Auditory standard oddball and visual P300 brain-computer interface performance

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Abstract. Brain-computer interfaces (BCIs) provide a non-muscular communication channel. Methods of performance prediction decrease the time needed for paradigm selection. We performed a visual P300 BCI session with 13 healthy participants. The correlation between the amplitude of the auditory standard oddball response and P300 BCI performance was analyzed. Significant differences in the auditory standard oddball response between high and low aptitude users were found in frontal EEG channels. Correlations of up to $r=0.72$ were found between oddball response and BCI performance. This shows that a short auditory oddball measurement can be used to predict P300 BCI aptitude.

1. Introduction

Injuries and neurological diseases such as amyotrophic lateral sclerosis (ALS) can lead to complete paralysis. Brain-computer interfaces (BCIs) bypass the need for muscular control by detecting the user’s intentions from signals recorded from the brain [Kübler and Neumann, 2005]. BCIs controlled using the visually elicited P300 ERP [Farwell and Donchin, 1988] have achieved a high level of success, in particular with ALS patients [Nijboer et al., 2008]. Finding predictors of performance for P300 BCIs is of particular interest.

2. Material and Methods

2.1 Participants, experimental design and data acquisition

Thirteen healthy participants were recruited from a group of students who took part in the study in return for course credits. Participants were seated in a chair 1 m away from a computer screen (43 cm diameter). Auditory stimuli were presented using stereo speakers. The auditory stimuli consisted of a low-pitched standard tone and a high-pitched deviant tone (the oddball, ratio of standard to deviant tones 4:1) both with a length of 160 ms. The inter-stimulus interval was set to 840 ms. In total 60 deviant and 240 standard stimuli were presented with a duration of 288 s. This data was used for performance prediction of the subsequent BCI session. We used a 6x6 P300 speller matrix with the letters A-Z, numbers 1-9 and space. Every row and column flashed ten times in random order with a flash duration of 60 ms and 120 ms inter-trial interval. Each participant wrote 38 letters without feedback. The first ten letters were used to train the classifier. All aspects of data collection were controlled by the BCI2000 software system. EEG data was recorded using a 32-channel Brainamp at 500 Hz. Ground was placed at AFz and reference at FCz.

2.4. Offline processing

The oddball data was high-pass filtered at 0.5 Hz, low-pass filtered at 20 Hz, re-referenced to A1 and A2 and baseline corrected (200 ms pre-stimulus). The P300 BCI data was re-classified offline with four sequences to avoid ceiling effects (with ten sequences six out of 13 participants reach 100 %).
3. Results

With ten sequences the participants achieved a mean accuracy of 86.8% (SD ± 20.5, range 32.1-100, N=13). After re-classifying offline with four sequences the participants achieved a mean accuracy of 59.8% (SD ± 20.3, range 11.4-78.6, N=13). The median of the offline performance (67.1%) was used to split the participants into groups of high and low aptitude users.

Figure 1. Differences in the averaged response to the auditory standard oddball on channel F4 shown separately for high (dark gray) and low aptitude users (light gray) with timepoints significantly different (Wilcoxon, p<0.05) between the two groups marked with a dark X (A), topographic distribution of AUC scores between high and low aptitude users at 234 ms (B) and the correlation r between oddball amplitude and visual P300 BCI performance with p-values <0.05 marked with a dark X (C).

Fig. 1A shows an EEG channel (F4) with the auditory oddball response of the high aptitude users in light gray and that of the low aptitude performers in dark gray. Significantly different time points are marked with a dark X (Wilcoxon, p<0.05). The area under the curve (AUC) score topography plot (see Fig. 1B) shows that high aptitude users tend to have higher amplitudes than low aptitude users on frontal channels. The correlation of the oddball amplitude with four sequence P300 speller accuracy reaches r=0.72 (p<0.05) at 234 ms (see Fig. 1C).

4. Discussion

We have shown a correlation between ERP amplitude of the auditory standard oddball and the performance achieved in a visual P300 BCI session. A measurement of the auditory standard oddball can be used to predict the aptitude of P300 BCI users without having to perform a P300 BCI session. A visual oddball may improve prediction. This is uncertain though because the P300 is influenced by modality, stimulus intensity and probability. In conjunction with performance prediction methods for other BCI paradigms [Blankertz et al., 2010] this will enable quick paradigm selection.

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References


