Rhythms of the Brain, Body, and Environment

A Neuroscientific Perspective on Atmospheres

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INTERFACES 4

Designing Atmospheres: Theory and Science

Zakaria Djebbara

Rhythms of the Brain, Body, and Environment: A Neuroscientific Perspective on Atmospheres

Abstract
Atmospheres enjoy ambiguity beyond the constraints of words. While the theory of atmosphere is well-established, its scientific testing remains challenging due to this ambiguity. Focusing on the effect of atmospheres, I discuss nonconscious processes and rhythms in the body and brain concerning behavior and atmosphere, arguing that the body's active engagement with the environment is crucial in our experience. Our sensory suppression of the atmosphere is actively used to adapt our behavior, making it a phenomenologically rich process. I conclude by providing a neuroscientific hypothesis on the mechanisms behind the enacted atmosphere and its impact on human cognition.

Keywords
neuroarchitecture
neuroscience of atmospheres
suppression dynamics
transthalamic pathways
rhythms

1 I will use the concept "atmosphere" in the architectural phenomenological context throughout the essay, that is, the *character of a space*.

Introduction

The following essay is a mélange between my lecture at Kansas State University, APDesign College, in March 2023, and the discussions the following few days. "Designing Atmospheres" was the symposium name, followed by the subtitle "Theory and Science." Note that the theory and science of atmosphere [1] are largely unbalanced, in favor of the theory (Böhme 2017; Griffero 2019; Canepa 2022). One reason for this imbalance may be due to the lack of consensus what the atmosphere *is* (Canepa 2022, chapter I) making it difficult to put through scientific testing. The problem arises from the practical exercise in the delineation of what it is, naturally affirming what it is not. It enjoys ambiguity, vagueness, and intangibility: it is *ineffable*. Yet, when theorists attempt to put it into words, a general perspective emerges. It alludes to multisensory and emotional engagement, encompassing the overall character, mood, and feeling created through architectural features, such as light, texture, sound, thermal qualities, and spatial configurations. These are arguably features that are present in everyday life, implying the existence of an everyday atmosphere. As long as we sense the world, there must be a perceived atmosphere — if not in the foreground, then surely in the background, continuously affecting us in ways that remain ineffable till we lay out the mechanisms for its impact. My approach in this essay will be scientific. Instead of focusing on the experience of atmospheres, I focus on the *effect*. This, I believe, will give us a way to design atmospheres.

The following neuroscientific perspective attempts to write to non-experts about the neuroscience and psychology behind nonconscious processes and rhythms in the body and brain. This essay is heavily guided by my personal research. I attempt to provide the first step in overcoming the quantification of atmospheres by twisting the question about space and form into *time* and *experience*. In other words, instead of taking

2 A similar argument has been puth forth by Jelić and colleagues (2016).

the atmosphere to exist in the form and space, I consider it to be an enacted and lived experience [2] that puts a greater focus on our biological rhythmic nature, paving the way for our adaptive skills in the domain of nonconscious processes. To help elucidate my way of thinking about this, consider the distinction between the external world and internal processes. Where does the experience of the atmosphere emerge? I argue that the emergence is contingent on both external features and internal processes in a bidirectional fashion with the body taking up a central role (Varela, Thompson, and Rosch 2016). The role of the body is to engage with the environment integrating sensory and motor information into a single coherent and contingent temporal alignment (O'Regan and Noë 2001). This essentially gives the active engagement with the environment a constitutive role in our experience — this is where I think neuroscience and architecture may begin having a conversation informing one another (see also Arbib 2021).

The essay is structured in the following way. I first provide examples of rhythmic nonconscious impact via sensorimotor dynamics, demonstrating how architectural features, as picked up by the visual periphery, can affect human behavior. Then, I turn towards the body's rhythmic and active nature in adjusting and adapting to the environment. Our nonconscious adaptive skills, I suggest, play a crucial role in our immediate understanding of space, that is, the gist of scene perception (Oliva and Torralba 2006; Djebbara et al. 2019), as the atmosphere is typically picked up by our peripheral senses. An important premise I draw on is that atmospheres play the role of the background of our lives, which we naturally suppress during our everyday interactions. However, I argue that suppression is not lost on us — instead, it is actively used to adapt our behavior, making the suppression dynamics inherently important to atmospheres. I elaborate on this premise before I provide a neuroscientific hypothesis on the underlying mechanisms of the enacted atmosphere and its impact on human cognition.

Nonconscious Adaptive Skills

Although Timothy Wilson (2004) provides an in-depth discussion on the usage of "unconscious" over "nonconscious," I prefer sticking to the latter as it holds the least psychoanalytical baggage, fits better with current literature of cognitive neuroscience, and essentially better frames my points. Similar to atmospheres, "the unconscious is notoriously difficult to define" (Wilson 2004, 23). Yet, Wilson provides a useful working definition, namely that the *adaptive [unconscious] nonconscious*: "mental processes that are inaccessible to consciousness but that influence judgments, feelings, or behavior" (2004, 23). We can disambiguate and interpret our environments to initiate a behavior effortlessly and nonconsciously, which is an immense biological advantage ensuring survival. Without these skills, the interaction with the world would be overwhelming and unbearable. However, the adaptive nonconscious processes are not always accurate and are limited to our attentional resources, the available sensed information in the environment, and prior experiences.

An example of where our adaptive skills fail us is in the experiments of Simons and Levin (1998). Their research question was on the topic of change detection and they wanted to know if failing to detect changes is based on the passive nature of mediated stimuli or an active one. To test this, they equipped two researchers, closely resembling one another, with a map of campus and had them ask unsuspecting pedestrians about a specific building, that is, a navigation task. After about ten to fifteen seconds of conversation between experimenter A and the pedestrian, two other experimenters carrying a door rudely walked between the pedestrian and experimenter A. Experimenter B who was carrying a portion of the door stayed behind, swiftly changed position with experimenter A, and continued asking for directions as the door passed. However, despite obvious differences in voice, appearance, and clothing, only 7 out of the 15 pedestrians claimed to have noticed the experimenters' change. A possible explanation is the limited attentional resources during the interaction due to the navigational task, where the role of attention is to actively suppress noisy information making the important pieces of information stand out (Carrasco 2011). Keep in mind, the sensory system is constantly active, sampling information about the environment as well as internal organs. This is a necessary biological step to maintain a *homeostatic balance* — a concept we shall return to.

Unfortunately for architects, for everyday interaction of non-architects, it is the architecture that is the noise that is being suppressed in favor of another objective or task. Walking home from the office entails a plethora of architectural interaction, yet, our conscious thoughts are occupied by social plans, what to make for dinner, or the football game tonight. The interaction is left to the nonconscious adaptive skills, which effortlessly move the body through the structure of the city, circumventing other moving bodies. As architects, this may be unfortunate news, as the hours spent designing cities and homes appear to go unnoticed. The truth is that suppression dynamics play an important role in our attentional resources as well as our awareness (Djebbara, Fich, and Vecchiato 2022). Furthermore, as we have different bodies and brains, interactions are not easily generalizable, which typically means losing some groups of

society in the swing of the pen during the design process (Tvedebrink et al. 2022). Suppression dynamics, which appear to be left with the nonconscious processes, are paradoxically phenomenologically rich. Despite the lack of conscious experience, which is the hallmark of phenomenology (Gallagher and Zahavi 2012), the suppressed nonconscious noise is constantly affecting us beyond our awareness. One might think of this as the *hidden power of architecture*.

