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Multimodal Sensor Fusion for EEG-Based BCI Typing Systems

B. Celik[1], T. Memmott[2], G. Stratis[1], M. Lawhead[2], B. Peters[2], D. Klee[2], M. Fried-Oken[2], D. Erdogmus[1*] on behalf of the Consortium for Accessible Multimodal Brain-Body Interfaces (CAMBI)

[1]*Northeastern University, Boston, MA, USA;* [2]*Oregon Health & Science University, Portland, OR, USA*

[*]409 Dana Research Center, 360 Huntington Ave, Boston, MA 02115, USA. E-mail: d.erdogmus@northeastern.edu

Introduction: For people with severe speech and physical impairments (SSPI), a robust communication interface is often a necessity to improve quality of life. Non-implantable electroencephalography (EEG)-based BCI typing systems are one option in the field to restore communication. In an EEG-based typing interface, a sequence of symbols are presented consecutively on a screen, and the intended symbol is probabilistically inferred by the resulting event-related potentials (ERPs) [1]. Selecting the intended symbol often takes multiple attempts due to a subset of all symbols being presented in each sequence, and a decision cannot be made if the EEG evidence does not strongly support the intended symbol.

Material, Methods and Results: Here we describe a multimodal fusion algorithm combining EEG and gaze tracking (i.e., fixation and trajectory) for control of an ERP-based BCI. This work focuses on a specific BCI paradigm called single-character-presentation (SCP) based visual presentation, which consists of symbols presented in matrix form and individually highlighted in randomized order. We develop and compare probabilistic Bayesian fusion algorithms of increasing complexity to observe the effect of probabilistic assumption sets on the multimodal BCI performance. We propose a method assuming positional and temporal dependence in gaze evidence. We collected calibration data from control participants (n=21, mean age 23.6±3.1 years) in a quiet lab room and participants with SSPI (n=8, mean age 62.6±15.7 years) in their homes. EEG data were collected using a DSI-24 cap (Wearable Sensing) at a sampling rate of 300 Hz, and the gaze data were collected using a portable eye tracker (Tobii Pro Nano) at a sampling rate of 60 Hz. The SCP matrix paradigm and the data acquisition modules are developed in BciPy [2], which is a standalone application for experimental data collection.

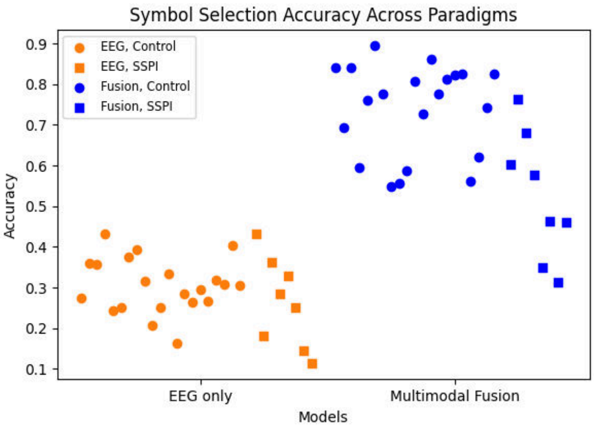

Figure 1: *Performance analysis of EEG only (orange) and Multimodal Fusion (blue) models for 21 control (circle) and 8 SSPI (square) participants. The sequential data is bootstrap sampled (N=100) and split into train-test subsets for typing performance analyses.*

Conclusion: Experiments with both control participants and people with SSPI show that the proposed multimodal Bayesian fusion method significantly improves performance in symbol selection (M=0.73, SD=0.11 for control; M=0.53, SD=0.15 for SSPI) compared to EEG-only BCI typing systems (M=0.30, SD=0.06 for control; M=0.26, SD=0.09 for SSPI) (see Fig. 1).

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