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A Neuropsychological Perspective on Praise and Rewards in Persuasive Technology

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Abstract. This paper presents the initial insights gained from a literature study, exploring how perspectives from neuropsychology, may contribute to the field of persuasive technology. Spring boarding from the work of Oinas-Kukkonen & Harjumaa and their definitions of persuasive principles, the study suggests an area in which the Persuasive Systems Design framework of Oinas-Kukkonen & Harjumaa may be extended to facilitate even more affective digital solutions. The study focused distinctly on principles of praise and rewards, however the insights gained motivates similar explorations of other principles in future research. Results indicate that there is a common neuro circuit in the brain identified as the 'reward circuit'. Activation within the reward circuit varies both according to context, and according to the nature of the reward itself. The discussion leads to the understanding that persuasive technology may benefit from these kinds of neuropsychological insights when designing features such as praise and rewards. Specifically, by considering different types of rewards and the context in which they are perceived.

Keywords: Persuasive technology, Cognitive Science, Neuropsychology, Neuroscience, Reward processing, Digital Pollution, Fourth Language

1 Introduction

For more than a decade, the field of persuasive technology has continuously grown both in areas of applicability and in theoretical and methodological underpinning. Initial steps in the field focused on translating well known and established principles of persuasion in the physical realm, into equivalent methods and structures in the digital domain. However, just as human language and manners of expressions are constantly changing and developing, so must the language in the digital realm, if computer mediated communication is to remain effective. It is with this in mind that we in this paper share immediate insights and reflections concerning the continuous development of the field and the potential need of recognizing computational design as a language of itself, rather than a parallel to that of the physical realm.

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This paper presents the initial findings from a literature study in which the impact of persuasive principles has been explored from a neuropsychological perspective. Neuropsychology methodologically seeks to understand human behaviour both by observing behaviour and by using neuroscientific tools to identify underlying neural patterns of behaviour [2]. Basing the understanding of principles on the work of Oinas-Kukkonen & Harjumaa [1] in which multiple theoretical perspectives on persuasion are brought together in the Persuasive Systems Design framework, the study has sought to explore the actual impact of persuasive principles, based on related neuropsychological studies. The study has been greatly motivated by a need to understand more thoroughly how and when persuasive technologies have an impact on users. While many users may be able to pinpoint specific features of a system which they enjoy, they seldom have the insight to explain what precisely persuaded them at a given moment. When also considering that persuasive impact is context and user dependent, persuasion becomes even more complex to grasp and consequently even more challenging to consider in a design. However, neuroscience has the potential to provide a different lens for understanding cognitive functions and the nature of the human mind and does as such comprise a valuable perspective to consider in the future of persuasive systems.

In this study we have a distinct interest in understanding areas in which persuasive principles may be further developed and thereby recognize both the neuropsychological insights and the previously mentioned constant progression in languages. Based on the study, we here recommend specific areas in which persuasive principles call for a more nuanced and scalable definition. To underline the practical and design-oriented focus, we narrow the scope for this paper to focus on principles of praise and rewards in persuasive systems. Since praise and rewards represent both a social and communicative aspect of being human these communicative features are commonly used in persuasive technology to provide social support [3]. This paper presents the initial steps towards answering the following two questions:

- Is cognitive reward processing context dependent, and if this is the case, does this imply a difference in cognitive processing of physically mediated rewards as opposed to digitally mediated rewards?
- To what extend do the possible differences in cognitive processing of rewards, hold implications for persuasive technology?

The literature review of the two cross-disciplinary fields of neuropsychology and persuasive technology, is aimed at identifying potentials of useful neuropsychological insights for persuasive technology. The study leads to the understanding that cognitive processing of rewards is not only strongly contextually dependent, but also subconsciously categorized as either primary or secondary. Food is for example a primary reward since it is directly related to survival while money is categorized as a secondary reward since it is not directly linked to survival [4]. Moreover, different neurological patterns in the brain are activated upon receiving a reward, depending on the nature of the categorization of the reward i.e., primary, or secondary. Activation within these patterns of activation in the brain varies, according to context, subjective expectations, and the way the reward is delivered.