In the visual modality, the suppressed noise can be thought of as the peripheral (visual) [3] information that currently holds little-to-no value relative to an ongoing task. This has famously been demonstrated in experiments of selective attention, which is the act of paying attention to a specific element of the environment for some amount of time. Due to the limited amount of attention we have, *selective attention* enables us to tune out irrelevant information and concentrate on what matters (see, for instance, the Monkey Business Illusion: Simons and Chabris 1999). The argument I make here is that the information is not entirely lost. It simply does not rise to conscious awareness, but it remains phenomenologically rich to the nonconscious adaptive skills. For instance, demonstrating how changing the optic flow [4] affects the walking speed in human locomotion, Ludwig et al. (2018) highlight the significance of the flow of sensory information. Ludwig and colleagues instructed their participants to walk down a corridor on which they had projected stripes at varying distances that were orthogonal to the direction of travel. Their participants were required to complete a perceptual discrimination task involving the orientation of a bar projected to the back wall while moving along the walkway. They consistently discovered a decrease in walking speed as the distance between projected lines grew closer together. In other words, when the rate of change in the periph-

3 I put "visual" in paranthesis here because the suppression of noise is in fact of all peripheral sensations relative to an going task. For instance, while reading this, you do not experience the clothes on your body or the floor under your feet. These are peripheral sensations relative to your ongoing task, which currently is to read.

4 *Optic flow* is a concept developed in ecological psychology by James J. Gibson (1986) describing the pattern of visual motion that is perceived by an observer as they move through an environment. It is how visual information changes on the retina as we move through the world. The flow provides crucial information about our own movement, the movement of objects in the environment, and the shape and layout of the environment itself.

eral vision had a high frequency, the optical flow suggests that we are moving very fast and the natural adjustment is to slow down our walking speed.

That animals use the same method to control their behavior suggests that this may be a fundamental strategy in nature. For instance, budgerigars were made to fly through a tunnel with either horizontal or vertical lines painted on either the left or right wall in a superb study by Bhagavatula and colleagues (2011). By combining the line directions with the walls, they were able to show that changing the direction of the line not only caused budgerigars' flight velocities to significantly change but also changed their trajectory so that they flew closer to the vertical lines. They were, however, significantly faster when horizontal lines were painted on both sides. It is interesting to note that the horizontal and vertical lines altered the permitted behavioral outcomes in different ways because they enact different responses. Hummingbirds, honeybees, and bumblebees have all been observed using visual control strategically (Srinivasan et al. 1996; Baird et al. 2005; Dakin, Fellows, and Altshuler 2016). A summary of these studies and others has been dealt with elsewhere (Djebbara et al. 2022).

These cases support the contention that everyday interaction with architecture affects us through phenomenologically rich (yet, nonconscious) peripheral dynamics that go unnoticed but manifest in our bodies and behavior. The underlying dynamics that enable such adaptive behavior are referred to as *sensorimotor dynamics*. It is the study of how sensory information, such as tactile or visual feedback, affects motor actions, which, in turn, affects the sensory input. In the study of perception and action, particularly in the context of comprehending how organisms interact with their environment, the idea of sensorimotor dynamics is frequently used (Vecchiato, Jelić, et al. 2015; Vecchiato, Tieri, et al. 2015; Djebbara et al. 2019; Djebbara, Fich, and Gramann 2021). Importantly, the coupling between the brain's sensory and motor regions, that is, sensorimotor dynamics, can reveal how the brain integrates sensory and motor information to produce nonconscious adaptive behaviors.

As demonstrated, our adaptive skills require no conscious effort — it just happens in the background of our lives. I think of everyday atmospheres in the same way. It is the backdrop of our lives, setting the contextual constraints through nonconscious sensorimotor adaptation. It systematically suppresses irrelevant signals, freeing up attentional resources that can be used for mind-wandering and contemplation. While the suppression dynamics, that is, the pattern of suppression, is an important question, the brain is only beginning to appear important. There is, however, a premise as to why the brain attempts to suppress and adjust to the environment in the first place.

Homeostasis and Process Philosophy

Biology teaches us at least two important lessons:

> the organism is the physical consequence of *adaptive changes* as a response to environmental changes;
>
> everything oscillates or displays some *resonant* or *rhythmic behavior*.

These two lessons are crucial to understanding the role of the brain in architecture. During the rebuilding of the United Kingdom's Commons

Chamber post the Second World War, Winston Churchill famously stated "first we shape the buildings, then buildings shape us." He preferred to keep the adversarial rectangular pattern rather than switching to the semi-circular or horseshoe shape that some legislative assemblies prefer. Despite the truth to this statement, Churchill got it all backward. Biology teaches us that the environment shaped us first, then we got control of it, allowing us to engage in a process of self-shaping through the built environment. Before this privilege, the environment shaped us through constantly changing processes. This interaction between a cell and its surroundings, through various processes, is what ensured the cell's survival. Inside the cell, chemicals are constantly being released by biochemical processes to balance the environment's ongoing fluctuations. The *homeostatic balance* is a fundamental process in all living cells that aims to maintain the physiological processes of the organism within a constrained acceptable range (Damasio 2010). For example, if the environment is perceived as being too cold, the organism must account for the error (cold) by moving to a warmer location or by producing heat through shaking and regaining a sustainable balance. These adjustments need to be accounted for immediately as once the damage is done, it may be too late (Sterling 2012). Timing thus naturally plays an imperative role in avoiding death and eventually extinction.

Temporal concepts, such as dynamics and change, are important aspects of our biology. Nicholson and Dupré rightfully attempt to put time back into biology (Dupré 2014; Nicholson and Dupré 2018). They see biology as the study of dynamic processes that take place over time rather than mere static structures or systems. According to their argument, conventional biological theories have the propensity to emphasize reductionist and mechanistic interpretations of living things, which has hindered our comprehension of the complexity and diversity of biological phenomena. Instead, we should turn to a *processual philosophy of biology*, which acknowledges the significance of context, history, and contingency in influencing the evolution of life while embracing the complexity and diversity of biological processes. That is, we should not focus on the state of things, but on their *dynamics* and *development*, which is an inherent property of homeostasis. [5]

Sensing the world is an active process that unfolds in an oscillatory fashion (Buzsáki 2004; Leszczynski and Schroeder 2019). Instead of passively viewing the center and processing the relatively coarse peripheral information, when viewing a scene, we use saccades to move our fovea to various parts of the scene to create a fuller grip of the environment. This process depends on sensory and motor neurons, cooperating through functional synchrony and rhythmic activity. Note here the emphasis on *process* rather than *substance*. Stimuli, as referred to in cognitive neuroscience, are not individual discrete sensory packages of information independent of time. According to ecological psychology, stimuli are arrays of energy overlapping with responses eventually occluding one another. [6] This means that, at any given time, no stimulus can be thought of in isolation because it is always connected to both its previous and incoming stimulus and response (Gibson 1977; Spivey 2008). They co-exist due to co-conditional sensory and motor dynamics. Following this continuous process-oriented (as opposed to discrete substance-oriented) theory of cognition, the act of adaptation can be thought of as the synchronization or temporal alignment of neural rhythmic behavior (Singer 1999).

