Using transcranial Direct Current Stimulation (tDCS) to Assess the Role of the Dorsolateral Prefrontal Cortex in Technology Acceptance Decisions: A Pilot Study

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Introduction. Recent evidence suggests dissociation between important technology acceptance research constructs in the brain, specifically perceived ease of use (PEOU) and perceived usefulness (PU) (Dimoka et al. 2011). PEOU was reported to be linked to activity in the dorsolateral prefrontal cortex (DLPFC), a structure associated with cognitive effort and working memory, along with many other mental processes (Ridderinkhof et al., 2004). PU, in contrast, was associated to brain activity in the caudate nucleus, the insula, and the anterior cingulate cortex, three structures that do not reside in the frontal lobes of the brain, and which are therefore, at least theoretically, less likely involved in cognitive processing or deliberate reflective thought processes. Dimoka et al.'s (2011) descriptive study was a useful pilot study in revealing neural correlate candidates of technology acceptance constructs. Given the importance of technology acceptance studies in Information Systems (IS) research, further investigation is necessary (a) to validate these original results and (b) to draw causal inferences since Dimoka et al. used fMRI to study the neural correlates underlying technology acceptance decisions, making direct causal inferences impossible.

In this paper, we assess the role of the DLPFC in technology acceptance decisions by using transcranial Direct Current Stimulation (tDCS). This tool allows for modulation of the excitability of a precise cortical structure. tDCS has been used for almost 20 years in cognitive neuroscience research in order to pinpoint the particular role of different cortical structures and to treat some psychiatric disorders (Nitsche et al. 2009). Depending on the parameters of the stimulation, it can either increase or decrease the excitability of the targeted structure. A reliable placebo condition can also be implemented with this technique, enabling a valid control condition.

Background Literature. One of the major contributions of NeuroIS research is that implicit processes leading to the formation of beliefs and decisions can now be assessed in a different way if compared to traditional IS research, where scholars often solely relied on the explicit report of the users (Riedl et al. 2010). For instance, Ortiz de Guinea et al. (2013) showed that implicit and explicit measures of PEOU (and PU) interact in a non-linear fashion. Thus, it is unlikely that the DLPFC's activation exclusively and predictably influences explicit measures PEOU. In addition, given the known functions of the DLPFC (e.g., spatial information processing and motor planning; see Hoshi (2006) for a review), it is more likely that this structure plays a role in the implicit aspects preceding the explicit report of PEOU. In order to assess how this transition from implicit to explicit occurs, influencing the plausible implicit precursors to the explicit measures is important. Specifically, to test the relationship between PEOU and DLPFC, prior research has used fMRI data and a website evaluation task (Dimoka et al. 2011, pp. 695-698). However, in order to ascertain this relationship with greater validity, data with higher temporal resolution (e.g., EEG instead of fMRI) is needed, ideally based on actual online shopping purchase decisions. Moreover, the causal impact of brain stimulation (i.e., tDCS) on DLPFC excitability allows a more reliable assessment of the functional role of this brain structure in technology acceptance decisions.

Generally, by DLPFC stimulation, we sought to determine whether this structure plays an important role in human interaction with computer interfaces. We expect that the participants' explicit statements about PEOU of a computer system will be altered, either positively or negatively, as a function of DLPFC excitability (which we either increased or decreased through tDCS). Considering the previous findings reported in Dimoka et al. (2011), we hypothesize that in a condition where the left DLPFC's excitability is decreased, a user's rating of PEOU should be lower, if compared to control conditions. Moreover, considering the results of Dimoka et al., PEOU should decrease to a larger extent than PU when DLPFC is manipulated.