We discuss that these insights implicate an important perspective for future research and design of persuasive technology, by gaining insights from neuropsychology on human perceiving, thinking, and 'liking'.

2 Neuropsychology and how it relates to persuasive technology

'Neuropsychology' is a term comprising different scientific fields (i.e., cognitive science, cognitive psychology, and neuroscience) dedicated to understanding both brain, behaviour, and the connection between these two interlinked aspects of being human [2].
In this section cognitive science, cognitive psychology and neuroscience will be shortly elaborated to provide the reader with an understanding of the perspective we hold when choosing neuropsychology as the lens through which this study is made.

Cognitive science is a cross disciplinary field drawing on psychology, philosophy, neuroscience, linguistics, and AI. Methodologically the field investigates information processing by *"logical analysis and computer simulations of cognitive processes*"[2]. Whereas cognitive psychology, which to a large extend overlaps with cognitive science, explicitly traces back to behaviourism, using experimental methods for studying behaviour. Cognitive psychology is distinct from behaviourism though (which is also aimed at understanding human behaviour), because the field of cognitive psychology as opposed to behaviourism, is focused on understanding internal cognitive processes related to outside observable behaviour [2].

'Cognition' is a set of steps in which the brain processes an abstract entity of 'information', and thus in principle, cognition can coincide with the manner in which a computer processes information. But an important aspect of understanding human cognitive processing, depends on understanding how cognition is realized in the brain i.e., understanding the neural processes underlying information processing. Thus, Cognitive neuroscience, is the science of understanding the neural basis of cognition, which is often done by use of neuroimaging data e.g., fMRI scans, measuring patterns of activation within the brain (i.e., neural circuits).

The title of this paper "A Neuropsychological Perspective...", is to be understood as a perspective combining cognitive psychology (understanding behaviour) cognitive science (understanding information processing prior to behaviour) and cognitive neuroscience (understanding the way cognition is realized in the brain). Thus, the term neuropsychology implies the combining of these closely related fields.

2.1 Digital pollution and attention

Neuroscience has revealed structural differences in brain structures between people born before and after 1980 [5]. These differences are caused by the rapid alterations happening as technology transcends most aspects of perception in everyday life. More specifically this means that the human brain, already from infancy, is perceiving a landscape of stimuli (i.e., information) very different from that of before 1980. Since it is possible, and in some contexts even impossible not, to manage several and seriously

distinct aspects of life, through a tiny smartphone screen, "digital pollution" [6] is now an actual and relevant concern.

Digital pollution describes the neuropsychological consequences which these alterations of environmental stimuli can have. The role of technology is essentially that of delivering information which, to be processed by the human brain, needs to stimulate it i.e., by seeing, hearing, smelling, touching, tasting etc. In our "natural" physical environment these stimuli are to a wide extent perceived through multiple different modes which, contextually, are distinct from each other. But the smart phone screen combines several of these different contexts, and thus combines multiple modes of perceiving stimuli into one and the same physical context. For example, reading a book and answering the phone are, contextually, two very distinct situations, not bound to influencing one another. Plausibly, in this imagined world free of smart phones, answering the phone requires of the individual to stop reading and moving somewhere else, to answer the phone. In other words, the person would have to consciously direct his or her attention somewhere else in space i.e., away from reading and towards answering the phone. In our world, smartphone world, reading a book and answering the phone can be done without moving at all. In fact, one can continue reading while at the same time speaking to a person on the phone. Though in most circumstances this would be considered rude, the reality is, that the book and the phone, in this context, are one and the same object. And thus, the division of attention between the book and the conversation is the task of directing one's attention between two things conceptually very different from one another, but which, objectively speaking, is but the same object. In the scenario of reading a book and speaking on the phone it is up to the individual to steer his or her attention towards the preferred source stimuli (reading or having a conversation). This perhaps sounds easy since the book, neither physical nor digital, (probably) is not delivering notifications. But extending the point even further, we argue, it is not difficult to imagine a person having a conversation on the smartphone while at the same time being attentionally interrupted by the sound of notifications, instant messages etc. Thus, in this scenario, the attention is directed towards one thing i.e., the conversation, but at the same time being caught by other things e.g., the sound and/or the vibrations from notifications.