Adaptation emerges from our embodied and active engagement with the world ensuring a coherent fit between an organism and its environ-

5 Homeostasis also has a predictive version referred to as *allostasis* (Sterling 2012). This view suggests that the changes need to be done before they damage occurs, otherwise, it is simply too late. Allostasis is different in the sense that it attempt to predict outcomes before they occur.

6 We could ask ourselves: what came first, the perception or the action? This is an age-old debate famously discussed by the psychologist William James on the topic of actions and emotions (see, for example, James-Lange theory).

ment. This particular view is referred to as *enactivism* (Thompson 2007; Varela, Thompson, and Rosch 2016). It is an approach to cognition and behavior that emphasizes an organism's sensorimotor capacities and body, essentially viewing cognition and behavior as ongoing, dynamic processes that are tightly intertwined with our bodily experiences and our interactions with the environment. Any moment is thus an adaptative process from the prior moment toward the future moment, making enactivism a future-oriented take on human nature.

Our future actions can be thought of as the function of perception. Or better yet, perception serves as *embodied predictions* (Clark 2015; Friston et al. 2017). Enter *affordances* (Gibson 1986). Affordances are a fundamental idea in enactivism. They refer to the possibilities for intervention and action that the physical world offers and are determined by the "fit" between an organism's physical structure, capacities, and the action-related properties in the environment (Clark 1999). Enactivists contend that these affordances are jointly constructed by the organism and its environment rather than being inherent properties of the environment. This means that an organism's sensorimotor capabilities, prior experiences, and context all influence how it perceives affordances — but how about atmospheres? What does atmosphere have to do with our nonconscious adaptive skills, our enacted being, and now affordances?

So far, I have suggested thinking of the atmosphere as the backdrop to our everyday life, constantly affecting us. Instead of considering what it is like to experience an atmosphere, I suggest approaching it through its effects, which makes it tractable. The evidence presented suggests that we couple with the environment nonconsciously expressed through

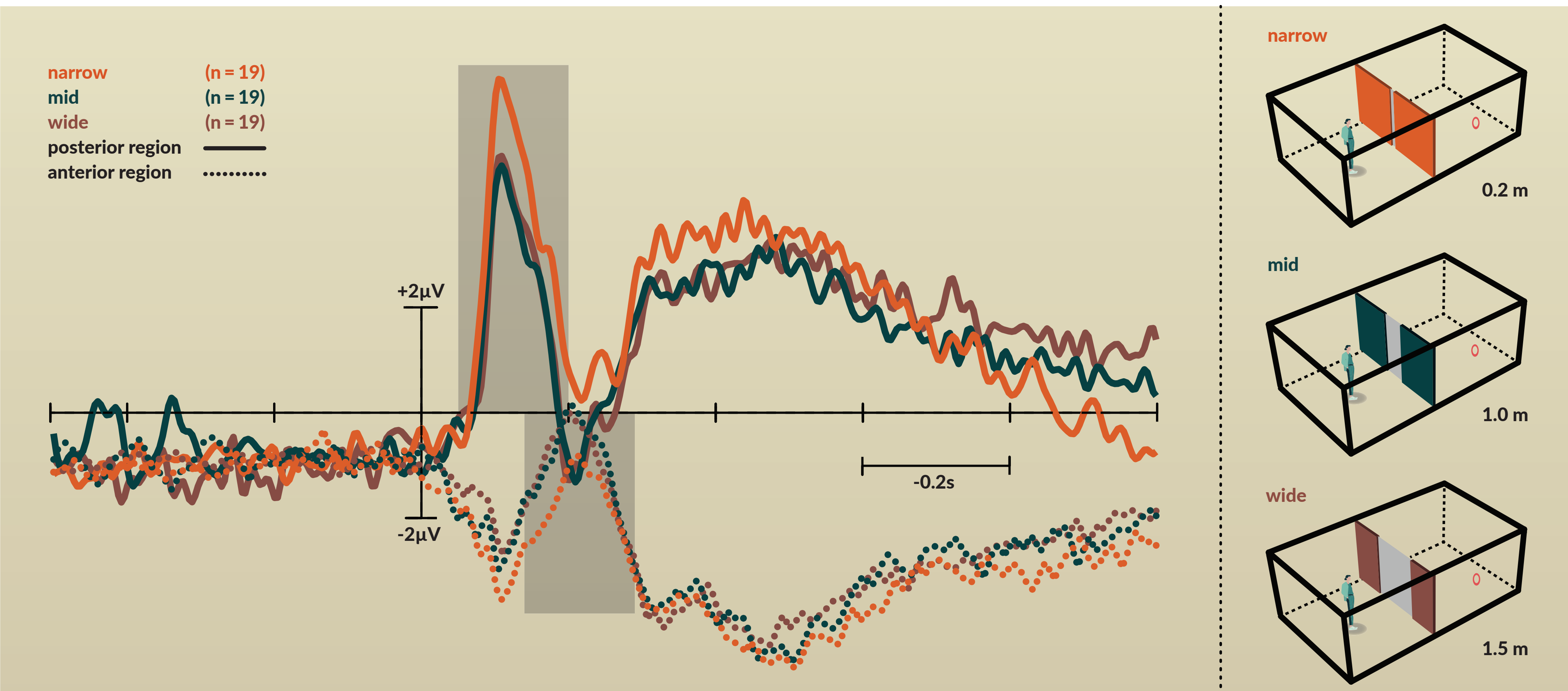
our adaptive behavior. More specifically, it is suggested that peripheral information, though unnoticed, is phenomenologically rich, in the sense that the sensorimotor dynamics we suppress are informative in a nonconscious way. And now, we have established that affordances shape these dynamics — at least, that is the hypothesis.

Sensorimotor Brain Dynamics and the Built Environment

The hypothesis can be stated more precisely: we should be able to measure systematic changes, covarying as a function of the perceived affordances over the sensorimotor brain region. This was precisely what we did in two studies in Berlin, Germany. The first study attempted to understand the temporal relationship between *perceptual processes*, e.g. visual cortex, and *motor-related processes*, e.g. motor cortex, by asking participants to pass through a door into another space (Djebbara et al. 2019). Equipped with virtual reality (VR), a mobile electroencephalogram (EEG), and 120 m^2 of laboratory space, we had the kind of control necessary for such an experiment. Participants' task was as simple as waiting till the door turned either green or red, signaling whether to pass or not to pass, respectively. Should the door turn green, their task was to pass into the second space and look for a floating red ring, which would elicit a monetary reward upon touch. By manipulating the affordances of an everyday object, like the door, we wanted to understand how the perceptual and motor-related processes were affected by changing affordances, that is, a 1.5-meter wide passable door, a 1.0-meter wide passable door, and a 0.2-meter narrow impassable door.

