at Austin

Searching the environment in a fast and efficient manner is a critical capability for humans and many other animals. Normally, multiple fixations are used to identify and localize targets. However, in the special case of covert search the target must be identified and localized within a single fixation. Here we present a theory of covert search that takes into account the statistical variation in background images, the falloff in resolution and sampling with retinal eccentricity, the increase in intrinsic location uncertainty with retinal eccentricity, and the prior probability of target presence and target location in the image. The computational steps of the theory are as follows.First, the effective prior probability distribution on target location is computed from the prior and the intrinsic location uncertainty. Second, the effective amplitude of the target (also dependent on retinal eccentricity) is computed and the target (if present) is added to the background. Third, template responses are computed at each image location by taking the dot product of a template (having the shape of target) with the image and then adding a random sample of internal noise. Fourth, the responses are correctly normalized by the sum of the internal noise variance and the estimated variance due to external factors (the background statistics).Fifth, the normalized responses are summed with the log of the effective prior on target location to obtain values proportional to the posterior probability.If the maximum of these values exceeds a criterion, the response is that the target is present at the location of the maximum. The theory predicts that i) misses occur more often than false alarms, ii) misses occur further in the periphery than false alarms, and iii) these asymmetries decrease with increasing target amplitude. Preliminary results show that the theoretical and human spatial distribution of errors are similar.

Acknowledgement: EY024662

63.451 Using Multidimensional Scaling to Quantify Category Heterogeneity Effects in Visual Search
Arryn S Robbins[1,2](arobbins@carthage.edu), Kory Scherer[1], Edin Sabic[2], Justin MacDonald[2], Ashley Ercolino[3], Joseph Schmidt[3], Michael C. Hout[2]; [1]Carthage College, [2]New Mexico State University, [3]University of Central Florida

Recent categorical search work demonstrated that searching for an exemplar among items of the same category is faster for heterogenous categories relative to homogeneous categories (Hout et al., 2017). However, precisely quantifying heterogeneity is difficult. Multidimensional Scaling (MDS) is a method used to model similarity (Hout et al, 2015), quantified as the distance between items in a hypothetical "psychological space." The more dissimilar two items are perceived to be, the larger the distance between them in space. We used MDS distances to quantify category heterogeneity. We selected stimuli from a large MDS image database (Hout et al., in prep) which provides similarity estimates for 1200 images across 20 distinct categories. To derive our measure of category heterogeneity from the database, we averaged the distances between each exemplar within each category (e.g., average distance between all cars). Therefore, categories with larger average distances could be described as more heterogeneous in appearance. We then correlated these values with performance in a visual search task in which participants searched for a single target item among non-targets from the same category. We expect RT's to decrease with increased heterogeneity because target-distractor similarity of any given search display should be lower given the within category nature of each display. Consistent with prior work, average RTs to target categories were negatively correlated with the average MDS distance. These results indicate that as average distance between exemplars within a category increases (i.e., category heterogeneity increases), search RTs for those exemplars decrease. We conclude that using MDS-derived similarity ratings to quantify category heterogeneity can be a useful and valid method to select stimuli for vision research.

63.452 Efficient search for unknown targets amongst known and unknown distractors
Alejandro Lleras[1](Alejandro.Lleras@gmail.com), Yujie Shao[1], Simona Buetti[1]; [1]Department of Psychology, LAS, University of Illinois at Urbana-Champaign

Previous work has shown that when observers are looking for a fixed target that is sufficiently different from the distractors, RTs increase logarithmically with set size. These results have been modeled in terms of a parallel evidence accumulation process where items in the display are compared to a target template in mind, and the time it takes to compute that comparison depends on the featural similarity between target and distractors. Here, we examine the role target and distractor uncertainty play in RT in efficient search, as a function of target-distractor similarity. In Experiment 1, we fixed the distractor color across the experiment while varying the target color on each trial. For each participant a random color in CIE space was defined as the distractor color. The target was randomly picked from one of three possible color angular distances away from the distractor (15-45; 45-75; 75-105). The results showed that RTs were within the efficient search range and increased logarithmically as a function of set size and with target-distractor similarity, for all three color separations. This suggests an equivalence between processing displays with a fixed target and with fixed distractors. In Experiment 2, both target and distractor colors were randomly selected on each trial (with the constraint that the current colors were at least 90 degrees different from the preceding trial colors). When target-distractor similarity is low, RTs decreased with set size, whereas they increased logarithmically when target-distractor similarity was relatively high. This is a qualitatively different pattern of results from Experiment 1 and highlights the importance of prior knowledge in efficient search. The results are discussed in the context of current models of visual search and computational models that propose RTs decrease with set size in oddball tasks because the target becomes more conspicuous as the number of distractors increases.