2.2 Dual-process-theory

Dual-process-theories build upon the notion that the brain, upon perceiving stimuli, processes information by usage of two different cognitive systems [7–10].The scope of the current paper is not to elaborate on the various kinds of dual-process-theories but instead to address the common denominator of these theories which is that cognitive information processing takes places within one of, roughly divided, two subsystems: a "fast/intuitive system" and a "slow/reflective" system. The key difference between these two systems is whether information is available to conscious reflection or not. The former representing the unconscious system and the latter representing the conscious system. Persuasive design and nudging are designed at targeting one of these cognitive systems [6] and while persuasive design aims at the slow and reflective system, nudging targets the fast and intuitive system. The concept of attention is thus,

already a large part of persuasive design in that 'dual-process-theories' are acknowledged as a common theoretical ground when designing persuasive systems.

Cognitive information processing happens upon perceiving stimuli through the modes of our 5 senses, and one can, attentionally, be directed towards one thing, and at the same time be perceiving other sources of information, without being consciously aware of this. E.g., the writer of the current paragraph was attentionally caught up in writing and did not notice the parallel perceiving of the refrigerator buzz before the sound of the buzzing suddenly stopped. Thus, the perception of e.g., a sound can happen without the individual's attention being consciously directed towards it. Thus, as the sound appears it either catches one's conscious attention – but if not, it is unconsciously perceived and cognitively processed as such.

The division of perception into conscious as opposed to unconscious perception implies a large degree of power when it comes to designing systems meant to catch the attention of the user. Knowledge of these so called dual-process systems makes designers capable of targeting operational functions of the system according to the kind of attention the system needs to "catch". The notion of digital pollution is relevant in this context since recent research [11, 12] indicate that the brain may not respond to rewards communicated digitally in the same manner as rewards communicated through a physical interactional context. Implying that translating physical reality e.g., as in the reading a book and answering the phone example illustrate, technology alters reality in a way which does not necessarily allow us to consider the digital realm as parallel to the physical realm.

Attention, perception, cognitive information processing and behaviour are all depending on context i.e., conscious, or unconscious information processing and physical context is not necessarily parallel to digital context. Thus, when processing stimuli perceived through the tiny smart phone screen, the context requires division of attention between different concepts, being represented by the same physical object, which we argue, is different from the context of dividing one's attention between different conceptual things which are also distinct from one another in space.

The human brain is evolutionary 'designed' to respond to certain stimuli by producing several neurotransmitters, which affect the individual emotionally. Amongst these, the neurotransmitter dopamine is produced to create the emotional feeling of joyfulness and feelings alike it. Dopamine is produced in situations, which, in an evolutionary perspective, helps us survive (e.g., food, sex etc.). Thus, dopamine is produced following exposure to a rewarding environmental feature and underlies motivated behaviour [6, 11, 12].

Not surprisingly, rewarding features are considered an important aspect to guide the user in the 'right direction' in persuasive technology. But Gram-Hansen points to researchers [11, 12] indicating that the brain may not respond to rewards communicated digitally in the same manner as rewards communicated through a physical interactional context.

3 Literature review

The research presented in this paper comprises the immediate results of a semi-structured literature review focused on neuropsychology and persuasive technology and subsequently the discussions and reflections inspired by this study. The initial search was structured to answer the questions stated in the introduction regarding possible differences in neurological and cognitive processing, relative to physical or digitally mediated rewards.

Representing a high-level publisher of research on persuasive technology and persuasive system design, Journal of Behavior and Technology was engaged as starting point for the literature study. We chose this venue because we consider the scope of our research to be characterized as preliminary insights. The initial search was initiated pursuing a line of thought represented in [6, 13], one discussing dialogue support within an empirical study [1, 13]. And the other discussing the possible differences in neurological reactions and cognition in relation to digitally mediated features of communication. Thus, the search was characterized by keywords represented in these papers:

- Digital pollution
- Context and neuroscience, cognition, neuropsychology
- Digital mediation
- Digital reward
- Physical reward

Based on this initial search, identified papers explored not solely with an interest in the content but also with a particular focus on references and related publications of relevance. This first step resulted in a further extended list of search terms, which were then applied in a subsequent broad literature search.