We found that perceptual processes related to passable doors occur in very similar ways, however, the impassable door was processed signifi-

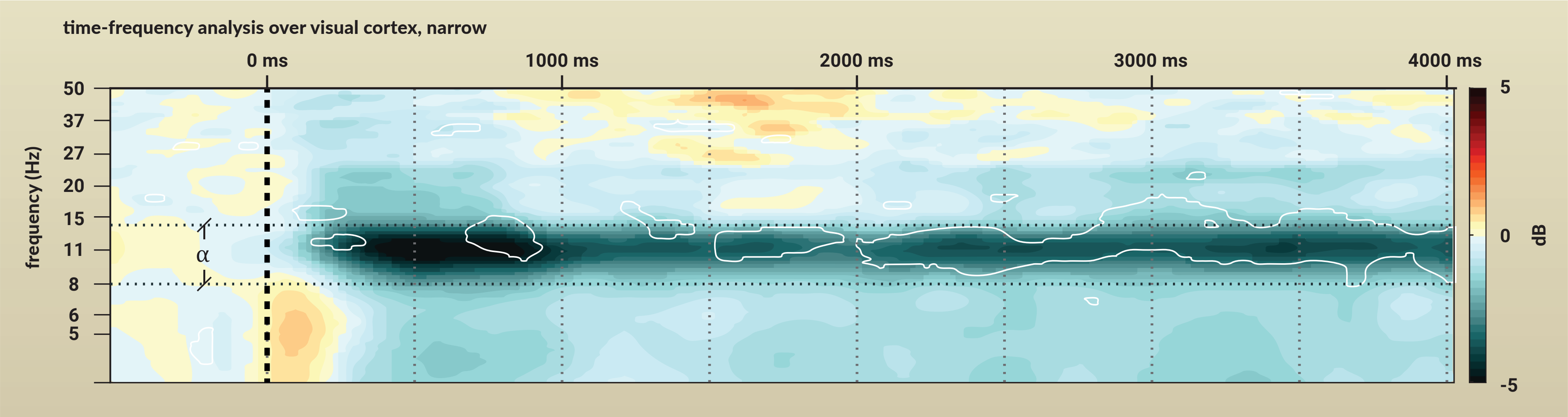
F1 The right-hand diagrams depict participants in three rooms, each with a door varying in width that either allows or forbids them from moving into the next room and offers a variety of affordances. The left side of the figure displays the event-related potentials measured over the visual and motor cortices. These are scalp-recorded voltage fluctuations that are time-locked to an event and reflect stages of information processing in the brain. They reflect the summed activity of postsynaptic potentials generated when many synchronized firings of cortical pyramidal neurons with similar orientations occur when processing information (Luck 2005).



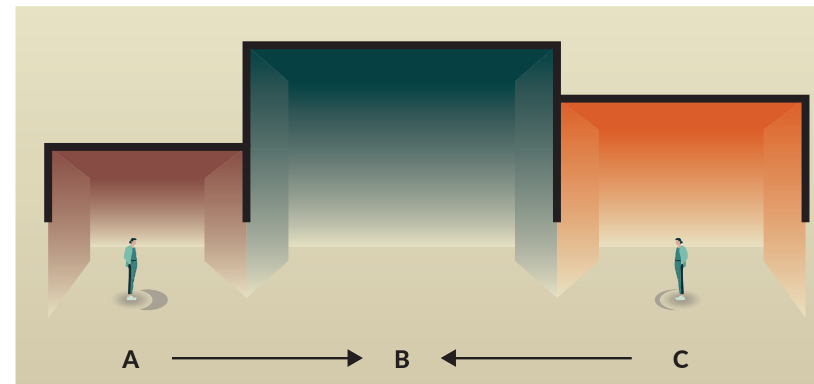
F2 Event-related spectral perturbation (ERSP) over the visual cortex for the narrow condition. The brain operates in distinct frequencies. Approaching a door that does not afford passing is expressed as significantly stronger alpha (8–12 Hz) suppression. For full details see Djebbara, Fich, and Gramann 2021.

cantly differently from the other conditions. This was also discovered to be the case over the motor cortex. Interestingly, we found that the processes related to sensorimotor dynamics are coordinated, meaning that the question "how can I act?" is tightly linked with "what do I perceive?" emphasizing the *action-perception cycle* relevant to architecture [**F1**]. These results are based on the immediate perception of the door, however, everyday interaction is, surprisingly, interactive. Approaching a door that does not afford to pass is expressed in the brain as a significantly strong alpha suppression over the visual and motor cortex [**F2**].

Surprisingly, the suppression is continuous suggesting that the affordances are continuously affecting us. These results reflect the importance of thinking in time when designing experiences as the immediate past will determine the start-position of the present, which again will affect the future. We can hardly think of any experience without situating it in time. The same goes for atmospheres. They are extended in time, and because sensorimotor processes operate in rhythms we can think of atmospheres as the slow background rhythms operating in the background, setting the stage for all other processes.



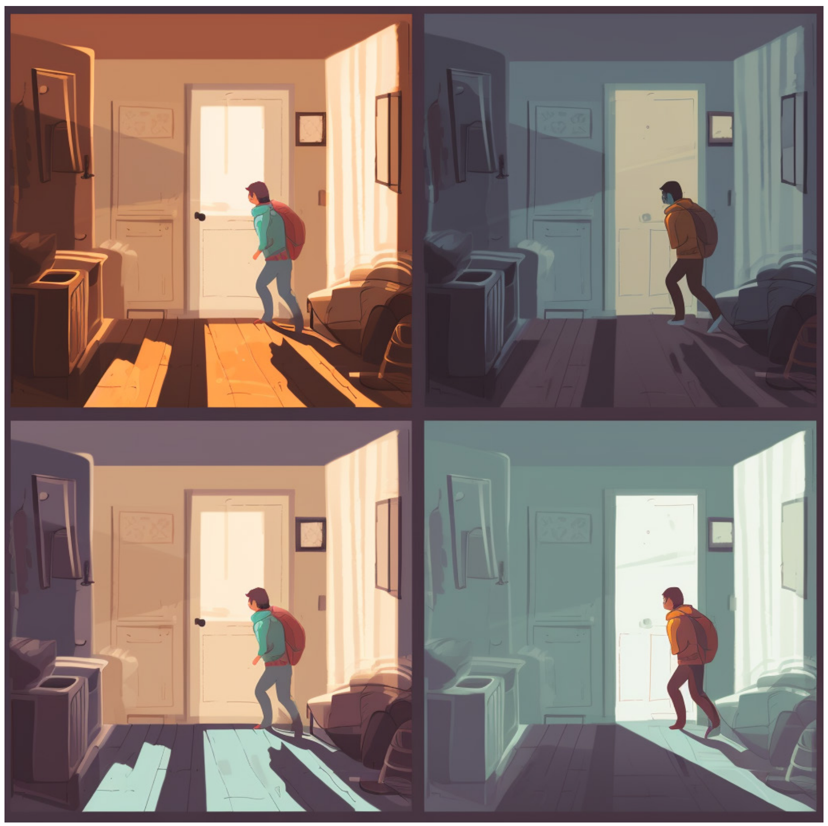
F3 A thought experiment of transitions to emphasize the importance of time when thinking about the experience and impact of the built environment. With three different spatial configurations, will the experience of space B be similar if we approach it from space A or space C?



