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The Effects of Motivation on Task Performance Using a Brain-Computer Interface

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Abstract

Non-invasive brain-computer interfaces (BCIs) provide communication that is independent of muscle control. Thus, BCIs are a viable communication option for severely disabled people. Most BCI research has focused on improving signal processing methods and paradigm manipulations. Examining psychosocial factors may be particularly important for disabled people who have several co-morbidities. The current studies hypothesize that participants will have higher motivation in a free-spelling paradigm than in a copy-spelling paradigm. In Experiment 1, non-disabled participants completed copy- and free-spelling tasks. Motivation was measured three times during each session. In Experiment 2, ALS participants completed the same BCI tasks and motivation was measured at the beginning and end of the session using a visual analogue scale and the Questionnaire for Current Motivation for BCI2000. Significant differences in motivation were not observed in either sample. In Experiment 1, the participants that completed the free-spelling task first had significantly higher accuracy on the subsequent copy-spelling task. No differences were observed in performance accuracy between the two tasks in Experiment 2.

Introduction

Noninvasive brain-computer interfaces (BCIs) use electroencephalogram (EEG) to provide non-muscular communication. A paucity of BCI research has considered how psychosocial factors affect task performance. Recent research suggests a need for studies that focus on specific qualities of BCI users, such as motivation and depression [Kleih et al., 2010; Nijboer, et al., 2010]. Examination of these factors may increase BCI performance by learning more about individual users, treating them as active participants, and addressing their specific needs. In the current studies, participants completed two tasks: copy- and free-spelling. After each task their motivation to perform the task was assessed with a visual analogue scale and one of two Likert scale measures. It is hypothesized that free spelling will lead to higher motivation and accuracy. This hypothesis is driven by the finding that autonomy in a task (such as free-spelling) is related to an increase in intrinsic motivation (Ryan & Deci, 2000). Learning about how and why a particular person may be motivated or unmotivated can help determine what tasks may lead to higher BCI performance by fully engaging participants in the task.

Experiment 1

Participants. Non-disabled participants (n=21) were recruited from the East Tennessee State University (ETSU) subject pool. All participants provided informed consent and the study was approved by the ETSU Institutional Review Board.

Materials. Guger Technologies g.USBamps were used to record EEG data, which were digitized at 256 Hz, and bandpass filtered from 0.5 to 30 Hz. Stimulus presentation, EEG data collection, and online processing were controlled via BCI2000 [Schalk, et al., 2004]. Stepwise-linear discriminant analysis (SWLDA) was used for classification. Eight electrode locations were used: Fz, Cz, Pz, Oz, PO7, PO8, P3, P4.

Methods. Participants were instructed to attend to a target item, by mentally saying or counting the item, when it flashed. Stimuli were presented in an 8x9 (72-item) matrix. Stimulus duration was 62.5ms with an SOA of 125ms (ISI=62.5ms). Copy- and free-spelling tasks were counter balanced for each subject. Before the copy- and free-spelling tasks, each participant copy spelled 18-characters without feedback. These data were then used for calibration. The resulting classifiers were used for online copy- and free-spelling tasks. The words used for calibration and in the online copy-spelling task were randomly selected from a database of 6,000 words.

The copy-spelling task consisted of three six-letter words presented as one string with a space in between each word (20 total selections). In the free-spelling task, participants constructed their own sentence. The sentence ranged from 20-24 characters. Before the free spelling task, each participant wrote his or her sentence on a sheet of paper (to calculate accuracy). They were also instructed to correct selection mistakes using the BACKSPACE character (denoted "Bs"). If the participant had not completed the sentence before the limit of 24 character selections the task was terminated by the experimenter in order to keep the number of character selections on the free-spelling task between 20 and 24 characters in length.

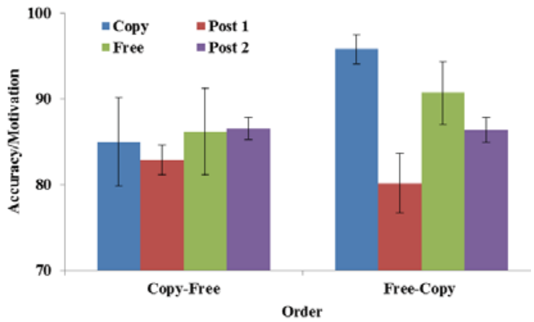

Figure 1: Average performance accuracy for the copy-, and free-spelling tasks, post 1, and post 2 motivation scores organized by task order.

In addition to the BCI tasks, participants also completed two surveys: the Stanford Sleepiness Scale (SSS), which was used to measure fatigue, [Hoddes et al., 1973] and the On-Line Motivation Questionnaire (OLMQ), which was used to measure motivation [Boekaerts, 2002]. The SSS and OLMQ were administered three times throughout the session. The OLMQ consists of pre- and post-task components. The pre-task OLMQ was completed before the first BCI task, the post OLMQ was completed after each of the two BCI tasks. The SSS was completed before the first BCI task and after each of the two BCI tasks.

