DOI: 10.3217/978-3-99161-050-2-142

Real-Time Classification and Modulation of the Distractor Positivity with an EEG BCI

Anastasiia Melnichuk[1*], Alexandra Mikhael[2], José del R. Millán[2,3,4*]

[1]Dept. of Neuroscience, [2]Chandra Family Dept. of Electrical and Computer Engineering, [3]Dept. of Neurology, [4]Dept. of Biomedical Engineering. University of Texas at Austin. * E-mail: amelnich@utexas.edu, jose.millan@austin.utexas.edu

Introduction: Every day, vast amounts of information compete for our limited attentional resources. Understanding how the brain filters out irrelevant stimuli is crucial, particularly for individuals with attentional deficits. In this study, we focused on the event-related potential known as distractor positivity (Pd), a positive voltage peak that occurs at parieto-occipital electrodes contralateral to salient distractors[1]. Pd amplitude has been linked to effective distractor suppression, whereas reduced Pd amplitude has been associated with severity of inattention symptoms[2]. Despite the significance of Pd, no prior studies have attempted to decode it in real time on a trial-by-trial basis or investigated whether it can be modulated via neurofeedback. Here, we demonstrate the feasibility of building a Pd-based decoder for real-time classification of distractor presence and of using closed-loop BCI to enhance Pd amplitude.

Material, Methods and Results: Five participants (2 males, mean age 25.4 ± 3.2 years) completed the additional singleton paradigm, where they searched for a target shape. On half of the trials, a salient red distractor appeared, creating "distractor present" and "no distractor" conditions. Participants underwent 3 sessions: calibration and online on day 1 and on day 2. Data from the calibration session was used to train a linear discriminant analysis (LDA) classifier to distinguish between distractor-present and no-distractor trials. During online sessions, participants repeated the paradigm while receiving real-time feedback based on the BCI output.

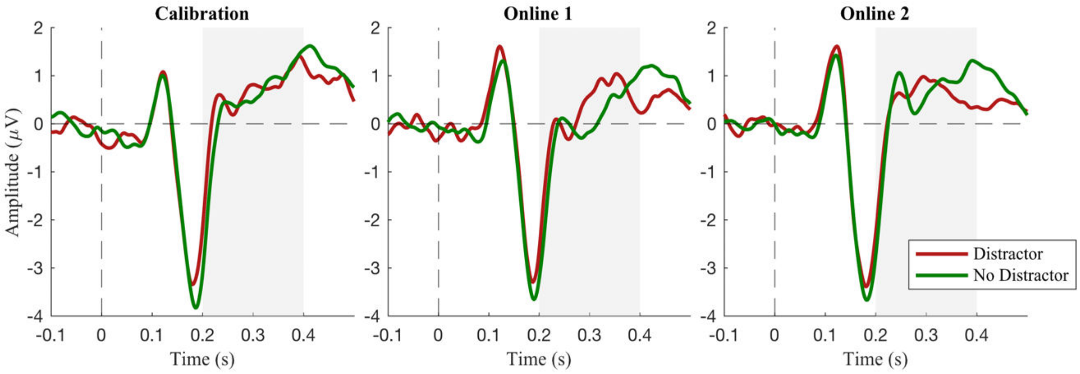

Figure 1. *Grand-average event-related potentials across 5 subjects during 3 experimental sessions: calibration, online 1 and 2. Shaded region indicates the time window selected for classification and amplitude analyses.*

We observed a significant interaction between condition (distractor vs. no distractor) and session in Pd amplitude ($F(2,8) = 4.74$, $p = 0.04$). From calibration to online session 1, the amplitude difference between distractor and no-distractor conditions increased, indicating successful modulation of the late Pd components (*Fig. 1*). The BCI achieved mean accuracies of 63±5% during calibration, 62±3% in the online session 1, and 62±6% in the online session 2 (*Fig. 2*). Remarkably, accuracy was stable across sessions. Nevertheless, across subjects, accuracy tended to decrease in the second online session, probably due to changes in the Pd components with respect to the calibration session. To test this hypothesis, we recalibrated the BCI for subject 5 (purple in *Fig. 2*) after the online session 1, leading to an accuracy increase in the online session 2.

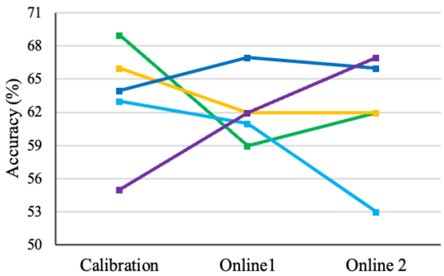

Figure 2. *Classification accuracy by subject and session. Each line represents accuracies from a single subject.*

Conclusion: This proof-of-concept study is the first to show the feasibility of a BCI for real-time decoding and modulation of the Pd components, a marker of distractor suppression. Results indicate that participants can learn to enhance Pd amplitude through BCI neurofeedback, laying critical groundwork for Pd-based interventions aimed at improving distractor suppression. Ongoing work includes additional measures to link enhanced Pd with behavioral improvements in attentional control, building better decoders that adapt to the changes of Pd induced by BCI feedback, and longer training sessions. As increased distractibility is observed in clinical populations (such as those experiencing cognitive aging), this line of research could ultimately inform novel treatment applications.

References:

[1] Gaspelin, N. et al. The distractor positivity component and the inhibition of distracting stimuli. *J. Cogn. Neurosci.*, 35:1693–1715, 2023.
[2] Rodríguez-Martínez, E. I. et al. Neurophysiological differences between ADHD and control children and adolescents during the recognition phase of a working memory task. *Neurosci. Res.*, 164:46–54, 2021.

Published by Verlag der Technischen Universität Graz