- Reward processing
- Physical versus digital mediation of rewards
- Neuroscience and digital reward processing
- Context and reward processing

Despite applying the broad range of search terms, only a limited number of relevant publications were identified. Consequently, it was decided to also conduct a search in Google Scholar to further broaden the scope of relevant journals just like relevant references of identified papers were included. These extensive searches confirmed that the initial research questions, had not previously been directly addressed. Instead, several themes of relevance to our research questions were identified. Thus, the 58 publications eventually included in the study, were chosen, and combined as the result of reading abstracts to identify concepts, thematic discussions, and empirical studies of relevance to this cross disciplinary research focus. E.g., empirical studies on cognitive neuroscience identifying common reward circuits in the brain, conceptual discussions of the cognitive effects of the Like on social media, and discussions about the importance of

using neuroscientific insights in persuasive design to protect neurodiverse groups. 11 papers had a specific focus on both neuropsychology, Information Systems and persuasion [5, 8, 9, 14–21] though, only 2 out of these 11 papers were specifically related to persuasion, an important gain from the literature search, was the identification of other academic themes of relevance, and consequently, an open coding process was initiated.

A systematic overview of the reviewed papers, their identified themes, as well as practical and theoretical specifications was accomplished by use of NVivo, by which a stringent categorization of themes was established. Primary themes were identified as: Neuroscience, Information Systems and Persuasion (11), fMRI & Persuasion (13), and last Neuroscience & Reward processing (10) [4, 22–29]. This process was driven by concepts from both persuasive technology and from neuroscience and does as such include terminology from both research areas. However, in accommodation of the page limit of these proceedings, and in line with the overall scope of this workshop, the following sections will focus distinctly on persuasive principles in relation to neuropsychology, namely themes:

- Neuroscience, Information Systems & Persuasion
- Neuroscience & Reward Processing

4 Neuroscience, Information Systems & Persuasion

The tradition of using neuroscientific insights when designing interactive technology stretches back only a decay and the most common areas of investigation within this field covers both neuroscientific theory, methodology and neuroscientific tools such as brain imaging techniques, cognitive and behavioral tools for understanding behavior and tools for understanding physiological responses in relation to different kinds of stimulus. These neuroscientific tools and insights help identify both brain activation patterns and behavioral responses to technologically mediated stimulus [18–21]. Identification of activation in specific brain regions related to attitude or behavior change is relevant to identify and contrast the information processing prior to the behavioral outcome following persuasive appeal. E.g., differences and similarities in people's neurological activation patterns, following exposure to specific persuasive appeal and in addition the identification of associated cognitive functions known to be controlled in the areas affected by these neurological patterns. The environment in which a person is being tested is, both physically and mentally full of stimuli outside the control of both the test person and designers of the study. Thus, the control of information flowing to the perceiving person is only to a limited degree controllable (e.g., an individual's thoughts, emotions etc. can have an impact on the way a person cognitively processes an otherwise controlled sequence of stimulus) [9]. Since information processing happens upon exposure to a continuously complex environment of non-controllable stimulus one cannot regard fMRI scans as deductively valid and thus cognitive psychology, as mentioned above, is a valuable methodological contribution to understanding cognition, neurological activation patterns and resulting behavior. Studies using neuroscientific tools such as fMRI scans, have identified patterns of activation across several individuals, resulting in prediction of behavior changes both immediately and several

months into the future. In fact these studies have been shown to predict behavior changes with more accuracy than self-report measurements of attitude – and behavior change [14]. Examples include both persuasion of sunscreen-use [16] smoking cessation [15]. In the latter, researchers measured brain activity upon receiving persuasive messages of highly tailored personal relevance, combined with measures of carbon monoxide levels in the body. The results showed that predicting behaviour change through brain imaging data was indeed successful [8]. Further, neuroimaging data have identified specific patterns of neurological activation in the brain and related the associated cognitive functions of these areas to social perception, self-referential thinking and affective processes such as reward, valuation and fear [8] [9]. E.g. persuasive messages that were perceived as highly self-relevant (e.g., smoking cessation messages tailored with personally relevant information) helped researchers predict attitude and behavior change. [8, 9].