63.453 The effect of distractor statistics in visual search
Joshua M Calder-Travis[1, 2](j.calder.travis@gmail.com), Wei Ji Ma[1]; [1]New York University, [2]University of Oxford

Behaviour and mechanisms in visual search tasks – where observers must detect or identify a target amongst distractors – have been extensively studied. Animals frequently perform visual search (e.g. detecting camouflaged prey), however naturalistic stimuli are far more complex than the stimuli usually studied.Here we aim to characterise the behaviour of humans under the more realistic condition of heterogeneous distractor items. While heterogeneous distractors have been studied before, how distractor statistics affect behaviour has not been explored with stimuli that can be varied parametrically. We presented participants with arrays of Gabor patches. The target was a Gabor patch of a specific orientation, whilst the distractor orientations were independently drawn from one of two distributions, depending on the current 'environment.' In one of the environments, distractors were likely to be similar to the target (von Mises distributed around target), whilst in the other, distractors took a wider range of values (uniformly distributed). For each trial we computed the distractor sample mean, sample variance, and most similar distractor to the target. All three statistics were predictive of behaviour. The effect of sample variance depended on the environment. This dependence suggests that observers accounted for the statistics of the environment, however a Bayesian model provided a poor fit to the observed data. In contrast, a simpler heuristic model, which only uses the item most likely to be the target to make decisions, outperformed the Bayesian model

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(AIC difference 85; 95% CI [47, 140]). The interaction between distractor variance and environment may be a consequence of the fact that increasing variance can push distractor orientations both towards and away from the target orientation. In addition to providing novel parametric descriptions of human behaviour in heterogeneous visual search, these results also suggest ways in which human visual search algorithms may deviate from optimality.

Attention: Neural mechanisms 2

Wednesday, May 22, 8:30 am - 12:30 pm, Pavilion

63.454 **Awareness-dependent Distribution of Visual Bottom-up Attention** Lijuan Wang[1](2018022951@m.scnu.edu.cn), Xilin Zhang[1,2]; [1]School of Psychology, South China Normal University, Guangzhou, Guangdong, China, [2]Guangdong Provincial Key Laboratory of Mental Health and Cognitive Science, South China Normal University, Guangzhou, Guangdong, China

The stimulus-driven contribution to the allocation of attention is bottom-up attention. Although bottom-up selection is typically quick and potent, it remains unclear how bottom-up attention will be distributed when multiple salient stimuli are presented simultaneously and whether this distribution depends on awareness. Here we performed psychophysical and functional magnetic resonance imaging (fMRI) experiments to examine these issues. In our experiments, each texture stimulus had a regular Manhattan grid of 13 × 37 low luminance bars, presented in the lower visual field on a dark screen. All bars were identically oriented except for the foreground region of 2 × 2 bars with another orientation. There were four different foregrounds with 0°, 25°, 50°, and 90° orientation contrasts between the foreground bars and the background bars. In each texture stimulus, a pair of foregrounds was centered in the lower left and lower right quadrants at 5.83° eccentricity, one of which was 90° foreground. Thus, there were three possible texture stimuli: 90° + 0°, 90° + 25°, and 90° + 50° in our experiments. Low- and high-contrast masks, which had the same grid as the texture stimuli, rendered the whole stimulus visible (Experiment 1) and invisible (Experiment 2, confirmed by a forced-choice test) to subjects, respectively. In the psychophysical experiment, the Posner cueing paradigm was adopted to measure the spatial cueing effect of 90° foreground on an orientation discrimination task and thus the other foreground (i.e., 0°, 25°, and 50°) served as the distractor. We found that, when orientation contrast of the distractor increased, both the cueing effect and the fMRI BOLD signal in areas V1–V4 of 90° foreground fell off monotonically in Experiment 1 (the "Gradient" mechanism), but was constant in Experiment 2 (the "Winner-take-all" mechanism). These findings indicate an awareness-dependent distribution of visual bottom-up attention in human visual areas.

