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The effect of task based motivation on BCI performance: A preliminary outlook.

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Abstract

BCI technology can provide a non-muscular method of communication. In the P300-based BCI, users focus their attention on a specific item within an array of flashing items. After the BCI selects an item, it is presented on a computer monitor as feedback to the subject. In the BCI literature, only a few studies have examined motivation. The current study examined the effect of an intrinsic motivation induction on BCI performance in a non-disabled population. Participants were randomly sorted into two groups. Before participating in the experiment, one group (i.e., Motivation) was read a vignette describing the significance of BCI research for individuals with amyotrophic lateral sclerosis (ALS); the other group (i.e., non-Motivation) was not. The Motivation group performed at 89.7% accuracy in a copy-spelling task and the non- Motivation performed at 80.6% accuracy. Further, data showed that BCI use causes a mild increase in sleepiness. Future studies should look into the role of motivation and sleepiness on BCI performance within the ALS population.

Introduction

A brain-computer interface (BCI) using the P300 event-related potential offers an alternative method of communication. Originally introduced by Farwell and Donchin (1988), users are shown a matrix that randomly flashes alphanumeric characters. The participant's task is to focus attention on the item they wish to select. When the desired item flashes, a discriminable ERP is produced. Several paradigm and stimulus presentation modifications have improved speed and accuracy of the P300 BCI (e.g., Sellers, Arbel, and Donchin, 2013). However, few studies have examined psychological and situational factors that may affect BCI use. The current study examines the construct of motivation.

Motivation as a psychological construct is commonly divided into intrinsic and extrinsic categories. Intrinsic motivation implies that an individual pursues a goal for the enjoyment of doing so, while extrinsically motivated individuals pursue a goal in order to receive some sort of outside compensation for completing a task (Kruglanski et al, 1975; Gillet et al, 2011; Reiss; 2012).

Goldstein et al. (2006) used a monetary reward to show that P300 amplitude increase was positively correlated with the amount of money that could be earned. Kleih et al (2010) reported similar findings using a BCI task; P300 amplitude was higher for participants that reported higher a higher level of motivation. Monetary rewards can be problematic because they provide an external reward separate from simply succeeding at the task. Moreover, payment has been shown to decrease intrinsic motivation (Anderson et al, 1976).

In a clinical population, extrinsic motivation may not be as relevant. It is reasonable to propose that clinical use of the BCI in certain populations may be more intrinsic in nature. Kleih and Kluber

(2013) examined the effects of intrinsic motivation using verbal and visual prompts to explain the importance of BCI research for a clinical population. They found a significant effect of grouping, participants in the motivation condition reported higher levels of motivation; however, the groups did not differ in copy spelling accuracy.

In the current study, we focused on intrinsic motivation. It is likely that individuals who need or desire assistive communication will be more intrinsically motivated. Thus, we focused on task-based motivation, operationally defined as 'willingness to participate in a task' (Appel & Gilabert, 2002). In order to manipulate task-based motivation, we designed an information vignette in order to elicit a reaction from the participants that may increase their intrinsic desire to perform well. This is novel in that it does not provide extrinsic motivation or mention a performance standard; rather, the manipulation is in the form of a personal choice. Our hypothesis is that copy-spelling performance will be higher in the Motivation group (Mot) than in the non-Motivational (nMot) vignette group. Further, we hypothesize that those in the Mot group would have higher P300 amplitude than those in the nMot group.

Methods

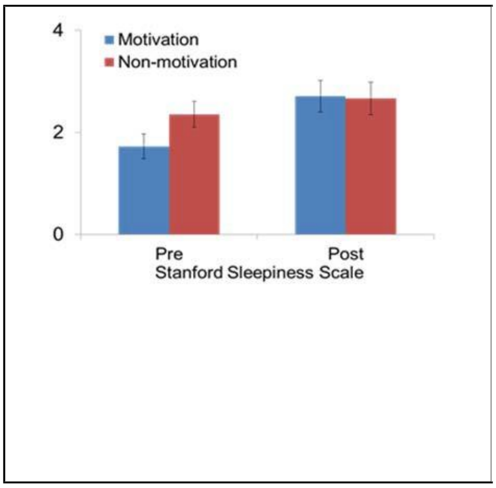

Figure 1. Pre and Post Stanford Sleepiness Scale means by group (range 1 – 7). Significant differences were observed between pre and post sleepiness scores. The Motivation group reported being less sleepy before the task than the Non-motivation group. Error bars represent Std. Error of teh Mean.

Thirty-six non-disabled students (11 male, 25 female) from East Tennessee State University participated in the study. Students were enrolled in psychology courses and received extra course credit for participating. The study was approved by the East Tennessee State University Institutional Review Board.