4.1 Scientific measurement of attitude

An important distinction to hold in mind within persuasion is the distinction between attitude and behaviour since behaviour is just the explicit and observable aspect of an individual's attitude[9]. Prior to any kind of action, a processing of information biased by personal attitude has taken place.

Attitudes then are subjective, psychological mechanisms, which to some degree make an individual predictable and characteristic.

Scientific measurement of attitude is often done by having participants conduct some sort of self-reporting on attitude, perceived persuasiveness, and behavioural intentions. Nevertheless, measurement of attitude is complicated by the fact that people do not have conscious access to all aspects of their perception and thus, are incapable of describing their cognitive processing of perceived stimuli [9].

An empirical study using fMRI shows that there is a relation between neural activation and future attitude change when scanning for 'cognitive dissonance' (the general subjective urge to act in accordance with one's personal beliefs) [14]. When having to argue in accordance with beliefs and attitudes opposite of one's personal attitude, fMRI shows neural activation patterns in areas associated with the connective processing of conflict, thus, indicating the subjective experience cognitive dissonance [14]. However, a person unconsciously influenced by internal stimuli e.g., emotional response to stress, cannot necessarily control their attitude towards a context.

5 Neuroscience & Reward Processing

When designing rewarding features in persuasive technology, it is strategically important to know where the cognitive processing of rewards is happening in the brain, and more generally, what is perceived as rewarding to the human brain in the first place. In this section we elaborate on the neuroscientific discoveries within this area.

Brain imaging data shows that rewards can be divided into two sub-categories i.e., primary and secondary rewards, each implicating the activation of specific neurological activation patterns i.e., a core "reward system" [4]. Further we elaborate on research identifying underlying sub-systems to the core reward system, activating dependeing on contextual factors

Primary rewards refer to things directly related to survival e.g., food, sex, and safety. Whereas secondary rewards refer to things not innately related to survival, but instead associated to survival e.g., money and social praise [4, 30]. Secondary rewards have been identified as being processed in more recent areas of the brain [4]. Thus, reward related activity in the brain is directly depending on the nature of the reward itself i.e., being primary or secondary, since neurological activation patterns vary, depending on the nature of the reward. For example, areas related to the computation of subjective emotional value, conscious awareness of emotional value, and an area linked to cognitive processing involved in decision making have been identified as common sub-regions of activation within the core reward system [4, 9, 22].

5.1 Rewards and Context

Research indicates that in a particular setting, the brain processes evaluation of rewards relative to the specific context i.e., the brain does a scaling of rewards relative to possible outcomes. In other words, the brain produces expectations of rewards and is sensitive to deviations of these expectations [28]. Izuma et al. [30] tested neurolocial activation as a response to receiving social assessment from other people, regarding personal valuable features and compared the results with monetary rewards. Reward activation pattern consistently showed more activation in distinguished areas associated with cognitive processing of social metalizing skills (the ability to imagine other people's emotional states), and self-reflection following social rewarding. These results are in line with other studies e.g., Sherman et al.s study on receiving and providing 'Likes' on social media[22].

The study by Izuma et al. [30] tested response following reception of other people's assessment of personal valuable features delivered with written words as opposed to Sherman et al. [22] whom studied neural response to 'Likes' on social media.

Research on the brain's neural response to the 'Like' on social media like Facebook, Instagram etc. reveals an association between the brain's core reward system and receiving/giving a 'Like' [22]. Processing of social media rewards are thus evidently also implicated in processing of primary and secondary rewards [22]. But face to face communication involves a qualitative transaction of information sharing (physical gestures both bodily and facial, vocal prosody etc.), while digital communication on social media is a quantitative transaction of information sharing (e.g., the 'Like') [22].