63.455 **Cue-evoked pupillary response reveals a left visual field bias in covert spatial visual attention** Sreenivasan Meyyappan[1](smeyyappan@ufl.edu), Abhijit Rajan[1], Harrison Walker[1], Yuelu Liu[2], George Mangun[2,3], Mingzhou Ding[1]; [1]Department of Biomedical Engineering,University of Florida,Gainesville, [2]Center for Mind and Brain, University of California, Davis, [3]Departments of Psychology and Neurology, University of California, Davis

The right hemisphere plays a dominant role in spatial cognition. Studies have shown that targets appearing in the left visual field are more effectively processed than targets appearing in the right visual field, an effect known as the left visual field bias. It is not known, however, whether such bias exists in covert visual spatial attention in which subjects direct their voluntary attention to either the left or right visual field in anticipation of target processing. We addressed this problem by measuring pupil dilation, a physiological index of effort, from subjects performing a cued visual spatial attention task where they covertly focused their attention to either the left or the right visual field based on an auditory cue. Following a random cue-to-target interval, two rectangular stimuli appeared, one in each visual field, and the subjects reported the orientation of the target in the attended visual field. The following results were found. First, reaction time was faster in the attend-left than attend-right conditions. Second, in response to the auditory cue, the pupils were significantly more dilated while covertly attending to the right visual field compared to the left visual field. Third, the difference in pupil dilation between attend-right and attend-left conditions was correlated with the difference in reaction time between the two conditions. These results (1) support the hypothesis that there is a left visual field bias in covert visual spatial attention (overcoming this bias is effortful and leads to increased pupil dilation) and (2) suggest that the left visual field bias in covert visual spatial attention and that in visual stimulus processing may share common neural substrate.

Acknowledgement: NSF grant BCS-1439188

63.456 **When Emotional Valence Matters: the Speed of Feature Binding in Object-based Attention** Mengsha Li[1](2018022939@m.scnu.edu.cn), Xilin Zhang[1,2]; [1]School of Psychology, South China Normal University, Guangzhou, Guangdong, China, [2]Guangdong Provincial Key Laboratory of Mental Health and Cognitive Science, South China Normal University, Guangzhou, Guangdong, China

Object-based theories of attention propose that the selection of an object's feature leads to bind all other constituent features, even those that are task irrelevant. However, whether this binding process depends on emotional valence remains unexplored. Here we used electroencephalography (EEG) to address this issue as human subjects` emotions were induced by negative, neutral, and positive stimuli on three sessions in a counterbalanced order. Subsequently, subjects performed an object-based attention task using stimuli consisting of a face transparently superimposed on a house, with one moving and the other stationary. They either attended to the motion direction or static position in a moving face with a static house (MFSH) and in a static face with a moving house (SFMH) conditions. We measured the amplitude and latency of the face-sensitive N170 event-related potential component during each condition. For all three emotional valences (i.e., negative, neutral, and positive), we found the classical object-based attention effect by showing significantly greater amplitudes of N170 in MFSH than SFMH when subjects attended to the motion direction, while an opposite pattern was found when subjects attended to the static position. No significant difference in this object-based attention effect was found among the three emotional valences (i.e., negative, neutral, and positive). However, we found that, compared to the neutral emotion, negative emotion increased and positive emotion reduced the latency of N170 in MFSH when subjects attended to the motion direction and in SFMH when subjects attended to the static position, but not vice versa. These results indicate a critical distinction between the perceptual correlates of negative and positive emotions, with negative emotion decreasing and positive emotion increasing the speed of feature binding in object-based attention.

