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Neural Correlates of User Experience in Gaming

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ABSTRACT

The objective of this research is to understand the neural correlates of user states of experience in human-computer interaction using electroencephalogram (EEG). Such user states include flow, boredom, and anxiety that are experienced when a user interacts with a computer-based system. We propose using a within-subjects experiment to collect EEG data to assess and compare the neural correlates of three main states of user experience (i.e., flow, boredom, and anxiety) as well as compare them with the resting state as a baseline. We expect the findings from this research to contribute to an improved understanding of psychophysiological means of assessing user experience.

Keywords

Neural correlates, flow, boredom, anxiety, electroencephalogram.

INTRODUCTION

Assessing and understanding user states of experience is crucial in any evaluation studies because it provides designers, developers and usability specialists the opportunity to improve the experience of users. The most common approach to assess user experience is through the use of questionnaires and interviews that are retrospective in nature. In order to work toward a more reliable way of assessing user experience, we study the neural correlates of user states using electroencephalogram (EEG). EEG signals are a form of neuronal oscillations in the brain (Okada, 1993) and they represent the global activity of electrical impulses that travel along millions of neurons (Millian et al., 2004). The EEG technology not only provides continuous assessments of user states, but also has the potential to offer more reliable and objective (i.e., less subjective) assessments as compared to self-reported user assessments. Hence, this research not only opens up a new direction for assessing user states of experience but also contributes toward improving the reliability and validity of such assessments (Siau et al. 2014; Zhao and Siau, 2016).

Csikszentmihalyi (1975, 1990, 1997) identified three main states of user experience: boredom, flow, and anxiety. Flow, which is a major focus of research in human-computer interaction as well as other fields, refers to a state of optimal experience where one is completely immersed and absorbed in an activity to the point where nothing else seems to matter (Csikszentmihalyi, 1990; Nah et al., 2010, 2011, 2014). Flow is the subjective experience of effortless attention, reduced self-awareness, and heightened enjoyment that typically occurs during optimal task performance. According to Csikszentmihalyi, flow occurs when there is a balance between challenge and skill. In contrast, boredom occurs when challenge is much lower than skill, while anxiety happens when challenge is substantially greater than skill. For flow to occur, both challenge and skill should be fairly balanced, but they both should not be low, or else apathy will occur (Csikszentmihalyi and LeFevre, 1989).

Given the importance of understanding user states of experience (i.e., flow, boredom, and anxiety) in the human-computer interaction context and the potential of EEG to provide a better and more reliable way of assessing them, our research question is as follows:

***Research Question*:** What are the neural correlates of user states of experience, specifically, boredom, flow, and anxiety?

BACKGROUND AND LITERATURE REVIEW

Flow is “the holistic sensation that people feel when they act with total involvement” (Csikszentmihalyi, 1975, p.36). Csikszentmihalyi (1990) conceptualized the flow state as comprising nine components: (1) balance between the ability of the person and the challenge of the task; (2) concentration and focus on the activity; (3) direct and unambiguous feedback of action results; (4) clear goals associated with the activity; (5) control over the activity; (6) autotelic (i.e., intrinsically rewarding) experience; (7) loss of self-consciousness (i.e., loss of awareness of oneself as a social actor); (8) distorted sense of time; and (9) merging of action and awareness.

A general concept of flow in the context of software use has been proposed and coined as *Cognitive Absorption* by Agarwal and Karahanna (2000). They defined Cognitive Absorption as "a state of deep involvement with software" (Agarwal and Karahanna, 2000, p.673) and conceptualized five key components: (1) temporal dissociation (i.e., distorted sense of time); (2) focused immersion (i.e., focus and concentration); (3) heightened enjoyment; (4) control; (5) curiosity. Hence, the conceptualizations of flow and cognitive absorption are highly similar except that cognitive absorption, being a more generalized concept than flow, comprises only a subset of the nine components proposed by Csikszentmihalyi (1990) and includes a new component termed curiosity. Furthermore, the conceptualization of cognitive absorption explicitly modeled enjoyment.