Rhythms of Atmosphere

To be sure, the claim is not that atmospheres have fingerprint cortical waves directly measurable from the scalp. The claim is rather that when we are not consciously aware of them, they exist in our sensorimotor suppression space with specific shapes and dynamics, which all matter to our current behavior and experience. Once again, I need to invoke the temporal aspect of human experience and physiology. However, this time through a thought experiment [**F3**]. The experiment is about comparing experiences to test for their uniqueness. Consider a sequence of three spaces, A, B, and C, each with its own spatial configuration and atmosphere. Imagine walking from space A to space B, and conversely, imagine walking from space C to space B. Is your experience of space B comparable in the two situations? Our intuition, for lack of a better word, rings the alarm; these are two different experiences. Our present is constituted by our immediate past and immediate future (Husserl 2001) and because our immediate past when arriving at space B is different in the two situations, they cannot be the same experience. This thought experiment has several limitations, but it conveys an important observation about the immediate human experience, name, that there is a principle of *continuity* (Fuchs 2007) that constantly integrates our immediate past with our immediate future, that is, integration between our sensory and motor capacities, where the *trajectory* matters. Note that we are dealing here with the immediate timescale, which is not to say that the history of the perceiver does not matter — quite the opposite (Albarracín and Wyer 2000; Raviv, Ahissar, and Loewenstein 2012; Brügger, Demski, and Capstick 2021). The resulting perception can thus be thought of as an immediate contrast between the past and future, which is an essential insight from Husserlian phenomenology (see, for instance, Bogotá and Djebbara 2023).

F4 Variations of the same scene with different atmospheres. Although we fixate on the person in the picture, our peripheral vision continuously informs us about the atmospheric quality of the scene. This series of pictures do not make justice to this real-world effect, however, it captures the gist of it.



My insistence on the position of atmospheres as the backdrop stems from two insights. First, attention is a funneling skill that gives us tunnel vision by suppressing all peripheral information. Experiencing atmospheres encompasses all of our sensory qualities, requiring us to become sensitive to all such qualities at the same time over some duration to bring them to the foreground to become fully attentive of an atmosphere. This is initially an extremely effortful exercise as most practitioners of (open monitoring) meditation know (Lutz et al. 2008). It is thus not unthinkable that the effortless and typical everyday interaction with atmospheres occurs in the background, available if needed, but not part of the tunneled vision. Second, contextual information is a great predictor of human experience, cognition, and behavior because it provides important cues that help us interpret and understand the world around us. For instance, a given object may be viewed and used differently depending on the context, and a given behavior may be interpreted differently based on the context.

This is hardly news for either scientists or theorists. We know that deep contemplation works in some surroundings better than others. We also know that we behave differently if there are other people around. We also know from the vast amount of visual illusions that contextual information affects our perception — for instance, the perceived color of the black/blue and white/gold dress is negatively correlated with the assumed illumination along the daylight locus (Witzel, Racey, and O'Regan 2017). In the context of atmospheres, the character of the space, for instance, through changes in light, can have a fundamental impact on our experience of the very same [**F4**]. Natural lighting conditions in specific atmospheres, e.g., sunsets or sunrises, can be thought of as a very slow environmental rhythm operating in the background. As hu-

7 By *environmental view*, I mean a view that includes the features of the environment when considering cognition and behavior. Something similar has been suggested by extended (Clark and Chalmers 1998) and grounded (Barsalou 2008) cognition, and more generally in 4E cognition (extended, embodied, embedded, and enacted cognition: Newen, De Bruin, and Gallagher 2018).

man-made atmospheres can change with a greater pace, from space to space, the rhythm can be considered to undergo a phase reset whenever we enter a new space (Zumthor 2006).

Placing atmospheres in the background consequently means raising its potential effect on our experience, cognition, and behavior. How does this "environmental view" [7] fit with the neuroscientific perspective where cognition and behavior are assumed to emerge from the interaction between major brain regions? In answering this question, we discover the importance of a very specific region in the brain, namely the *thalamus* — also known as, "the neuroscientists' graveyard" simply because it is a massively complex and dense region that many scientists have spent their careers understanding without much luck (Fiebelkorn and Kastner 2019). Are we going to fare any better?

Transthalamic Transmission

Anatomically, the thalamus can be parcellated into approximately 60 different small nuclei, linked with the cortex in distinctive ways (Jones 2007). A specific challenge lies in understanding the upward and downward connections between the cortex and the thalamus. All ascending sensory information (safe olfactory) passes through the thalamus before entering the neocortex from where it appears to be behaviorally and cognitively useful (Buzsáki 2019). The thalamus is a hub at the center of the brain, in a subcortical area alongside other deeply important structures relevant to movement and sensation (Cover et al. 2023). Indeed, motor-related processes too are known to be deeply involved in subcortical connections giving rise to basic cognitive skills, such as learning, memory, and attention (La Terra et al. 2022; Wolff, Ko, and Ölveczky 2022).

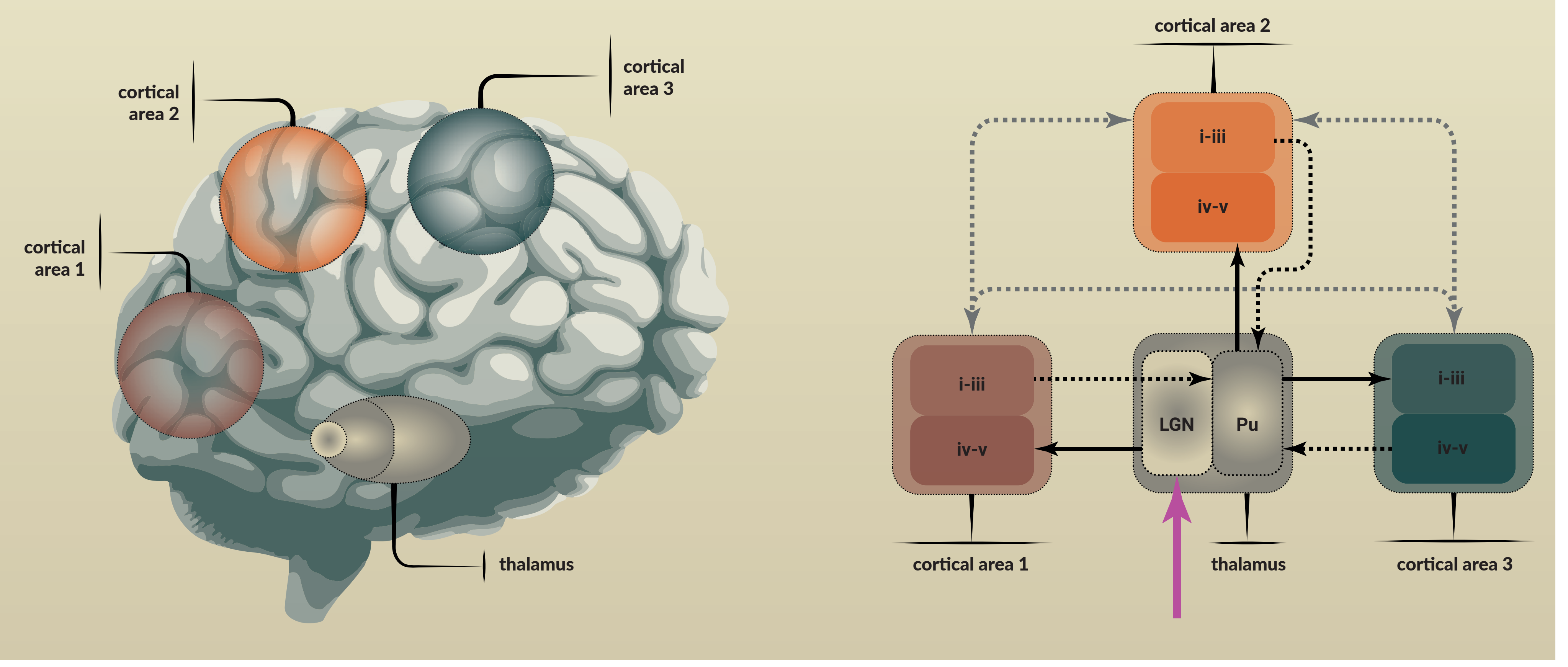
8 *Cortico-cortical connections* simply mean "from neocortex to neocortex." The neocortex is generally shortened to cortex in the literature. However, thalamo-cortical connections mean "from the thalamus to the cortex," while the opposite means the descending direction, i.e., cortico-thalamic connections mean "from the cortex to the thalamus."

