Facial Stimulus-based Virtual Environment BCI for At-Home Use in ALS

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Synopsis

Amyotrophic lateral sclerosis (ALS) progressively impairs voluntary movement and speech, creating a need for accessible communication tools and systems that support environmental interaction. We developed a low-cost, wireless P300 brain-computer interface (BCI) designed for practical at-home use. The system integrates individualized face-based visual stimuli for navigation within a virtual environment. Six stimulus conditions were evaluated, including familiar and unfamiliar human faces and a blank-face control, in 8 participants with ALS and 8 healthy controls. Preliminary findings indicate that the system was usable across both groups and suggest that personalized face stimuli may improve BCI performance in individuals with ALS.

Background

Amyotrophic lateral sclerosis (ALS) progressively impairs voluntary muscle control and may ultimately eliminate speech, creating an urgent need for effective augmentative and alternative communication (AAC) systems. Visual P300-based brain-computer interfaces (BCIs) offer a promising AAC pathway, but the canonical flashing-grid paradigm often yields only moderate accuracy (reported as low as 66%). Prior work suggests that replacing simple flashes with more salient visual stimuli, particularly human faces, can enhance P300 responses and evoke additional event-related potentials (ERPs), including the N170 (Caharel & Rossion, 2021), a face-sensitive component occurring around 170 ms over occipito-temporal regions. Because N170 amplitude is influenced by facial familiarity (Jin et al 2012), leveraging both P300 and N170 responses may improve BCI performance.

Methods

We developed a new custom BCI using a wireless, battery-powered EEG system integrated with a virtual-environment control interface. Instead of conventional letter or icon flashes, the system presents individualized face-based stimuli. In order to assess the impact of face stimuli on the BCI performance, the modular software supports six stimulus conditions: (1) male celebrity, (2) female celebrity, (3) male stranger, (4) female stranger, (5) participant-selected familiar face (family member or close friend), and (6) blank-face icon control.

The system utilized for data acquisition was g.tec's Unicorn Hybrid Black, a wireless, Bluetooth EEG device with semi-dry electrodes. Eight electrodes were placed based on the 10-20 System for EEG: Fz, C3, Cz, C4, Pz, PO7, Oz, PO8. Data was collected at a 250 Hz sampling rate. A

reference electrode was placed behind the ear at the right mastoid, A2, and a ground electrode was placed behind the ear at the left mastoid, A1 (disposable surface electrodes). OpenVibe software (Renard et al 2010) was used to display the stimuili BCI matrix and process the EEG data. MazeSuite software (Ayaz et al 2008) was used for creating and displaying virtual environment (VE). During the experiment, VE was displayed on an external monitor setup next to the laptop.

Eight adults with ALS and eight age-matched healthy controls completed copy-spelling tasks across all conditions. Single-trial ERPs (including P300 and N170) were extracted using common-average referencing, and features were classified using stepwise linear discriminant analysis (SWLDA).

Results

The BCI was usable in both cohorts, and all participants completed the sessions following brief training. ERP analyses are ongoing; and initial review of signals show consistent differences in P300-related features across face conditions relative to the blank-face control. Full statistical results, including comparisons across stimulus types and participant groups, will be presented at the conference.

Discussion

Incorporating human face stimuli may improve BCI usability and support personalization in at-home AAC applications. Face-based stimuli may also provide an advantage for users with weaker or less reliable P300 responses by engaging earlier face-sensitive visual ERP components (e.g., N170). Preliminary observations suggest that familiar-face personalization may be especially beneficial, warranting further investigation in larger studies and extended at-home trials.

References

Ayaz, H., Allen, S.L., Platek, S.M., and Onaral, B. (2008). Maze Suite 1.0: a complete set of tools to prepare, present, and analyze navigational and spatial cognitive neuroscience experiments. *Behav Res Methods* 40(1)**,** 353–359. doi: 10.3758/BRM.40.1.353.

Caharel, S., & Rossion, B. (2021). The N170 is sensitive to long-term (personal) familiarity of a face identity. Neuroscience, 458, 244-255.

Jin J, Allison BZ, Kaufmann T, Kübler A, Zhang Y, et al. (2012) The Changing Face of P300 BCIs: A Comparison of Stimulus Changes in a P300 BCI Involving Faces, Emotion, and Movement. PLOS ONE 7(11): e49688

Renard, Y., Lotte, F., Gibert, G., Congedo, M., Maby, E., Delannoy, V., Bertrand, O. and Lécuyer, A., 2010. Openvibe: An open-source software platform to design, test, and use brain–computer interfaces in real and virtual environments. *Presence*, *19*(1), pp.35-53.