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Neurophysiological correlates of cognitive absorption in an enactive training context

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ABSTRACT

Various aspects of intrinsic motivation have long been theorized as key determinants of learning achievement. The present research seeks deeper insights into these intrinsically motivating mechanisms by investigating neurophysiological correlates of cognitive absorption in the context of enactive learning, specifically simulation-based training on the use of enterprise resource planning (ERP) software. An experiment was conducted in which 36 student trainees used ERP software to make decisions while running a simulated company. Consistent with flow theory, skill, difficulty, and their interaction significantly influenced cognitive absorption (R^2 = .16). Five neurophysiological measures were captured for each trainee: EEG alpha, EEG beta, electrodermal activity (EDA), heart rate, and heart rate variability. Each of the five neurophysiological measures explained significant unique variance in cognitive absorption over and above skill, difficulty, and their interaction, and collectively more than doubled the explained variance to R^2 = .34. Overall, cognitive absorption was positively related to a more relaxed, less vigilant state. Cognitive absorption was significantly related to the training outcome. These findings provide new insights into the psychological states that are conducive to experiencing cognitive absorption during enactive training.

1. Introduction

End-user training has long been recognized as a key factor in the acceptance and effective use of information technology (IT) (Compeau & Higgins, 1995; Nelson & Cheney, 1987). The objective of end-user training is to produce a skilled user who is motivated to apply this newly acquired knowledge in order to perform a job-related task (Gupta, Bostrom, & Huber, 2010). Moreover, organizations are investing significant resources in end-user training. According to the US Bureau of Labor Statistics, every year over 170 Billion US$ is spent on employee training and development; the American Society for Training and Development (ASTD, 2011) estimates that IT training accounts for 10% (on average) of all formal learning hours over the past ten years. Research shows that poor or insufficient training results in limited acceptance of the technology, which prevents organizations from fully realizing the benefits from these significant new investments (Compeau & Higgins, 1995; Nelson & Cheney, 1987). For example, undertrained end-users could cost five to eight times more to support than a well-trained worker (Fiering & Kirwin, 2006).

Among the various techniques used to train IT users, researchers call for more enactive methods (De Freitas & Jarvis, 2007; Derouin, Fritzsche, & Salas, 2005; Hays, 2005; Hedberg, 2003; Kirkle, Tomblin, & Kirkley, 2005; Mayo, Singer, & Kusumoto, 2006). Enactive learning is based on social cognitive theory (Bandura, 1986) and is a form of observational learning that involves learning as a consequence of one's interaction with and feedback from the environment. Gupta et al. (2010) provides evidence that combining enacting learning with vicarious learning (learning by observing others) leads to better training outcomes compared to vicarious learning alone. Realistic simulations provide a training context that generates relevant feedback in response to learner actions. More research is needed to properly understand such enactive learning in IT training (Martocchio & Webster, 1992; Sein, Bostrom, & Olfman, 1999). Computer-based simulation games have been demonstrated to be more effective than alternative forms of training for teaching work-related knowledge and skills (Sitzmann, 2011). Moreover, computer-based simulation games more readily incorporate enactive learning (as opposed to learners simply observing others). Consequently, the advantages of computer-based

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simulation training are theorized to result primarily from intrinsic motivation experienced by trainees when they actively engage in learning the training material (Sitzmann, 2011). Léger et al. (2012) report that learning is perceived to occur moreso during the enactive period (such as during a simulation of an IT training) as compared to other more direct instruction periods (such as a more formal presentation). While the literature provides evidence of the effects of affective and cognitive states on training outcomes, further investigation is needed on the impact of such psychological states on training effectiveness in enactive learning contexts (Gupta et al., 2010).

The present research focuses on the relationships between neurophysiological measures and the cognitive and affective states related to effective enactive IT training. The purpose of the paper is to determine the relationships, if any, that exist between neurophysiological measures and cognitive absorption (CA). Specifically, the paper focuses on the relationships between individuals' cognitive absorption (and its dimensions) and EEG (electroencephalography), EKG (electrocardiography), EDA (electrodermal activity) and HR (Heart rate). Understanding these relationships could further enhance end-user and IT training as well as user acceptance of technology and systems. Moreover, the results of such studies not only contribute to the current call for research on end-user training, but also point to the importance of considering neurophysiological factors along with trainees' experience and task difficulty when developing effective IT training. Enactive training programs can perhaps be designed to induce neurophysiological states that will result in more efficient and better use of the technology. Such insights could open up new frontiers for advancing the development of more efficient, effective, and enjoyable training environments; and hence, enhanced user acceptance and efficient use of technology. Given the continuing high failure rate of new information systems implementations, much of which can be directly attributed to inadequate training practices, the quest for such insights warrants urgent attention.

