DOI: 10.3217/978-3-99161-050-2-004

Evaluation of a P300 BCI for augmentative and alternative communication in children with disabilities

Jason Leung [1]*, Tom Chau [1,2]
[1] Holland Bloorview Kids Rehabilitation Hospital, Toronto, ON, Canada; [2] University of Toronto, Toronto, ON, Canada

Introduction: P300 brain-computer interfaces (BCIs) have been previously investigated as an access method for augmentative and alternative communication (AAC) applications. However, the efficacy of P300-BCI-AAC for functional communication in children with severe physical disabilities remains underexplored [1]. In pursuit of practical communication, the present study aims to evaluate event-related potential (ERP) characteristics and user experience in children with motor impairments during a P300 task for functional communication.

Methods and Results: A 16-year-old non-verbal male participant (GMFCS Level III) was recruited for 5 sessions. The participant was instructed to attend to a target button in a personalized 2x2 grid created with the Tobii Dynavox AAC application. In each trial, buttons were flashed in a random order with an inter-stimulus interval of 450 ms until the cumulative probability of any button exceeded a dynamic threshold. Upon successful selection of the target button, a YouTube video was played as a reward for the participant. During each session, EEG were acquired using a 32-channel BrainVision Liveamp with the R-Net system (Brain Products GmbH). Eye gaze data were recorded simultaneously to track visual attention and reject trials where participants did not attend to the target stimuli. EEG signals were bandpass filtered between 1 and 40 Hz, and epochs were extracted from -200 ms and 800 ms around the onset of the visual stimuli. During online trials, Xdawn covariances from single-trial ERPs were classified with a Riemannian geometry classifier using the Mindset BCI system [2]. Figures 1a and 1b show the averaged ERP response for the target stimuli and the eye gaze heat map, respectively, during online trials across all sessions. Table 1 presents BCI performance metrics such as the target button cumulative probability, selection accuracy and information transfer rate (ITR), as well as eye gaze metrics, including the dwell time, continuous dwell time, and trial duration for each session and for all sessions combined. Chance levels for different number of trials were estimated based on simulation results over 10000 iterations with a confidence interval of α = 5% [3].

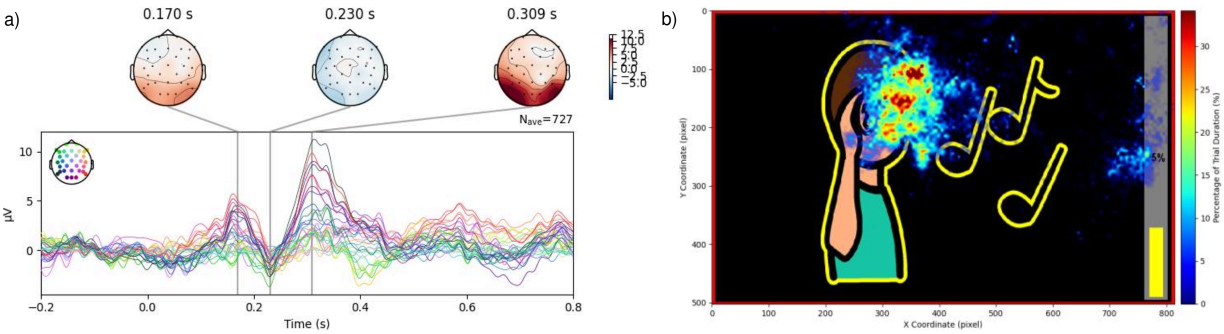

Figure 1: a) Averaged event-related potential during target stimuli across all online sessions; and b) heat map of eye gaze coordinates during online trials plotted over the target button in the 2x2 communication grid presented on the monitor

Table 1: Brain-computer interface and eye gaze performance metrics for online trials

Session	Num. of trials	Stimuli per trial (avg. ± std.)	Target Button Cumulative Probability (%) (avg. ± std.)	Chance Level (%)	BCI Accuracy (%)	BCI ITR (bits/min)	Dwell Time (s) (avg. ± std.)	Continuous Dwell Time (s) (avg. ± std.)	Trial Duration (s) (avg. ± std.)
1	48	18.06 ± 13.58	90.31 ± 4.38	37.50	50.00	1.54	7.51 ± 5.62	6.09 ± 4.87	8.07 ± 6.11
2	52	11.17 ± 10.08	90.81 ± 4.76	36.54	55.77	3.71	4.68 ± 4.52	4.24 ± 4.12	4.99 ± 4.60
3	48	9.96 ± 4.73	91.92 ± 4.08	37.50	75.00	10.79	4.20 ± 2.11	3.72 ± 2.02	4.41 ± 2.13
4	43	18.33 ± 12.37	90.42 ± 4.78	39.53	55.81	2.27	7.12 ± 5.30	6.16 ± 4.85	8.19 ± 5.59
5	57	15.25 ± 10.05	89.39 ± 3.96	36.84	50.88	1.94	6.27 ± 4.07	4.45 ± 2.46	6.87 ± 4.55
All	248	14.45 ± 10.99	90.53 ± 4.43	30.65	57.26	3.14	5.92 ± 4.61	4.88 ± 3.89	6.46 ± 4.97

Note: BCI = brain-computer interface, ITR = information transfer rate

Discussion and Significance: The P300 component was distinctly observed in the ERP plot as a positive peak in posterior channels up to 10 µV in amplitude approximately 300 ms after stimulus onset. A weaker but noticeable P200 component was also observed, potentially indicating some aspect of high-order perceptual processing and attention modulation. These ERP components may have supported online selection with the BCI system. The eye gaze heat map and dwell duration metrics confirm visual attention towards the target button, which likely facilitated elicitation of the visual P300. Although BCI performance varied across sessions, BCI accuracy and ITR reached 75% and 10.71 bits/min respectively in the best performing session. Further investigation into the factors contributing to variability in BCI performances is warranted. Potential factors such as user fatigue as well as cognitive and visual attention levels should be systematically examined to understand their impact. Future research will also include a larger and more diverse participant sample to ensure findings are generalizable to children with other disability profiles. Additionally, further optimization of the BCI system, such as fine-tuning the stimuli and signal processing parameters, will be explored to further enhance BCI performance. This study provides preliminary evidence supporting the feasibility of P300-based BCI access for AAC in children with disabilities. The findings pave the way for refining BCI-AAC systems and broadening their use in functional communication applications.

References:

1. K. M. Pitt, 'Development and preliminary evaluation of a grid design application for adults and children using scanning and bci-based augmentative and alternative communication', Assist Technol, pp. 1–8, Oct. 2024.
2. J. Leung and T. Chau, 'Mindset—A General Purpose Brain–Computer Interface System for End-Users', IEEE Access, vol. 12, pp. 112249–112260, 2024.
3. G. Müller-Putz, R. Scherer, C. Brunner, R. Leeb, and G. Pfurtscheller, 'Better than Random? A closer look on BCI results', International Journal of Bioelektromagnetism, vol. 10, pp. 52–55, 01 2008.

Published by Verlag der Technischen Universität Graz