63.457 **Neural representations of attention across saccades: More similar to shifting or to holding covert attention?** Xiaoli Zhang[1](zhang.4734@osu.edu), Julie D Golomb[1]; [1]Department of Psychology, The Ohio State University

We can focus our visual spatial attention by covertly attending to relevant locations, moving our eyes, or both simultaneously. How does shifting versus holding covert attention during fixation compare with maintaining covert attention across saccades? We acquired fMRI data during a combined saccade and covert attention task. Participants began each trial by fixating a cross while covertly attending to one of multiple peripheral rapid serial visual presentation (RSVP) streams. There were four critical conditions. On eyes-fixed trials, participants either held attention at the same initial location ("hold attention") or shifted attention to another stream midway through the trial ("shift attention"). On eyes-move trials, participants made a saccade midway through the trial, while maintaining attention in one of two reference frames: "retinotopic attention" and "spatiotopic attention". The retinotopic condition involved holding attention at a fixation-relative location but shifting to a different stream relative to the screen, whereas the spatiotopic condition involved holding attention on the same screen-centered location but shifting relative to the eyes. We localized the brain network sensitive to attention shifts (shift>hold attention), and used multivariate pattern time course (MVPTC) analyses to compare whether patterns of brain activity for spatiotopic and retinotopic conditions were more similar to shifting or to holding attention. In the attention shift network, we found transient information both about whether covert shifts were made and whether saccades were executed; additionally, both retinotopic and spatiotopic conditions were represented more similarly to shifting than to holding attention. In contrast, an exploratory searchlight analysis revealed some additional regions where retinotopic attention was relatively more similar to "hold" while spatiotopic more to "shift", and some other regions, vice versa. Thus, maintaining retinotopic and spatiotopic attention across saccades may involve different types of updating that might be represented with "hold" and "shift" signals combined across different sets of regions.

Acknowledgement: NIH R01-EY025648 (JG), Alfred P. Sloan (JG), H. Dean and Susan Regis Gibson Award 2016 (XZ)

63.458 **Role of superior longitudinal fasciculus in visual spatial attention** Xiangfei Hong[1,2](hongxiangfei@gmail.com), Liyun Zheng[1], Abhijit Rajan[1], Mingzhou Ding[1]; [1]J. Crayton Pruitt Family Department of Biomedical Engineering, University of Florida, Gainesville, FL, USA, [2]Shanghai Mental Health Center, Shanghai Jiao Tong University School of Medicine, Shanghai, China

Superior longitudinal fasciculus (SLF) is a major white matter tract connecting frontal and parietal cortices. Here we examined the role of SLF in the control of visual spatial attention. Diffusion MRI data were recorded from 19 subjects; from the same subjects, simultaneous EEG-fMRI data were also recorded while they performed a cued visual spatial attention task. In the task, each trial started with an auditory cue, directing subjects to attend to the left or right visual field. For validly cued trials, following a random cue-target interval (CTI), two rectangles were displayed, and the subjects were required to discriminate the orientation (vertical or horizontal) of the rectangle in the cued location. For invalidly cued trials, following a random CTI, one rectangle appeared in the uncued location, and the subjects were required to discriminate the orientation of the rectangle. The cue validity effect, which measures the behavioral benefits of deploying preparatory attention to the target location, was defined as invalid-cued RT minus valid-cued RT. The following results were found. First, SLF track-count showed a positive correlation with the cue validity effect. Second, SLF track-count was positively correlated with fMRI decoding accuracy (left versus right) within the dorsal attention network (DAN). Third, a statistical mediation analysis showed that SLF track-count was the mediator for the relationship between the neural representations in DAN and the cue validity effect. Fourth, subjects who showed larger alpha event-related desynchronization over the hemisphere contralateral to the attended location during the CTI were found to have larger SLF track-count. Taken together, these results suggest that SLF plays an important role in mediating the behavioral benefits of valid cuing in visual spatial attention, and it is doing so by enabling the neural representations of attended information in DAN and by facilitating the implementation of sensory biasing according to behavioral goals.