EEG was recorded with a 32-channel tin electrode cap (Electro-Cap International, Inc.). All channels were referenced to the right mastoid and grounded to the left mastoid. Impedance was reduced to below 10.0 kOhm before recording. Two Guger Technologies g.USBamps were used to record EEG data, which were digitized at 256 Hz, and bandpass filtered from 5 to 30 Hz. Stepwise linear discriminant analysis was used to classify ERP responses. Only electrodes Fz, Cz, P3, Pz, P4, PO7, PO8, and Oz were used for online BCI operation (Krusienski et al., 2006).

Upon arrival, students were randomly assigned to one of two categories: Mot (n=18) or nMot (n=18). The Mot participants were told that it was essential that their full attention and effort could be applied to the task. They were given the option of leaving without penalty (i.e., they would be awarded full extra credit if they felt as though they could not perform at top capacity). It was reasoned that those who agreed to participate even after being informed that they could leave without penalty would be more motivated to perform the task than those performing the task without prompting. The Mot participants were then read a vignette describing the importance of BCI research for severely disabled people who may eventually depend on BCI technology. The nMot group was not given the opportunity to leave upon arrival nor where they read the vignette.

Prior to completing a copy-spelling BCI task, all participants completed the Online Motivation Questionnaire (OMQ) (Boekaerts, 2002) and the Stanford Sleepiness Scale (SSS; Hoddes et al, 1973). The OMQ measures task-based motivation in a learning environment. The BCI task was novel to all of the participants; thus, we assumed it would be a good measure of motivation. The SSS was selected because BCI use may increase sleepiness, and there may be an interaction between motivation and sleepiness. After the participants completed the OMQ and the SSS, they were provided experimental instructions and completed the BCI task. Each participant copy spelled three randomly selected six- letter words. These data were used for calibration (SWLDA was used to derive the classification coefficients). After calibration, they copy spelled four randomly selected six-letter words and were provided with online feedback as to the accuracy of the BCI classification. When the BCI task was complete, each participant completed the SSS for a second time (i.e., post task).

Results

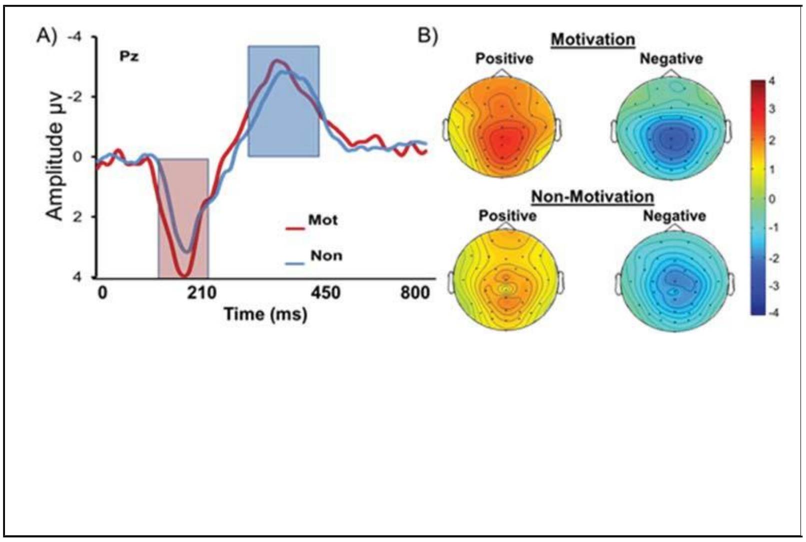

Figure 2. (A) P300 waveforms for the Motivation (red) and Non-Motivation (blue) conditions. The motivation condition resulted in higher early positivity and late negativity in the motivation condition. (B) Topography for the P300 for Motivation and Non-motivation conditions. The higher amplitude in the motivation waveform is observed for the positive and negative peaks. The data are averaged over the positive window of 145 - 182 ms (Figure 2A red box) and the negative window of 359 - 547 (Figure 2A blue box).

A 2x2 mixed model ANOVA (group (Mot vs. nMot) x SSS (pre vs. post score)) was used to examine whether sleepiness scores varied across group or time. Only the main effect of SSS score was significant ($F(1, 33)= 7.25$, $p=.004$; see Figure 1), indicating that both groups reported being more sleepy after the BCI session. However, mean scores were generally high; mean ratings were "awake but relaxed" after the session. Independent samples t-tests were used to examine motivation and accuracy. Motivation was statistically similar for the nMot and Mot groups ($t<1$, ns.) Accuracy was also statistically similar across the nMot and Mot groups ($t(27$; adjusted$)=1.84, p=.072$); however, accuracy in the Mot condition (Mean=89.7, SD=11.2) was higher than the nMot condition (Mean=80.6 SD=17.2).