Personally tailored persuasive appeal activates regions identified with rewards and specific kinds of psychological processing [17] and further, some studies in non-human primates, primed to have expectations of rewards in specific contexts, investigated the dopaminergic firing as a response to contextual expectations of rewards. The results indicated that the contextual expectation of rewards increased neurological activation in the reward system, more than the actual reward itself [24].

In sum, rewards are processed within the core reward system and within this system, sub—regional activation patterns are activated relative to the nature of the reward. In addition, the perceiving individual's expectations may also have implications to neurological and cognitive processing of the reward, essentially affecting the individual's subjective experience of it.

6 Discussion

In this section we will connect the concepts initiating the current study, with the findings of our literature study and discuss what these findings imply for future research in persuasive technology. Because of the sub-regional differences in activation in the brain following both persuasive appeal and rewards, it is theorized, that there are brain related differences to be identified, between both qualitative and quantitative contexts of praise and reward. This qualitative context bears multimodal information for the receiving brain to perceive while the quantitative kind of praise and reward is sort of one dimensional since it is countable (e.g., Likes on social media), and delivered for reasons not available to real time interpretation as opposed to physical human interaction.
Targeting dialogue support in persuasive technology software can potentially benefit both from neuropsychological insights in reward processing, and from keeping the complexity of context in mind, i.e., both rewards and contexts are to be categorized into different levels i.e., primary/secondary, and physical/digital contexts. As mentioned above, the findings of reward processing being sensitive to context and subjective perception, emphasize the traditional grounding of persuasion in rhetoric [6], by extending the principles from rhetoric by potentially backing these up with empirical data. Keeping the traditional principles from rhetoric in mind can potentially function as a guidance to establish a distinguishing between the physical and the digital realm e.g., by distinguishing between digital Kairos and physical Kairos in persuasive technology. Moreover, there are contextual differences, to be considered not only in the physical realm but also within the digital domain – e.g., the difference between interpersonal persuasion via social media, and persuasion through interactive technologies.

Contexts requiring careful attention (e.g., reading and responding to a message from your children's teacher) is at great risk of being digitally polluted by notifications, cues and rewards processed by the fast and intuitive system. Conscious reflection is at risk of being overruled by software designs created to transcend perceptive capacity without the user noticing [6, 11]. Thus, it is essential to address dual-process-theories and seek evidence of their relation to persuasive technology design [8] to accommodate future research to the challenge of the human perceptual system. Digital pollution implies the perceptual system having to navigate several different meta-contexts through one and the same physical artefact. Further, it is important to keep in mind, that the smart phone is not the last step in this rearranging of ordinary living since it is plausible that technologies of the near future will be far more pervasive.

If digital rewards from persuasive technology activates either more or less of the common reward system compared to physical praise and reward i.e., not quite reproducing the human quality of these communicative features, then it is evident, that

translating communicative features from the human physical interaction, cannot happen in a parallel 1:1 manner as discussed by Gram-Hansen [6].

It is commonly recognized that the semantic structures of language develop and so does the linguistic system itself. If the digital sphere cannot comprehend and fully reproduce social aspects and semantic features of human communication, this might entail the foundation of a new computerized communicative system, a fourth computational language [6]. This could potentially create a common ground for both users and designers thus, creating a way of designing technology that adapts and supports the human sphere instead of transcending the borders of perceptive capacity. In a physical environment the nature of the rewards has a major qualitative characteristic whereas computer mediated rewards are of a far more quantitate value, hence it is very plausible that there is an important distinction to make in this contextual difference. Physically interactive praise is human to human communicated thus, they bear multimodal information (i.e., sensory stimuli like touch, auditory, visual, and facial expressions, intonation etc.) whereas rewards communicated from computer to human are of a more quantitative character and thus, plausibly, feels different to the user.

Enabling adaption of persuasive technology to human practice in this manner would make a significant tool in overcoming global problems calling for universal behaviour change in complex domains such as health, sustainability, and climate change.

