Psychophysiological Measures of Cognitive Absorption

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ABSTRACT

Cognitive absorption (CA) corresponds to a state of deep involvement with a software program. CA has widely been studied over the last decade in the IT literature using psychometric instruments. Measuring ongoing CA with psychometric tools requires interrupting a subject's ongoing usage behavior to self-evaluate their level of absorption. Such interruptions may alter or contaminate the very CA state the researcher us attempting to measure. To circumvent this problem, we are investigating the effectiveness of psychophysiological measures of cognitive absorption. This paper reports preliminary results from an ongoing research project by looking at the correlation between electrodermal activity (EDA) and several dimensions of the CA construct.

Keywords

Cognitive absorption, electrodermal activity, ERP system

1. INTRODUCTION

Cognitive absorption (CA) is a state of deep involvement with a software program (Agarwal et al. 2000).. CA has widely been studied over the last decade in the IT literature using psychometric scales that ask subjects to self-evaluate their level of absorption. (Lin, 2009; Shang et al. 2005, Rutkowski et al, 2007, Magni et al. 2010). Paradoxically, such an approach may take the subject out of the cognitive absorption state in order to answer the survey.

To circumvent this problem, we investigate the potential of measuring CA using a psychophysiological method - electrodermal activity (EDA). This paper reports preliminary results from an ongoing research project which investigates the psychophysiological measures of CA. This project is investigating the correlation between several psychophysiological measures and the different dimensions of the CA. The goal of this project is to explore the predictive perceptions of CA based on an objective psychophysiological measurement. This research is consistent with the call for more triangulations in IT research and in the use of neurophysiological measurement tools in order to seek convergent validity of current IT psychometric tools (Dimoka et al. 2010). The main objective is not to replace the existing IT validated constructs, but to complement and enrich them with other sources of empirical evidence which were previously hard to collect in a valid and reliable way.

This paper shows early results from a pre-test conducted with four enterprise end-users involved in a simulation game based training over a period of 12 hours. Preliminary results seem to suggest correlations between EDA and several dimension of the CA construct.

2. LITERATURE REVIEW

2.1 Cognitive absorption

CA is theoretically rooted in the concepts of *absorption* (Tellegen and Atkinson 1974), *flow* (Csikszentmihalyi 1990), and *cognitive engagement* (Webster and Ho 1997). A cognitively absorbed IT user is conceived to be intrinsically motivated and in a state of deep attention that consumes all of this individual's resources (Shang et al. 2005; Saade et al. 2005). According to the theory of flow (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.

CA has been conceptualized by Agarwal et al. (2000) as a multi-dimensional construct with five dimensions: *Temporal dissociation* (the ability 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).

Prior research suggests that CA significantly affects behavioural intention through perceived usefulness and perceived ease of use (Agarwal et al. 2000). This effect has been replicated in various IT contexts, such as virtual communities (Lin 2009), online learning (Saade and Bahli 2005), online shopping (Shang et al. 2005), and exploration of a new technology (Magni et al. 2010). CA has also been used to observe the performance of teams

(Rutkowski et al. 2007) and the enhancement of computer self-efficacy on technology acceptance in an ERP training tool context (Scott and Walczak 2009).

2.2 Psychophysiological correlates of flow related constructs

Previous studies outside the context of information systems use report significant correlations between several psychophysiological measures (e.g. EKG, EDA and EEG) and different dimensions of flow-related constructs (Drachen et al. 2010; Mandryk et al. 2007; Nacke, 2009, Yannakakis, 2008). Considering the preliminary nature of this investigation, we have chosen to only focus on electrodermal activity (EDA) to conduct this pre-test.

EDA - also called galvanic skin response or skin conductance (Boucsein 1992) - refers to the production of sweat in the eccrine sweat glands, which is entirely controlled by the human sympathetic nervous system Cacioppo (2007). EDA is an index of autonomic nervous system activity measured by the potential difference between two areas of the skin; increased sweat gland activity is related to electrical skin conductance. EDA has been widely used as an objective measure of emotional arousal and research suggests significant correlation with valence (Lang 1995; Bradlet et al. 1993).