Acknowledgement: This work was supported by NIH Grant MH117991 and NSF Grant BCS-1439188. X. Hong was additionally supported by National Science Foundation of China (No. 61601294).

63.459 **Phasic alerting effects on visual processing speed are associated with intrinsic functional connectivity in the cingulo-opercular network** Marleen Haupt[1,2](marleen.haupt@psy.lmu.de), Adriana L. Ruiz Rizzo[1], Christian Sorg[3,4], Kathrin Finke[1,5]; [1]General and Experimental Psychology, Department of Psychology, Ludwig-Maximilians-Universität München, Munich, Germany, [2]Graduate School of Systemic Neurosciences (GSN), Ludwig-Maximilians-Universität München, Munich, Germany, [3]Department of Neuroradiology, Klinikum rechts der Isar, Technische Universität München, Munich, Germany, [4]Department of Psychiatry and Psychotherapy, Klinikum rechts der Isar, Technische Universität München, Munich, Germany, [5]Hans-Berger Department of Neurology, University Hospital Jena, Jena, Germany

External warning cues without any spatial or feature-based information lead to short-lived changes in preparatory states defined as phasic alertness. Parametric modelling of whole report task performance based on the computational theory of visual attention (TVA) has demonstrated higher visual processing speed in cue compared to no-cue conditions. Regarding the underlying neural mechanisms, individual visual processing speed has been related to intrinsic functional connectivity (iFC) within the cingulo-opercular network. The present study set out to investigate whether iFC in the cingulo-opercular network is also related to the individual ability to actively profit from warning cues, i.e. to the degree of phasic alerting. 32 healthy young participants took part in a resting-state functional magnetic resonance imaging (rs-fMRI) session and an offline administered TVA-based whole report paradigm session. We analyzed the imaging data by combining an independent component analysis of rs-fMRI time courses and dual regression approach in order to determine iFC in the cingulo-opercular network. A subsequent voxel-wise multiple regression revealed that higher individual phasic alerting effects on visual processing speed were significantly associated with lower iFC in the cingulo-opercular network, with a peak in the left superior orbital gyrus. Phasic alertness was neither related to intra-network connectivity of other attention-relevant, auditory, or visual networks nor associated with any inter-network connectivity patterns. Taken together, the results suggest that cue-induced alerting benefits on visual processing speed are selectively associated with iFC in the cingulo-opercular network.

63.460 **Functional Differentiation of Visual Attention Processing Within Human Cerebellum** Ryan D Marshall[1](ryanmars@bu.edu), James A Brissenden[1], Kathryn J Devaney[2], Abigail L Noyce[1], Maya L Rosen[3], David C Somers[1]; [1]Boston University, [2]Stanford University, [3]University of Washington

Portions of human cerebellum are recruited during visual attention and visual working memory tasks (Allen et al., 1997; Stoodley et al., 2012; Brissenden et al., 2016). Moreover, the existence of two cortico-cerebellar subnetworks that support different aspects of visuospatial cognition has recently been reported (Brissenden et al., 2018). Here, we examine cerebellar recruitment across multiple visual attentional tasks. fMRI data were collected at 3 Tesla while subjects participated in visual attention and/or working memory tasks. Task contrasts examined visual working memory load in a change detection task, oddball processing, 2-back working memory, multiple object tracking, and long-term memory guided attention. Collectively, the tasks activated: a lateral region spanning the Lobule VI/Crus I border, A medial region spanning Lobule VI, Crus I/II and Lobule VIIb, a mid-lateral region spanning lobules VIIb/VIIIa, and a mid-lateral region spanning lobules VIIIb/IX. These regions exhibit strong resting state functional connectivity with portions of the cortical Dorsal Attention Network and Cognitive Control Network. Additionally, each of the 5 tasks exhibited distinct patterns of cerebellar activation. Notable differences include a medial portion of lobule VIIIa with strong connectivity to the cortical dorsal attention network that was robustly recruited during high-load visual working memory but not during during 2-back VWM. Long-term memory guided attention selectively recruited the lateral Lobule VI/Crus I region, while oddball stimuli selectively drove medial Lobule VI and Crus I/II. These studies serve to distinguish specialized recruitment of cerebellar regions in support of different aspects of visual cognition.