Our literature study did not identify any research investigating the question we initially sought an answer for i.e., are there differences in neurological patterns of activation and cognitive processing of rewards, relative to the mediation of these being either physical or digital. We consider the no finding in our study, as a "finding" in itself, thus emphasizing the importance of investigating this question.

7 Conclusion and future directions

In this paper we have sought to introduce and discuss components of neuropsychology which indicates areas that may facilitate the development of more affective and effective persuasive solutions in the future. The primary benefit of including a neuropsychological perspective in persuasive designs, may be that it provides designers with an understanding of aspects which are otherwise invisible. As designers, we are skilled in applying the multimodality of digital resources when we aim to influence and change our users. However, both in design and evaluation, we are limited to insights which can be actively demonstrated or articulated by the users. By including insights from neuropsychology, we gain insights concerning the aspects which are otherwise invisible to both the user and the designers aiming to facilitate a change

While the conducted literature review has not resulted in clear cut conclusions related to persuasive principles, it has provided strong indications that call for consideration, particularly in relation to praise and rewards. In the literature included in the current review, there is no explicit differentiation between technologically mediated rewards versus praise communicated in physical interaction.

Overall, this study provides us with the following insights, calling for further research and consideration:

1. The reaction to praise and rewards very likely differs depending on whether it is delivered in the physical ore the digital realm. Concepts of praise and rewards cannot as such be directly translated between the two.
2. When designing praise and rewards in persuasive technologies, it may be necessary to distinguish between primary and secondary rewards.
3. As a result of rapid growth in digital resource since 1980, designers may need to distinguish between 3 different types of users, with 3 different perceptions of reality – not solely based on experience but also on cognition.

As we strive towards stronger and more efficient principles for offering praise and rewards in the digital realm, future research should seek to further understand the possible difference between neurocognitive processing of digital rewards as opposed to praise in a physical, human, setting. This distinct focus comprises a challenge which calls for collaboration between neuropsychologist and persuasive design experts if qualified results are to be reached. A main area of interest and relevance is the bridge between persuasive technology and neuroscience, and the design of digital praise with actual neuropsychological affect. In other words, understanding the requisites for "translating" these features into the digital domain in a way that enacts the kind of processing needed to stimulate the individual with the subjective feeling of being praised or rewarded.

Based on the insights concerning cognitive processing of praise and rewards, it may be relevant to consider multiple levels within these principles, namely primary and secondary level. Furthermore, because of a greater digital presence amongst users, it may be relevant to revisit previous discussions on the difference between persuasion through social media compared to persuasion through interacting with a digital resource. In much research, the persuasive principles are defined identically across different types of digital contexts, however from a neurocognitive perspective these are in fact different and motivate different cognitive reactions.

While praise and rewards comprise a distinct principle in the design of persuasive technologies, the conducted study also motivates broader reflections on the notion of persuasion in a modern digital realm. Not only do we stress that future research on specific principles must entail empirical studies in the wild, but we also recommend investigating the possible differences in the discourses of digital and physical communication.

As noted in the introduction people born after 1980 are believed to have altered brain structures compared to people born before 1980 because of technology transcending the perceptive field of everyday life. Consequently, this population has a different ontological understanding of what it is like to "be" in this world. But people born in 1980 are 41 years old now and thus, likely to have almost grown-up kids of their own whom inevitably have a very distinct experience of technology and the alterations of life that comes from this rapid development. This taken into consideration, designers may be facing 3 different levels of users with very different understandings of reality: those borne before 1980, those born around 1980, and the generation following them. That the world is perceived differently by younger generations is not novel, however, the recognized neuropsychological changes, may stress the need to continuously develop

the language of the digital realm to accommodate this change and progression. While those born before 1980 may potentially also in the future respond to "likes" we have yet to understand how to reach the desired effect and response from younger generations. Although the concept of persuasion can be traced back to classical rhetoric in ancient Greece, persuasion in a digital age requires the recognition as a 4th language, equal to the already established spoken, written and mathematical ways of communicating.

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