2. Cognitive absorption

Based on flow theory (Csikszentmihalyi, 1990), cognitive absorption is conceptualized as a state of deep involvement with IT (Agarwal & Karahanna, 2000). Research suggests that cognitive absorption significantly affects trainees' behavioral intention to use the target information system both directly and through its indirect effects via perceived usefulness and perceived ease of use (Agarwal & Karahanna, 2000; Saadé & Bahli, 2005; Scott & Walczak, 2009; Shang, Chen, & Shen, 2005). Stated differently, training that can enhance cognitive absorption is of high interest because it is theorized to lead to better training outcomes and, in turn, enhanced acceptance and more effective use of information systems. Neuroscience provides insights into how brain activity changes during the acquisition of a new skill or competence (Hill & Schneider, 2006). Initial skill acquisition places great demands on domain-general control circuitry generally located in the prefrontal cortex (Hill & Schneider, 2006). As a learner becomes more effective at a task, activity in the prefrontal areas of the brain reduces significantly (specifically in regions related to task control and working memory). As a new cognitive skill is acquired, one evolves from a state of controlled processing of stimuli to more automatic and effortless processing involving subcortical circuitry.

A cognitively absorbed IT user is intrinsically motivated and in a state of deep attention that consumes all of this individual's resources (Saadé & Bahli, 2005; Shang et al., 2005). CA has been conceptualized by Agarwal & Karahanna (2000) as a multi-dimensional construct with five dimensions – *temporal dissociation* (the inability to register the passage of time while engaged in interaction), *focused immersion* (the experience of total engagement where other attentional demands are ignored), *heightened enjoyment* (the pleasurable aspects of the interaction), *control* (the user's perception of being in charge of the interaction), and *curiosity* (the extent to which the experience arouses an individual's sensory and cognitive curiosity). There is longstanding theory and research linking various aspects of intrinsic motivation and cognitive absorption in learning achievement context (Ryan & Deci, 2000; Skinner, 1996), but also in other contexts such as online shopping and social media.

CA is theoretically rooted within the concepts of absorption (Tellegen & Atkinson, 1974), cognitive engagement (Webster & Ho, 1997), and flow (Csikszentmihalyi, 1990). According to flow theory (Csikszentmihalyi, 1990), individuals experiencing this state are so intensely concentrated on the event that they lose track of time, and feel in total control of the situation. It is also theorized that in such as state, "people are willing to do an activity for its own sake, with little concern for what they get out of it" (Csikszentmihalyi, 1990: 71). The balance between the challenge of a task and the skills required to execute this task is generally seen as a key antecedent to the emergence of a flow state (Csikszentmihalyi, 1990). When the level of difficulty under a specific task matches the skills, the individual is then able to perceive being in control of the task at hand, and can devote all their attention to its realization. The task must present sufficient challenges so that the resources of the individual are fully dedicated to its realization. In contrast, when the difficulty outmatches the skill, the individual is likely to be too anxious to achieve a flow state. Similarly, if the difficulty is too low for the given skill, the individual is likely to be bored. For an application of this concept in the context of sports, see Ellis and Voelkl (1994).

Rani, Sarkar, and Liu (2005) report the self-perceived psychological state of players in video games under various difficulties. Their results show that, when a player perceives that the difficulty is too low, subjects seem to be bored, and when the difficulty is too high, subjects are perceived as being anxious. Subjects who were reported being in a state of flow were neither bored nor anxious. Nacke and Lindley (2008) show that, when there is a linear progression of difficulty, players are more likely to build their skills, and over time achieve a self-reported state of flow. They also find that when players are faced with an initial difficulty which surpasses their skill level, the anxiety of the player makes it very unlikely to achieve a state of flow. Drachen, Yannakakis, Nacke, and Pedersen (2009) find similar evidence by manipulating the level of skills within a gaming context under various levels of difficulty; their results support the emergence of the various states of mind described by Ellis and Voelkl (1994) when skills and challenge are not balanced.

3. Neurophysiological correlates of cognitive absorption

Hanin (2000) proposes a framework to capture the psychological and physiological states of the flow state for an individual task. Their model suggests that the overall psychophysiological disposition of an individual is also an important factor in being able to achieve a state of flow. In this framework, the psychological dimension refers to the affective, cognitive, and motivational components; while the physiological dimensions consist of behavioral and bodily-somatic factors. According to Hanin (2000), both psychological and physiological dimensions are essential to understand cognitive and emotional conditions underlying a flow state. Peifer (2012) proposes an integrative definition of flow experience which states that flow is a positive valence state (affective component), resulting from an activity that has been appraised as an optimal challenge (cognitive component), characterized by optimized