The waveforms for the Mot condition showed higher early positivity and later negativity than the nMot condition. Although not statistically significantly different, the differences were in the hypothesized direction. Figure 2A shows Pz waveforms for the Motivation and non-Motivation groups. Figure 1B shows topographies that correspond to the shades boxes in panel 2A.

Discussion

This study examined the effect of an intrinsically based motivation induction on BCI performance and waveform morphology. The study revealed several noteworthy findings. Most importantly, the group that was exposed to the motivation induction was 89.7% accurate, whereas the group that was not exposed to the motivation induction was only 80.6% accurate. Although the difference in accuracy was not statistically significant, we suggest that the current findings have high practical significance. For example, based on a Monte Carlo simulation conducted by Sellers et. al. (2006), to produce an error corrected message containing 100 characters would require 130 selections at 90% accuracy and 170 selections at 80% accuracy. To put this finding into context, participants in the motivation condition would complete their message 12.45 minutes more quickly than participants in the non-motivation condition would complete their message. This is in spite of the fact that the motivation questionnaire did not reveal statistical significance. A possible explanation for this finding is that our motivation induction was not effective. However, this is unlikely because the ratings for both groups were near ceiling. Thus, the most likely explanation of this finding is that the questionnaire was not sensitive enough to detect existing differences in motivation. The waveform data support the ceiling effect explanation; higher early positivity and higher late negativity was observed for the motivation group.

The results also suggest that participants are sleepier after BCI use. Despite being sleepier, pre-experiment mean ratings were reported as: “Functioning at high levels, but not at peak; able to concentrate,” and mean post-experiment ratings were: “awake but relaxed; responsive but not fully alert.” It is recommended that future studies examine the effects of motivation and sleepiness in an ALS population. Presumably, people with ALS would have more intrinsic motivation to perform well. At the same time, people with ALS may become tired more quickly than non-ALS participants, which could cause frustration when sleepiness begins to affect accuracy.

References

Anderson, R., Manoogian, S.T., & Reznick, J. (1976). The undermining and enhancing of intrinisic motivation in preschool children. J Pers Soc Psychol, 34(5), 915-922.

Appel, C., & Gilabert, R. (2002). Motivation and task performance in a task-based web-based tandem project. Recall: Journal Of Eurocall, 14(1), 16-31.

Boekaerts, M. (2002). The on-line motivation questionnaire: A self-report instrument to assess students’ context sensitivity. In P. R. Pintrich & M. L. Maehr (Eds.) Advances in Motivation and Achievement, Volume 12: New Directions in Measures and Methods. (pp. 77-120). New York: JAI / Elsevier Science.

Farwell, L. A., & Donchin, E. (1988). Talking off the top of your head: Toward a mental prosthesis utilizing event-related brain potentials. Electroen Clin Neuro, 70(6), 510-523.

Gillet, N., Vallerand, R. J., & Lafrenière, M. K. (2012). Intrinsic and extrinsic school motivation as a function of age: The mediating role of autonomy support. Social Psychology Of Education, 15(1), 77-95.

Goldstein, R. Z., Cottone, L. A., Jia, Z., Maloney, T., Volkow, N. D., & Squires, N. K. (2006). The effect of graded monetary reward on cognitive event-related potentials and behavior in young healthy adults. Int J Psychophysiol, 62(2), 272-279.

Hoddes, E. (1973). Quantification of sleepiness: A new approach. Psychophysiology, 10(4), 431-436.

Kleih SC and Kübler A (2013) Empathy, motivation, and P300-BCI performance. Front. Hum. Neurosci. 7:642.

Kleih, S. C., Nijboer, F. F., Halder, S. S., & Kübler, A. A. (2010). Motivation modulates the P300 amplitude during brain–computer interface use. Clinical Neurophysiol, 121(7), 1023-1031.

Kruglanski, A. W., Riter, A., Arazi, D., Agassi, R., Montegio, J., Peri, I., & Peretz, M. (1975). Effect of task-intrinsic rewards upon extrinsic and intrinsic motivation. J Pers Soc Psychol, 31(4), 699.

Reiss, S. (2012). Intrinsic and extrinsic motivation. Teaching of Psychology,39(2), 152-156.

Sellers, E.W., Arbel, Y., Donchin, E. (2012). P300 event-related potentials and related activity in the EEG. In J.R. Wolpaw and E.W. Winter Wolpaw (Eds.). Oxford University Press Inc. NY. (pp. 215-226).