Effects of Workload on P300 BCI Signals and Accuracy

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Abstract. Mental workload during a P300 spelling task was experimentally manipulated. As a result of auditory distraction, we found a significantly reduced P300 amplitude in the high workload condition compared to the medium workload condition. Despite high demands of the secondary tasks, 19 subjects were able to spell 100 characters with an average accuracy of 80% (14.8 bits/min) in the medium and 65.5% (10.8 bits/min) in the high workload condition. The study is an important step toward the integration of a mental workload detector into an asynchronous P300 BCI. A system is desirable that pauses if high workload is detected or reduces workload through the adaptation of stimulation parameters. The study further demonstrates the robustness of the P300 speller during a long session with distraction that is encouraging for BCI use in a home environment.

Keywords: P300 Speller, EEG, Workload, Auditory Distraction, Asynchronous BCI, Mental State

1. Introduction

As a first step toward the development of an asynchronous (self-paced) mode of control for the P300 BCI, the current study aimed to identify neurophysiological markers of high workload. A P300 BCI that adapts to the mental state of the user (e.g. pauses if high workload is detected) is highly desirable when designing systems for assistive technology. We experimentally manipulated the workload during a P300 spelling task and were interested in the effect on the P300 amplitude. We hypothesized reduced P300 amplitude with higher workload. We further investigated the effects of intensive use on spelling accuracies during a 2.5 hours BCI session.

2. Methods

2.1. Participants

Nineteen healthy subjects participated in the study (11 female, 8 male, mean age 25 years, SD = 5.08, range: 18-40). Participants were compensated with 8€/hour. None of the subjects had previously participated in a P300 BCI study.

2.2 Data acquisition

The electroencephalogram (EEG) was recorded with 31 active Ag/AgCl electrodes, and sampled at 256 Hz with two g.USBamp amplifiers (g.tec). Channels were referenced to the right earlobe and grounded to position AFz. The BCI2000 software framework was used for stimulus presentation and data acquisition.

2.3. Procedure

Participants completed ten online P300 spelling runs based on the paradigm first described by [Farwell and Donchin, 1988]. In each run, participants had to select 25 predefined characters from a 6x6 matrix. In addition to the primary spelling task, subjects performed a secondary task. In 5 runs, the task induced medium workload and in the other 5 high workload. Runs of medium and high workload alternated in pseudo-random order.

Rows and columns of the 6x6 Matrix were intensified for 62.5 ms and both flashed five times in random order for one character selection. The inter-stimulus interval (ISI) was set to 125 ms. Online classification was performed using stepwise linear discriminant analysis (SWLDA).

The secondary task was a dichotic listening task. For the first five minutes of all runs (20 characters to be copied), two concurrent stories were presented over headphones. One story was presented over the left and another over the right headphone speaker. Participants were either instructed to ignore the stories (medium workload condition) or pay attention to the content of both stories (high workload condition). After the first run of every

condition, the NASA-TLX questionnaire was administered as a measure of subjective workload. After every run, participants answered 6 questions about the content of the stories.

3. Results

The average accuracy, bitrate, peak amplitude at Pz, the scores of the NASA-TLX questionnaire and the average number of correct answers to the control questions for both workload conditions are displayed in Table 1.

Table 1. *Results of both workload conditions.*

	Medium Workload	High Workload
Accuracy (%)	80	65.5*
Bits/minute	14.8	10.8*
Amplitude at Pz (µV)	3.53	2.98*
NASA-TLX	49.52	61.31*
Correct answers	3	4.3*

all differences between the conditions are significant at the 0.001 level

Amplitude at Pz was significantly reduced ($p < 0.001$) during the high compared to the medium workload condition. For seventeen subjects, a reduction in P300 amplitude (peak between 200-600 ms post stimulus onset) was found. Subjects answered more questions correct for the high workload conditions, reported a higher workload and their spelling accuracy was lower (all significant at $p < 0.001$). Fig. 1 depicts the grand average at Pz for all participants in the medium and high workload conditions.
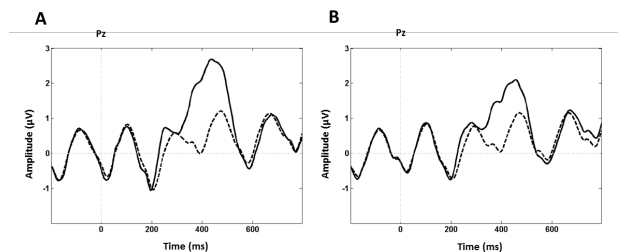

Figure 1. *ERP grand average at Pz for targets (solid line) and non-targets (dashed line) for all participants and all runs with medium workload (A) and high workload (B).*

4. Discussion

As expected, workload affected performance and the P300 amplitude during spelling. Thus, significantly reduced P300 amplitude could serve as an indicator of high workload. Together with data from the frequency domain of the EEG, this information could be used to activate the "stand-by mode" of a BCI. The P300 amplitude at Pz was reduced during the high workload conditions for most, but not for all users. This is in line with findings that show inter- and intra-individual differences regarding the P300 as a measure of workload [Kok, 2001]. Further, the study demonstrates that satisfactory accuracies can be achieved with the P300 speller, even if users are pursuing the task for a long time and are additionally distracted by spoken words.

Acknowledgements

References

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