Acknowledgement: NIH R01EY022229, NIH R21EY027703

63.461 **Individual retinotopic organization in human intraparietal sulcus predicted by connectivity fingerprinting** James A Brissenden[1](brissend@bu.edu), Sean M Tobyne[2], Ray W Lefco[2], David C Somers[1]; [1]Psychological and Brain Sciences, Boston University, [2]Graduate Program for Neuroscience, Boston University

Human intraparietal sulcus (IPS) has been shown to be retinotopically organized (Swisher et al., 2007). However, the reliable identification of IPS visual field maps in individual subjects requires the collection of a substantial amount of data. Connectivity fingerprint models have proven to be a successful method for predicting area-level organization from structural and resting-state connectivity measures (Saygin et al. 2011; Osher et al., 2015; Tavor et al., 2016; Tobyne et al., 2018). However, these methods have not yet been successfully applied to predict finer scale functional organization, such as that revealed by retinotopic mapping procedures. Here, we applied a connectivity fingerprint model to the Human Connectome Project 7T dataset (N = 181) to characterize individual intra-areal IPS retinotopic organization. A Bayesian regression model was trained to predict vertex-wise IPS polar angle preferences from patterns of resting-state functional connectivity. Model performance was evaluated using a split-half cross-validation scheme. Model predictions were found to accurately reflect IPS polar angle organization in individual subjects. Predicted polar angle maps further allowed for the delineation of boundaries between adjacent intraparietal retinotopic regions, IPS0-3. This work presents a method for potentially examining the retinotopic organization in individuals for which the collection of sufficient retinotopic mapping data is difficult. These findings also extend connectivity fingerprinting methods to predict fine-scale gradients in functional organization within a cortical area.

Acknowledgement: R21 EY027703-01A1 NSF GRFP DGE-1247312

63.462 **Stimulus presentation type effects in retinotopic parietal cortex** Summer Sheremata[1,2](ssheremata@fau.edu); [1]Department of Psychology, Florida Atlantic University, [2]Center for Complex Systems and Brain Sciences, Florida Atlantic University

While the parietal cortex plays an integral role in visual attention and short-term memory, the mechanisms underlying these cognitive functions are elusive.Retinotopic mapping studies have demonstrated a mapping structure of parietal cortex using attended stimuli that traverse the visual field by moving through continguous spatial locations. While phase-encoded mapping methods depend upon this stimulus pattern, newer methods such as population receptive field mapping (pRF) allow for presentation of stimuli in randomized locations. In contrast to parietal cortex, occipital cortical maps have been found using non-contiguous mapping stimuli have been used to demonstrate maps in occipital cortex questioning whether contiguous stimuli offer attentional cues that facilitate retinotopic mapping in the parietal cortex. In order to test this assumption, contiguous and non-contiguous stimuli were used to assess pRFs in the parietal cortex. Participants maintained fixation while a checkerboard bar traversed the visual field and monitored for a dimming of the mapping stimulus. To determine whether discontiguous stimuli elicit retinotopic structure, the preferred location and visual field extent were compared across the two stimulus conditions. Then each condition was split into two sets of runs and the test-retest reliability of each measure was compared. The results suggest only a modest relationship between contiguous and discontiguous stimulus presentations. Furthermore, test-rest reliability was higher for the contiguous stimulus presentation condition. Together these results suggest that contiguous stimuli are most effective for demonstrating map structure in parietal cortex. However, pRF size was larger in the contiguous stimulus presentation condition, supporting claims that visual field maps are susceptible to stimulus motion direction for continuous stimuli. These results demonstrate a benefit for contiguous stimuli for retinotopic mapping in parietal cortex and suggest that retinotopic mapping can yield insights into the cognitive mechanisms underlying acitivity in parietal cortex.