In the HCI literature, various researchers have investigated the link between flow and EDA. Nacke (2009) finds that players in a flow condition are likely to have a significantly higher level of EDA, and therefore are more physically aroused, than in other non-flow conditions. Also, Drachen et al. (2010), results suggest that high level of EDA is related to flow-related emotions, such as frustration. Mandryk et al. (2007) also find a correlation with a level of perceived challenge and excitement. These results are in line with Frijda (1986) who reported high correlation between task difficulty and the electrodermal activity.

3. METHOD

3.1 Subjects

Four subjects were tracked in a simulated based-training on SAP. The subjects were all new trainees in a large Fortune 1000 organization. None of the subjects had experience with SAP. All four participants voluntarily consented to take part in this research, which had been approved by the IRB of HEC Montréal and University of Arkansas. The four subjects were all part of the same team and competed against four other teams in the simulation.

3.2 Procedure

A simulation technology, called *ERPsim,* used to simulate a realistic usage context of an ERP system (Léger 2007; Léger et al. 2007). End-users are placed in a situation where they must make decisions and manage the operations of their enterprises using a real-life ERP system (SAP). One key characteristic of ERPsim is that all decisions made by the participants must be entered into the ERP system and acted upon based on information from extracted standard reports within the ERP system. One can think of ERPsim as a flight simulator for ERP system where end-users are flying a real corporate information system in a virtual business environment.

Phychophysiological data were gathered using the Procomp Infinity encoder from Thought Technology. Upon consent, skin conductance sensors were attached to the palm of the participants' hands using pregel electrodes.

The training lasted 12 hours and spanned a consecutive two-day period. The subjects played nine rounds of the simulation; each round was preceded by a discussion period and followed by another round consisting of 30 virtual days of simulation (every virtual day lasted, on average, one minute).

3.3 Psychometric measurement

During the simulation games, the CA survey was answered at the end of each round, i.e. on the 30th day. Each of the five dimensions (temporal dissociation, heightened enjoyment, curiosity, focused immersion and control) was measured by 3 items that were adapted from Agarwal et al. (2000) to the context of usage.

To further triangulate the measurement of the emotion, we also used the SAM (Self-Assessment-Manikin) scales to obtain a self-perceived evaluation of the emotion experienced by the subject during the experiment. Introduced by Lang (1995), the SAM five state scales use pictures of manikins in order to measure three emotional dimensions: *Valence* (happy to unhappy), *Arousal* (calm to excited) and *Dominance* (controlled to in-control). Participants were asked to rate their feelings by clicking on or in-between manikins that best represent their emotions. All four subjects had to answer the SAM survey on days 1, 15 and 30 of each round during the simulation.

Each of the four participants had to answer the survey 25 times, leading to 100 observations; 64 observations included only the SAM items (i.e. survey answered on days 1 and 15) and 36 observations included both the SAM items and CA items (i.e. survey answered on day 30).

3.4 Data processing and analysis

EDA data was collected at 32 HZ and was processed using Matlab (signal processing, curve fitting and financial toolboxes) Following Cacioppo (2007), we have normalized and transformed each sample in the percentage of the span of the signal of a given round in the game (including the discussion period); a minimum and a maximum were identified for each participant for every round of the game. The % EDA was calculated as follows:

$$\% \text{ EDA} = \left(\frac{\text{EDA}_\text{i} - \text{EDA}_\text{min}}{\text{EDA}_\text{max} - \text{EDA}_\text{min}}\right)$$

Each time a survey was answered, we have calculated the instantaneous % EDA, as well as the *EDA moving average* and the *EDA moving standard deviation* over 4 windows: 1, 2, 5 and 10 minutes.

Finally, the financial *profit* results of the team was standardized in a Z score to take into account the performance of the team in relation with the performance of the others.

4. RESULTS AND ANALYSIS

Given the number of observations, spearman's rho was used to measure the relationship between the research variables.