Recent studies have utilized psychophysiological techniques to understand user states, one of which is an experimental study by Berta et al. (2013). They found that the most informative frequency bands for differentiating between boredom, flow, and anxiety states include those around the low beta band. Frequency wavelength has been widely used to classify EEG oscillations and the commonly used frequency bands are delta (1-4 Hz), theta (4-8 Hz), alpha (8-12 Hz), beta (12-30 Hz), and gamma (30-32 Hz). Li et al. (2014), on the other hand, demonstrated that the density of theta oscillations from the left side of the dorsolateral prefrontal cortex can explain the degree of user engagement. Berka et al. (2007) found that task engagement, which is a concept closely related to flow, relies heavily on EEG variables not only in the beta and gamma bands, but also in the delta, theta, and alpha bands. As Jackson (2014) has noted, "Knowing what is occurring at a neuro- or psycho-physiological level during flow has long been regarded as a critical area for furthering understanding of this concept." Recent development of brain imaging technologies, such as EEG, has made it possible to address this critical area.

Our review of the literature suggests that the neural mapping of user states of experience, such as flow, boredom, and anxiety, is unclear. In this exploratory study, we will use an experiment to collect EEG data for these user states to address the research question.

RESEARCH METHODOLOGY

We designed a laboratory experiment to capture EEG data for boredom, flow, and anxiety based on the experimental design by Berta et al. (2013) who used a 4-electrode EEG for their study. We adapted their design to the context of our study that uses a different video game, i.e., Tetris, and a 64-electrode EEG system called Cognionics (http://www.cognionics.com/).

A within-subjects experiment is used to manipulate four user state conditions: three states of user experience (i.e., boredom, flow, and anxiety) and a resting state. A video game called Tetris will be used to manipulate these user states, and manipulation checks will be conducted. We chose Tetris because it is a very popular game that has the tendency to induce engagement of its players to experience the flow state.

The four user states are manipulated as follows. The resting state is operationalized by having the subject look at a small cross on a blank screen of the same color as the background of the game used in the experiment. The boredom state is induced by setting the challenge of the game to be at the lowest level (i.e., level 1) and with the mouse disabled so that the subject cannot shorten (or shortcut) the wait for the falling block to reach the base. The anxiety state is induced by setting the challenge of the game to be so high that the user is not able to keep up with the game. From our pilot study, we found that setting the level of the game at 15 created anxiety in the players. Our pilot study also indicates that players experienced the flow state at level 5. Hence, the flow state is operationalized by setting the game at level 5 and letting the subject play the game until all the blocks pile up to the top, which ends the game. EEG activities and skin conductance are captured during the experiment.

The experiment will begin with a training session where the subject will learn and familiarize with the game, Tetris. From the training session, we will also obtain a baseline of the skill level of each subject. Even though we had initially planned to match the challenge (i.e., level) of the game to each subject's skill level in operationalizing the three main states of experience studied, our pilot study indicated that setting the levels at 1, 5, and 15 worked well for the manipulations for boredom, flow, and anxiety. Hence, after the pilot study, we fixed the experimental manipulations to these three levels of the game. After the training session, the subject will experience the resting state for one minute, which will be followed by the manipulations for boredom (for three minutes), flow (i.e., till all the blocks are stacked up), and anxiety (for four times of game play). After each manipulation, the subject is asked to fill out a questionnaire that is used to validate the manipulation, and hence, serves as the manipulation check. The questionnaire includes items on the perceived balance of challenge and skill, the user state that is experienced, and various scale items of flow and cognitive absorption.

A retrospective process tracing is then carried out by having the subject verbalize his or her user experience while viewing a video recording of the session. The retrospective process tracing is used to identify the best segment of each of the three user states, i.e., the segment in which the subject articulates that he or she is experiencing a high state of flow, boredom or anxiety within the respective manipulation. Based on the subject's verbalization, we will identify a 30-second interval in each of the boredom, flow, and anxiety conditions for data analysis. The most stable 30-second interval of the resting condition will also be identified and treated as a baseline to compare with the 30-second intervals of the other three main user states.

Data analysis will be carried out on the EEG measurement of the various states to understand their neural correlates.

CONCLUSION AND EXPECTED CONTRIBUTION

From this research, we will gain a better understanding of the neural correlates of user states of experience and offer theoretical and practical implications. From a theoretical perspective, our study will help to map the user states of flow, boredom, and anxiety to neural activities of the brain. From the practical perspective, it will help to offer more reliable and accurate feedback to designers, developers, and usability specialists to improve the overall user experience of computer-based systems. In addition, we will develop predictive models that can provide insights and guidance for brain-computer interface (BCI) initiatives to better monitor and assess dynamic fluctuations in users' cognitive states. The long-term goal of this research is to develop neural correlates of user experience that extend beyond flow, boredom, and anxiety to other user states such as apathy, addiction and frustration.

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