Traditionally, the thalamus is considered a relay station that gates and suppresses irrelevant sensory information so that the neocortex could operate on the currently relevant information. For instance, at a cocktail party, we can suppress the noise from other ongoing conversations and listen to the person in front of us. This view of the thalamus naturally paved the way for thinking that consciousness, which after behaviorism is considered an important factor for cognition and behavior, would emerge from cortico-cortical connections [8] (Rees, Kreiman, and Koch 2002; Dehaene and Changeux 2011; Koch et al. 2016). From this perspective, sensorimotor-related processes stemming from the thalamus are considered nothing but representations of the world with the sole purpose of representation; the cognitive process occurs in the neocortex, particularly based around the functions of the prefrontal cortex (Brown, Lau, and LeDoux 2019).

In contrast, the transthalamic perspective suggests a form of interregional communication that utilizes the thalamus as a crucial transmission center (Sherman and Guillery 2011; Sherman 2016). It is believed that this kind of transmission is critical for supporting fundamental cognitive abilities and functions like memory, motivation, attention, and perception (Saalmann et al. 2012; Schmid, Singer, and Fries 2012). That is, these pathways enable communication between various brain regions, that is, cortico-cortical connections, through the thalamus and thereby creating cortico-thalamo-cortical pathways, which can aid in integrating and coordinating cognitive processing across various brain regions (Kastner, Fiebelkorn, and Eradath 2020; Eradath, Pinsk, and Kastner 2021).

The transthalamic view results from the bottom-up, ground-work done in the laboratory at the level of single neurons and slices of rat brain (Sherman and Guillery 2006). It was discovered that the thalamus re-

F5 The left side portrays the position of the thalamus and the cortical areas relative to each other (for cortical areas relevant to the built environment, see Djebbara, Fich, and Vecchiato 2022). The right side portrays their connections, where the dashed lines represent the higher-order connections, the solid lines represent the first-order connection, and the gray dashed lines represent the cortico-cortical connections. The magenta arrow represents the ascending peripheral sensory information. The Roman numerals represent the layers in the neocortex. This schematic is highly simplistic example of the relationships (LGN: lateral geniculate nucleus; Pu: pulvinar).



9 Due to the enormous amount of downward projecting connections from several major brain regions, among other things, it is thought that the neocortex is in the game of generating predictions about the world. In other words, this view suggests that our sensorimotor processes rely less on first-order inputs and more on higher-order feedback inputs from the cortex (Wolff et al. 2021).

ceives direct peripheral sensory information and projects (or relays) sensory information upwards through *first-order* connections to the cortex. A textbook example is the lateral geniculate nucleus (one of many nuclei in the thalamus), also known as the LGN, projecting visual information to the primary visual cortex. Another kind of connection is known as the *higher-order* connection, which is thought to play a critical role in the integration of information among distinct brain regions, being strategically placed to bridge information through downward connections [**F5**]. The exciting part [9] is that the number of downward connections, that is, cortico-thalamic connections, outnumber the upward connection by 5-10 fold (Guillery 1995), suggesting that these connections may not only be associative but also have a feedback role allowing for the bridging of several cognitive processes (Wolff et al. 2021).

The difference is clear; the former perspective is centered around cortico-cortical connections, which is arguably the dominant perspective in the literature, while the latter perspective emphasizes the thalamus and bridging of information in cognition. Only the former considers the structure of the sensory information and allows it to have a structural impact on the cognitive and behavioral processes. In other words, instead of basing cognitive and behavioral processes on (dead) representations of the environment, as in the former perspective, the latter is susceptible to the (lively and rich) dynamics of the environment. If the transthalamic perspective is right, what are the next steps to understanding atmospheres from a neuroscientific point of view?

There is growing evidence that information transmission through the thalamus is critical for the communication between major brain regions empirically (Saalmann and Kastner 2009, 2011; Cover et al. 2023) and

computationally (Cortes, de Souza, and Casanova 2020; Cortes et al. 2021; Worden, Bennett, and Neacsu 2021). Higher cognitive skills and behavior depend on major brain regions communicating, meaning that if atmospheres may affect the transmission in the thalamus, then atmospheres may affect us to a greater extent than expected. Note that this view does not attempt to understand the experience of an atmosphere, but *the effect on our human skills*. The skill and behavior are in the foreground while the atmosphere remains in the background, affecting us implicitly. That is, atmospheres affect our adaptive behavior through its susceptibility to ongoing sensory (suppression) dynamics that goes unnoticed due to our limited attentional resources.

The hypothesis is that if atmospheres affect us through their background presence, limited to our sensory suppression of sensorimotor information, then it should be expressed in the transthalamic pathways as a function of affordances. This view rests on the following three premises:

> the examples of *nonconscious adaptive skills* were based on sensorimotor brain dynamics;
>
> the *sensorimotor brain dynamics* are directly related to cognition and behavior;
>
> the *suppression dynamics* are actively relevant and integrated with ongoing neural processes, consequently affecting *cognition and behavior*.

If these three premises are correct, we have reasons to believe that the everyday atmosphere is constantly, in a nonconscious fashion, affecting us through phenomenologically rich, yet unnoticed, *suppression dynamics*.

10 "Neurophenomenology and Sacred Architecture: Toward an Experimental Theological Aesthetics" Symposium, School of Architecture and Planning, Catholic University of America, Washington, DC, March 23–25, 2023.