63.463 **Using Frequency Tagging to Understand the Impact of Bilingualism on Visual Attention** Ethan Kutlu[1](ethankutlu@outlook.com)**,** Ryan Barry-Anwar[1]**,** Lisa S. Scott[1]; [1]Department of Psychology, University of Florida

Although bilingualism has been associated with cognitive control advantages, we know little about how bilingualism impacts visual attention. Here the ability to simultaneously attend to two different visual stimuli was examined before and after a novel object label learning task in bilingual (n=17) and monolingual (n=16) adults.Before and after learning, participants completed a frequency tagging task while steady state visual evoked potentials (ssVEPs) were recorded (Figure 1). ssVEPs were measured as an index of attention in response to two overlapping visual stimuli (faces and novel objects) presented at a rate of 5Hz and 6Hz, respectively. Label training included one set of novel objects labeled with individual level names (e.g., "Boris") and the other set labeled with a single category name (e.g., "Hitchel"). The signal to noise ratio (SNR) at each frequency (i.e., 5Hz or 6Hz) was analyzed across posterior cortical regions. Although there were no differential neural responses between monolinguals and bilinguals for objects, for faces there was an interaction between pre- and post-test, label type, and bilingualism, $F(1, 31)=5.84$, $p = .02$, such that monolinguals showed a significantly reduced SNR in response to faces at post-test than at pre-test when viewed concurrently with objects trained at the individual level, $p = .004$. These differences were not present when monolinguals viewed faces with objects trained at the category level, and no effects were seen for bilinguals (Figure 2). Relative to bilinguals, monolinguals showed a reduced SNR in response to faces at post-test when presented with objects trained at the individual level, $p = .02$. These results suggest that individual level label learning may result in differential visual attention to faces when objects are presented simultaneously. Additionally, monolingual and bilingual individuals differentially distribute attention to faces viewed in the presence of objects learned at the individual level.

63.464 **Measuring the fidelity and connectivity of stimulus representations provides a richer neural characterization of attentional fluctuations** David Rothlein[1](david.rothlein@gmail.com)**,** Joseph DeGutis[1,2]**,** Michael Esterman[1,3]; [1]VA Boston Healthcare System, [2]Harvard Medical School, [3]Boston University School of Medicine

Sustaining visual attention requires numerous dynamic cognitive processes acting in concert. Consequently, a diverse set of factors underlie fluctuations in performance during a sustained attention task and identifying a specific cognitive cause from fMRI-based measures like mean activation or functional connectivity (FC) is rife with ambiguity. In the present study, we provide richer characterization of how large-scale neural networks relate to attentional fluctuations by considering novel information-rich measures that use Representational Similarity Analysis to quantify the fidelity and connectivity of stimulus-specific representations across a set of brain regions. Participants (N=145) performed the gradual onset Continuous Performance Task (gradCPT) during an fMRI scan. This entailed viewing a series of city or mountain scenes, responding to cities (90% of trials) and withholding responses to mountains (10%). Representational similarity matrices (RSMs), reflecting the similarity structure of the set of city exemplars (n=10) were used to quantify the representational fidelity (RF) and connectivity (RC) of the stimulus representations by computing the inter-participant reliability of RSMs within (RF) and across (RC) each brain network. Critically, we computed how changes in behavioral measures of attentional state related to changes in univariate activation, FC, RF, and RC. Examining the visual network, we found that better performance was associated with greater mean activation, greater RF, greater RC with the Dorsal Attention Network (DAN) but lower FC with the Default Mode Network (DMN; all $p < 0.05$). These results provide direct support for the notion that visual-DAN connectivity reflects the communication of stimulus-specific information while visual-DMN connectivity reflects distracting stimulus-unrelated information. Across various brain networks and measures of task performance, we demonstrated that considering multiple dynamic measures of neural processing--particularly representational similarity-based measures--can greatly enrich conclusions regarding the neural and cognitive processes that underlie attentional fluctuations.

Acknowledgement: This work was supported by the U.S. Department of Veteran Affairs through a Clinical Science Research and Development Career Development Award (Grant Number 1IK2CX000706- 01A2) to M. E.

URL: Confirm Conflict Disclosure Policy

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