We have found that *heighted enjoyment* to be positively correlated with *valence* (0.49, p= 0.003), arousal (0.43, p= 0.008) and *dominance* (0.47, p= 0.004). In addition, a *standardized profit* is strongly correlated with *valence* (0.42, p= 0.000), *arousal* (0.35, p= 0.000) and *dominance* (0.25, p= 0.014), while *heighted enjoyment* is not related to *standardized profit* (0.13, p value .463); this could be indicative that making a profit is not required for subjects to achieve this component of the flow. Not surprisingly, *curiosity* is correlated with *valence* (0.48, p= 0.003), and *control* with *dominance* (0.57, p= 0.000).

Interestingly, *temporal dissociation* is negatively correlated with *standardized profit* (-.35, p= 0.038). It would suggest that the less profit one makes, the more temporal dissociation this person will feel. It is possible that lower profit increases the challenge and therefore the temporal dissociation dimension of CA. This result is consistent with previous findings by Mandryk et al (2007) on the impact of perceived challenge on the flow experience. *Curiosity*, a useful attitude for learning in a problem solving context, is positively correlated with *standardized profit* (0.36, p =0.03).

Table 1 illustrates the correlation between EDA and all psychometric variables, as well as *standardized profits*. Unexpectedly, EDA does not correlate with *arousal* but seems to be correlated with *valence*. While the correlation with *valence* is not unusual (see Bradlet et al, 1993), the lack of association between EDA and arousal needs to be further investigated. One possibility would be the wording of the arousal scale in a business context as one may be less inclined to admit being "exited", while being "happy" is more socially acceptable. Future research might benefit from using facial EMG to capture positive and negative emotions to further explore these relationships.

We find positive and significant correlations between the *EDA moving standard deviation* and two dimensions of the CA construct: *curiosity* and *focused immersion*. This result implies that the more variations in EDA over the four timespans (1, 2, 5 and 10 minutes), the more focused and curious the subjects felt. In other words, the subjects felt more immersed and driven by curiosity when variation in EDA is experienced. These variations might be triggered by a problem solving situation that requires a cognitive absorption state of mind, and specifically *focused attention* and *heightened curiosity* to find the right solution.

5. CONCLUDING COMMENTS

This research is still at an early stage and preliminary results were obtained using a sample of only four subjects. However, the results are promising and support the continuation of the data collection. Our next step includes capturing other biosignals, such as electrocardiogram (ECG), facial electromyography (EMG), and electroencephalogram (EEG). Also, the next stage of this research also requires incorporating ERP usage data (clickstream) to better contextualize and interpret the cognitive absorption in the context of a large corporate information system.

		Valence		**Arousal**		**Dominance**		**Temporal dissociation**		**Heighted Enjoyment**		**Curiosity**		**Focused immersion**		**Control**		**Profit**	
	Electrodermal response	Corr.	sig	Corr.	sig	Corr.	sig	Corr.	sig	Corr.	Sig	Corr.	sig	Corr.	sig	Corr.	sig	Corr.	sig
	% EDA	.248	**	.007		.119		-.135		.173		.202		.119		-.050		.174	*
Moving average	1 min	.267	***	.061		.158		-.237		.154		.122		-.028		.071		.191	*
	2 min	.238	**	.033		.175	*	-.158		.026		.005		-.131		.145		.151	ns
	5 min	.228	**	.040		.155		-.017		.024		-.055		-.170		.122		.096	ns
	10 min	.171	*	.010		.075		-.032		.010		.011		-.151		.033		.113	ns
Moving standard deviation	1 min	.088		.084		.016		.121		.008		.375	**	.255		-.244		.229	**
	2 min	.008		-.052		-.094		.134		-.030		.381	**	.314	*	-.239		.177	*
	5 min	.035		-.056		-.018		.112		-.013		.271		.467	***	-.203		.222	**
	10 min	.031		.017		.129		.233		.134		.299	*	.506	***	-.050		.265	***

Table 1 - Correlation between EDA, psychometric measures and profits

Non parametric correlations (Spearman Rho).

Number of observation varies (Valen, Arousal, Dominance and Profit were measured 100 times, while Temporal dissociation, Heighted Enjoyment, Curiosity, Focused immersion, Control were measured 36 times).

**** $p < 0.001$, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

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