Method. Our approach relies on finding the impact of a structure's activation on different aspects of a task, instead of going the other way around (i.e., trying to find

which structures are involved in an aspect of a task). The tDCS system, shown in Figure 1, consists of two electrodes linked to a specially designed case. This case delivers a small and controlled amount of electric current (1.5 mA in our case) between the two electrodes. In order for current to be safely delivered to the skull, the electrodes are inserted in small sponge sleeves soaked in saline. When applied on the skull, the current passes through the cerebral structures in between the two electrodes, mostly following in the nerve fibers between them (Sparing & Mottaghy 2008). Hence, a bilateral stimulation of the DLPFC, for example, would require that an electrode is placed on each DLPFC and depending on the direction of the current, either the right cortex's excitability is increased and the left ones decreased, or the left cortex's excitability is increased and the right ones decreased. Except for a tingling or itching sensation at the stimulation site on the scalp, no other major adverse effect is observed when standard safety procedures are followed.

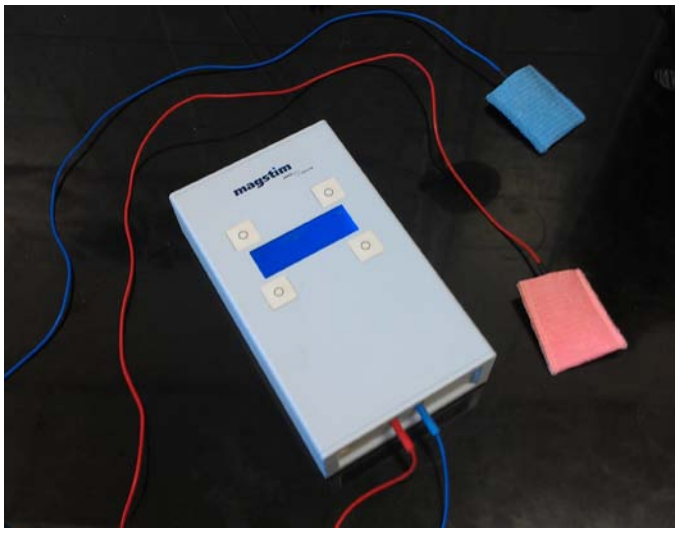

Figure 1. Magstim tDCS device

In order to test the relationship between PEOU and DLPFC we performed a laboratory experiment. The study was approved by the research board of the Université de Montréal. Participants were given information about tDCS before the experimental session took place and only those who were completely comfortable with the procedure took part in the experiment. Special attention was given to the participant's reaction to tDCS and the research assistants emphasized the possibility to terminate the experiment at any time. However, no participant reported discomfort important enough for them to stop the procedure. tDCS typically induces a warm tingling sensation on the sites of stimulation for about 30 seconds at the beginning and the end of the procedure.

A Magstim DC stimulator (London, UK) was used to deliver the tDCS stimulation for 15 minutes at 1,5 mA. The electrodes were placed on the left and right DLPFC, corresponding to the F3 and F4 sites of the 10-20 system. During the task, eye movements were also recorded using a Tobii X60 system. Moreover, heart rate, respiration, and skin conductance were recorded using Biopac instruments. Cerebral activity was recorded at all times except during the stimulation using EGI 32 electrodes nets.

Participants had to purchase music on a given website over multiple visits. The experimental protocol is illustrated in Figure 2 and described in the following. In the specific context of purchasing music online, Sénécal et al. (2012) showed that at least three visits are necessary to be cognitively locked-in to a music website; i.e., when a user's cognitive load has stabilized. Given the known impact of tDCS on learning (Fritsch et al., 2010), tDCS was used once this stabilization of the behavior was established.