Coda

All of the above does not in any way resolve how to design atmospheres. Rather, I have provided a framework for studying the impact of atmospheres — a critical step in the process of crafting them. The act of designing, as a whole, is an arduous undertaking, which makes the creation of *guidelines* and *rules* equally challenging. Guidelines and rules of design are closely related to the idea of optimization, in the sense that some designs are considered superior to others. Before this conference, I presented at Julio Bermudez's symposium, named "Neurophenomenology and Sacred Architecture," where sacred experiences were the focus. [10] With the presence of architects, design guidelines and rules were again considered as they have an instructive power similar to a recipe. Admittedly, the discussions that emerge after a series of presentations over a few days, tend to be the most thought-provoking and captivating ones. However, post-conference discussions are also somewhat like shower-thoughts; you realize new relations and think "this is what I should have said!" At least three important points were raised during my post-conference shower that I will speculate about below.

First, the *challenge of generating design guidelines and rules* is a recurrent theme in the field. There are several ways research can be materialized by architects. One is to convert scientific results into building regulations and laws, which is essentially a top-down approach. Alternatively, a conversation between scientists and architects on how research could improve their unbuilt projects suggests a bottom-up approach where the architect is included in designing the guidelines. The challenge lies in how to shape such guidelines; *affirmative rules*, that is, "here are what you need to do", or *restrictive rules*, that is, "here are what not to do." Affirmative guidelines suggest, in the positive, what should be done, whereas restrictive guidelines prohibit certain actions and solutions. Providing a set of affirmative rules to a group of architects will eventually result in projects with limited variation, which is the hallmark of the death of creativity. However, provide a set of restrictive guidelines and we might expect highly varied projects, which is the hallmark of creativity. Just like how doctors study the principles of a healthy and functioning body, and how mechanicians study the principles of a functioning car, architects need principles on the effect of the built environment on cognition and behavior. Though not applicable to the doctor's case, the principles of a functioning car depend on the design of the car, and this is exactly what complicates the case for architects and other creative fields. The principles themselves need to be designed and translated from the literature. Evidence-based design requires a process of translation and interpretation, which will be contingent on the interpreter.

On the other hand, it is assumed that the current scientific results are mature enough to be considered as guidelines, while the truth is that most research in our field is not ready for implementation. Essentially, because being an architect requires engaging with a creative process, the knowledge accumulated in science simply needs to be available and accessible. My hunch is that neither affirmative nor restrictive guidelines can be general enough to work by principle. Instead, there is a need for *principles that describe functional relations between the human body and the built environment* from which the designers can create personalized interpretations. This is a much harder task as the scientific field has simply not matured to generate such principles.

This brings me to the last and final point; there will be a need for a new profile in the architectural industry. Research and development are

11 Not to be confused with the *experience* of atmosphere.

gaining popularity with architectural firms, as they realize their potential in several aspects. For instance, developing customized solutions to create performative projects, engaging with innovative solutions providing a competitive edge, generating measurable sustainability solutions, producing new business opportunities, and evaluating existing projects to enhance predictability for future projects. From a scientific perspective, this calls for a profile that can function as the bridge between the scientific literature of cognitive neuroscience to assess the projects and the architectural design process. *Assessment* and *evaluation* will become key skills alongside the *capacity to translate science into design principles*.

As Elisabetta Canepa said during a discussion on this topic: "the role of this new profile could be to act like a coach. The coach does not touch the ball but evaluates and assesses the work of the team to improve the outcome." *Every project is unique*, making assessment and evaluation invaluable as they are necessary to understand how that specific finalized solution affects its users, which will consequently improve future projects. I resonate beyond any doubt with this statement, and perhaps even more with Robert Condia's take on teaching architecture, which is arguably the role of a research department at an architectural firm. Paraphrasing his take, he stated that becoming an architect is a deeply personal journey that cannot be imparted by others through teaching alone. The desire to shape the world through design is the driving force behind this profession, and it is this motivation that can be cultivated and nurtured through mentorship and coaching.

Conclusion

The atmospheres of our everyday life speak to all of our senses, making them experientially entangled, indistinguishable, and infamously ineffable. The ineffability associated with atmospheres is both what makes them intriguing and attractive, but also what makes them scientifically intractable. In my attempt to make them tractable, I have demonstrated how the *peripheral sensory information*, though unnoticed, does not go lost, but is utilized for nonconscious adaptive skills. Specifically, I have provided some evidence for how sensorimotor dynamics display nonconscious adaptive skills, constantly informing our every move, and how sensory suppression in everyday experiences consequently remain phenomenologically rich. As atmospheres operate in the domain of our peripheral senses, that is, the backdrop to our lives, it is suggested that their impact occurs through nonconscious adaptive skills that in turn are expressed in transthalamic pathways. In my pursuit of tractability, I have suggested a potentially fruitful approach to the quantification of the *effect* of atmospheres [11] through transthalamic processes. The elusive nature of atmospheres may seem daunting, but it is precisely what draws us to them. So let us embrace the ineffable and allow ourselves to be inspired by their nonconscious effect that connects us to the world around us.

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Symposium

Designing Atmospheres: Theory and Science

March 28, 2023
Recent advances in science confirm many of the architects' deep-rooted intuitions, improving knowledge about the experience of space and the meaning of architectural and urban design. The "Designing Atmospheres: Theory and Science" Symposium presented to an audience of students, educators, architects, and scientists a conversation about human perception of design and building, specifically talking about atmospheres, affordances, and emotions. It was an Interfaces event of the Academy of Neuroscience for Architecture (ANFA), sponsored by the EU's Horizon 2020 MSCA Program — RESONANCES Project, the Perkins Eastman Studio, and the Architecture Department at Kansas State University (K-State). The event was organized by Elisabetta Canepa and Bob Condia and hosted in the Regnier Hall of K-State College of Architecture, Planning and Design (APDesign), Manhattan, Kansas.

Speakers
Kory Beighle (APDesign — K-State), Elisabetta Canepa (MSCA Fellow — UniGe | K-State and ANFA AdCo), Bob Condia (APDesign — K-State and ANFA AdCo), Zakaria Djebbara (CREATE — AAU and TU Berlin), and Harry Francis Mallgrave (IIT and ANFA AdCo).

Lectures
Recorded videos of each lecture are available on the RESONANCES Project website (www.resonances-project.com/harvest) and its YouTube channel (www.youtube.com/channel/UCk32skDiT4Bz1AHnltT51Yg).

Support
Special thanks go to the P\Lab2003 team for the technical-organizational work, the videographer Matthew Knox, and the video editor Reid Posinski.

“What then is the relation between thinking and making? To this, the theorist and the craftsman would give different answers. It is not that the former only thinks and the latter only makes, but that the one *makes through thinking* and the other *thinks through making*.”

Ingold 2013, 6: original italics

“The more pressing question remains: is the architect a theorist or a craftsman? Architects may want to respond that they are both, but are they really so magisterial?”

Mallgrave 2018, 129

Ingold, Tim. 2013. *Making: Anthropology, Archaeology, Art and Architecture*. Abingdon and New York, NY: Routledge.

Mallgrave, Harry F. 2018. *From Object to Experience: The New Culture of Architectural Design*. London and New York, NY: Bloomsbury.