Results

Performance accuracy for the copy-spelling condition was calculated by dividing the number of correct selections by the number of total selections. Performance accuracy for the free-spelling condition was calculated by comparing the message completed through the BCI to the intended message. Mean accuracy in the copy- and free-spelling conditions did not show a significant difference (91.19% and 88.71%, ($t<1$)). No significant differences in OLMQ scores were observed at any of the three time points (pre, post 1, and post 2). Similarly, SSS scores were not significantly different across the three time points. For BCI accuracy there was an order effect. The participants who completed free-spelling first had significantly higher accuracy in copy-spelling task than the participants in the copy-free order ($F(1, 19)=5.617$, $p=.029$). Figure 1 shows the relationship between motivation and accuracy for the copy- and free-spelling tasks and post 1 and post 2 motivation.

Experiment 2

Participants. Participants with ALS (n=6) were recruited based on participation in previous studies. All participants provided informed consent and the study was approved by the ETSU Institutional Review Board. ALSFRS-r scores were recorded for all participants indicating level of functionality ranging from 0 (completely locked-in) to 48 (fully functional). ALSFRS-r scores were as follows: 1, 5, 21, 30, 33, 33.

Materials. The materials were identical to Experiment 1 except that only one 16-channel amplifier was used and the cap contained 16 instead of 32 electrodes.

Methods. Participants wore a 16-channel electrode EEG cap and attend to a screen that presented a 6x6 item matrix. In contrast to Experiment 1, stimulus duration was 187.5ms and ISI was 62.5ms. In general, we have used longer stimulus durations when testing people with ALS [Townsend et al., 2010]. All other methods were the same as those used with the non-disabled participants.

Participants with ALS also completed two survey instruments: visual analogue scales were used to measure motivation and mood and the Questionnaire for Current Motivation for BCI2000 (QCMBCI2000) was used to measure motivation [Kleih, Nijboer, Halder, & Kübler, 2010]. The researchers found the QCMBCI2000 after the first experiment was competed and decided to use it as a measure of motivation for the second experiment since it has been previously used to measure motivation to perform a BCI task in people with ALS. The visual analogue scales for motivation and mood and the QCMBCI2000 were given to participants with ALS twice; once at the beginning of the session and once at the end of the session. At the conclusion of the session, participants were asked a qualitative question describing their motivation for participating in the study (i.e., "What was your motivation for participating in this study?"). This served as additional data to confirm participants' responses to the surveys. The majority of participants described their main motivation as helping others to communicate.

Results

Mean accuracy in the copy- and free-spelling conditions did not show a significant difference (73.33% and 83.33%, respectively (t<1)). The visual analog scale for motivation was not statistically different at pretest (9.60) and posttest (9.19; *p*=.52). Similarly, the visual analog scale for mood did not show a significant difference at pretest (8.75) and posttest (8.47; *p*=..64).Figure 2 shows the relationship between accuracy and motivation organized by the order in which the tasks were performed (i.e., copy first/free second or free first/copy second). No significant differences were observed in the four subscales of the QCMBCI2000.

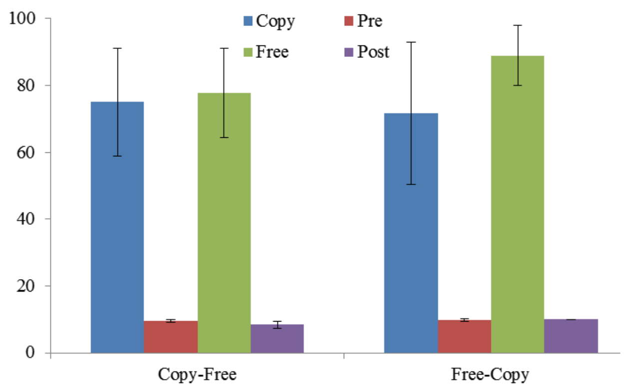

Figure 2: Average performance accuracy for the copy-, and free-spelling tasks, pre, and post motivation scores organized by task order.

Discussion

This study examined the hypothesis that participants will be more motivated in a free-spelling paradigm than in a copy-spelling paradigm, which would provide higher accuracy in a free-spelling

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task. In Experiment 1, no differences were observed in motivation as measured by the OLMQ, or in fatigue as measured by the SSS. In terms of BCI performance, copy-spelling accuracy was higher for participants who completed the free spelling task first. The researchers speculate that this increase in accuracy on the copy-spelling task is due to a practice effect combined with a reduced workload. In other words, the free-spelling task requires the participant to perform four tasks: 1) pay attention to the flash of the character to be selected, 2) remember their entire statement, 3) know their position in that statement, and 4) decide the next character selection by evaluating the feedback (i.e., correct errors made by the system). In contrast, during the subsequent copy-spelling task there is only one task, pay attention to the target character. Free spelling acts as intensive training improving the allocation of attentional resources for the BCI task. When copy spelling follows this training, the participant has honed in their task related skills and the subsequent task becomes easier.

In Experiment 2, no differences were observed in motivation, mood, or BCI accuracy regardless of the order in which the tasks were performed. Unfortunately, a limitation of this study was that motivation was only measured twice. Nonetheless, people with ALS may have a higher personal investment than nondisabled participants, which results in uniformly high scores on the measures of motivation and mood. Therefore, regardless of BCI task, the inherent intrinsic motivation of a person with ALS does not vary with task demands. Based on the findings of this study, additional research that investigates specific tasks to improve attentional allocation may prove to be fruitful.

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