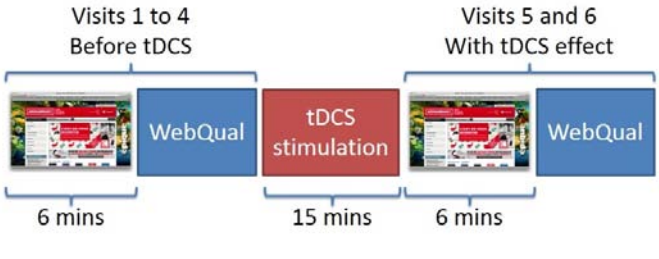

Figure 2. Experimental protocol

Based on Dimoka et al.'s (2011) and Senecal et al.'s (2012) findings, once the user has a stable cognitive script to use a given system (in our case a website), manipulating the brain structure that presumably underlies PEOU should influence the user's perception of the system, and maybe even affect his or her behavior with that system. By keeping the stimulus constant and altering the excitability of the DLPFC, it is possible to understand the causal role of this structure in a user's interaction with the system, and also interactions between PEOU and PU can be established at a neural level.

The website the participants visited was of average PEOU and PU (based on a pretest evaluation of expert coders who performed the experimental task on the given website). Altogether, participants had to go through the process of choosing and buying a song online six times (see Figure 2). Each visit lasted a maximum of 6 minutes in order to have a relatively constant exposition to the website. After each visit, participants completed a questionnaire assessing the website PEOU and PU using Loiacono, Watson, and Goodhue's (2007) Webqual measurement scale. Forty-five participants (3 groups of 15) underwent the experimental protocol. The first group received right anodal and left cathodal stimulation, the second group received right cathodal and left anodal stimulation and the third group received placebo stimulation. The three groups consisted of 9, 5, and 10

females, and the average age was 22.41, 23.46, and 23.8 (SD: 2.64, 2.84, and 3.01).

Preliminary Results. Scores of the WebQual (Loiacono et al., 2007) were obtained after each visit and the scores were calculated separately for PEOU and PU. The results were standardized using Z scores and are reported in Table 1 and Table 2.

Table 1. PEOU scores for each visit, by group (average (std. deviation))

Visit	Anodal stimulation	Cathodal stimulation	Placebo stimulation
1	-.261 (1.25)	.370 (.937)	-.167 (1.16)
2	.028 (.903)	.328 (1.10)	-.177 (.919)
3	-.205 (1.09)	.313 (1.11)	-.255 (.865)
4	-.211 (1.04)	.416 (1.16)	-.373 (.819)
5	-.194 (.941)	.354 (1.16)	-.182 (.844)
6	-.200 (.902)	.370 (1.02)	-.084 (764)

Table 2. PU scores for each visit, by group (average (std. deviation))

Visit	Anodal stimulation	Cathodal stimulation	Placebo stimulation
1	-.270 (1.34)	.113 (1.05)	-.357 (1.06)
2	.308 (1.01)	.209 (1.05)	-.044 (.960)
3	-.127 (1.10)	.203 (1.05)	-.188 (.855)
4	-.114 (.976)	.161 (1.17)	-.267 (.929)
5	-.159 (1.02)	.258 (.951)	-.146 (.719)
6	-.003 (1.08)	.119 (1.15)	.053 (.750)

In order to determine if the modulation of the DLPFC's excitability changed the explicit reports of PEOU and PU, a repeated measures ANOVA comparing the three groups for each of the six visits was conducted. For PEOU and PU respectively, neither any between subjects main effect of group ($F(2) = 1.687$; $p = .199$), ($F(2) = .523$; $p = .597$), nor a within subject main effect of visit ($F(5) = .360$; $p = .875$), ($F(5) = 1.764$; $p = .122$) could be observed. The analysis also failed to find a significant interaction between these two variables ($F(10) = .456$; $p = .916$), ($F(10) = .185$; $p = .787$). As it was expected following Dimoka's results, modulating the DLPFC's excitability had no impact on subjective measures of PU. Altogether, our preliminary results point towards an absence of a specific effect of the DLPFC on technology acceptance decisions, at least with respect to the explicit report of PEOU.

In order to assess the implicit impact of the DLPFC on lower order cognitive processes potentially also involved in technology acceptance decisions, further neurophysiological and behavioral data is necessary. Methods similar to those used by Sénécal et al. (2012) could be applied.

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