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An Interfaces event of the Academy of Neuroscience for Architecture, sponsored by the EU H2020 MSCA program —— Resonances project, the Perkins Eastman studio, and the KSTATE APDesign

Kory Beighle
Elisabetta Canepa
Bob Condia
Zakaria Djebbara
Harry Francis Mallgrave
and P\Lab2003

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A symposium organized by Elisabetta Canepa and Bob Condia

Kansas State University
Università di Genova

The Resonances project has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement no. 101025132 —— www.resonances-project.com

28 March 2023
8:30 —— 12:30
Regnier Hall, APDesign
Kansas State University

Authors

Kory A. Beighle (M.Arch., Ph.D.) holds the position of Assistant Professor in Kansas State University's Department of Architecture. His teaching responsibilities include design studios, architectural history lectures, and theory seminars. Prior to joining K-State, he was the inaugural Park Creative Arts Professor at Miami University in the College of Creative Arts' Department of Architecture and Interior Design. Dr. Beighle received a Ph.D. in Architecture from the University of Cincinnati in 2020, where the major focus of his studies addressed twentieth and twenty-first century architectural theory, particularly issues of disciplinarity and architectural tools, with a minor focus on theories of visuality. His dissertation, entitled *Architectural Alchemy: Collaging Disciplinarity in the Kaleidoscopic*, examined these issues through critical analysis of the interdisciplinary practice of Charles and Ray Eames. His work as a historian, theorist, scholar, and educator is framed through design to explore the intersection of tools, pedagogy, disciplinarity, and spatial narrative in our kaleidoscopic paradigm. His research has been recognized and presented in national and international conferences, art exhibitions, film competitions, and journal publications.

Elisabetta Canepa (MS.Eng., Ph.D.) is an architect and researcher from Genoa, Italy. She is currently an EU Marie Curie Fellow running the RESONANCES project (2021–2024) in collaboration with the University of Genoa, Kansas State University, and Aalborg University. Her research focuses on the hybrid connection between architecture and cognitive neuroscience, analyzing topics such as atmospheric dynamics, the emotional nature of the architectural experience, embodiment theory, the empathic phenomenon between humans and space, and experimentation in virtual reality. Dr. Canepa is an Advisory Council member of the Academy of Neuroscience for Architecture (ANFA), based in San Diego, California. She is a faculty member in the Neuroscience Applied to Architectural Design (NAAD) Master's Program at the Iuav University of Venice and serves as an Adjunct Professor in the Department of Architecture at Kansas State University. Elisabetta Canepa wrote *Architecture Is Atmosphere: Notes on Empathy, Emotions, Body, Brain, and Space* (2022), published by Mimesis International within the *Atmospheric Spaces* book series.

Bob Condia (M.Arch., FAIA) is a Professor in the Department of Architecture at the College of Architecture, Planning and Design (APDesign) of Kansas State University. He is the design partner at Condia+Ornelas Architects, Manhattan, Kansas. The 2017–2020 Regnier Chair of Architecture at Kansas State University, Prof. Condia teaches design as art with consideration to the biology of perception, the real, the ancient megaliths of man, and the sensible poetics of an architectural experience. He has been a studio critic for more than thirty years in architecture and interior design. Prof. Condia's place in the neuroscience for architecture debate is as an architect and studio critic, seeking the consequences of applied science for architects. Bob Condia is an Advisory Council member of the Academy of Neuroscience for Architecture (ANFA), based in San Diego, California. Regarding architectural affordances, atmosphere, and mood, he edited three books published by New Prairie Press: *Meaning in Architecture: Affordances, Atmosphere and Mood* (2019), *Affordances and the Potential for Architecture* (2020), and *Generators of Architectural Atmosphere* (2022 coedited with Elisabetta Canepa). He is the director of the *Interfaces* book series (New Prairie Press).

Zakaria Djebbara (Cand. Polyt., Ph.D.) is an architecture researcher attempting to understand how spatial configurations relate to human experience, cognition, and behavior. To reveal such relations, Dr. Djebbara employs mobile electroencephalographic neuroimaging methods in combination with virtual reality and physiological measures. His research is supported by computational modeling of human experience and neural dynamics. He currently holds a postdoctoral position at Aalborg University, Denmark, and focuses on the role of sensorimotor brain dynamics in behavioral and cognitive performance. Zak Djebbara is a member of the Lundbeck Foundation Investigator Network (Copenhagen), the Berlin Mobile Brain/Body Imaging Lab (Berlin Institute of Technology), and the Situated Mobilities and Sensing Bodies Group (Aalborg University). He edited the book *Affordances in Everyday Life: A Multidisciplinary Collection of Essays* (2022), published by Springer Nature.

Harry Francis Mallgrave (M.Arch., Ph.D.) is a Distinguished Professor Emeritus from Illinois Institute of Technology and an Honorary Fellow of the Royal Institute of British Architects. He received his Ph.D. in architecture from the University of Pennsylvania and has enjoyed a career as a scholar, translator, editor, and architect. In 1996 Prof. Mallgrave won the Alice Davis Hitchcock award from the Society of Architectural Historians for his intellectual biography *Gottfried Semper: Architect of the Nineteenth Century*. He has published more than a dozen books on architectural history and theory. His most recent book, *Building Paradise: Episodes in Paradisiacal Thinking* (Routledge, 2021), argues on behalf of a design and planning ethic centered squarely on cultural needs and personal aspirations. Harry Mallgrave is an Advisory Council member of the Academy of Neuroscience for Architecture (ANFA), based in San Diego, California.

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Designing Atmospheres:
Theory and Science

2023
New Prairie Press
Kansas State University Libraries
Manhattan, KS, USA

Designing Atmospheres: Theory and Science successfully begins to demystify the seemingly ineffable or elusive nature of architectural atmosphere by offering empirical approaches and experiments that, in relation to the clear theoretical and historical background included in its pages (not to mention the prior three Interfaces issues), advance our scientific and phenomenological understanding. The writing is convincing, the intention is clear, the timing is impeccable, the combination of (theoretical, design, historical, and scientific) voices is ideal, and the result is, unsurprisingly, excellent.

—— Julio Bermudez, Ph.D.
ACSA Distinguished Professor
The Catholic University of America

Is designing atmospheres an easy problem that we can solve scientifically? Or is it a hard problem that must be left to the sensitive experience of the individual architect? This is the scope of both perplexing and tantalizing questions covered by the discussion in **Interfaces 4**. Enjoy!

—— Lars Brorson Fich, Ph.D.
Professor of Architecture
CREATE, Aalborg University

Entering a room evokes an immediate impression —— it might be pleasant, drab, or even dangerous —— every place has a "pervasive unifying quality" as John Dewey put it, that can instantly shift our mood. Indeed, no space is neutral. Yet, this basic fact seems to have been forgotten. Decades of fascination with form and surface have divested space of place, and the growing concern with atmospheres is now compensating for this impoverishment. This volume, perhaps more than any other on the topic, searches diligently to understand how atmosphere and mood are interlinked, to rigorously question what factors come together to create this unifying quality that we call atmosphere, and how something so basic to human experience could get lost along the way. Coming closer to understanding something as elusive as atmosphere brings us a step closer to understanding ourselves, and our profound interdependence with the world around us. **Hopefully, this new knowledge and awareness may contribute to making places that appeal to the whole of our humanity**.

—— Sarah Robinson
Professor of Architecture
CREATE, Aalborg University
NAAD Master's Program, Iuav University of Venice