Evaluation of cue-based protocol implementations in motor imagery - based brain-computer interface experiments

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ABSTRACT

Introduction: Non-invasive Brain-Computer Interface (BCI) studies mostly centre on the motor imagery (MI) concept, where multi-channel Electroencephalogram (EEG) signals are collected and characterized by patterns for different imagined tasks. Previous studies put extensive efforts into data-driven techniques to improve classification performance on benchmark datasets; however, other aspects, such as experimental factors, still lack thorough investigation. This pilot study aims to evaluate the effect of different cue-based protocols on within-subject MI-BCI baseline performance to better guide the experimental instructions on a specific group of users. **Materials and Methods:** An Emotiv EEG headset kit integrated into the Lab-Streaming-Layer (LSL) was used for data acquisition. Three PsychoPy-based protocols were designed, namely, G1, G2, and G3, incorporating different visual instructions of image-cue, arrow-cue, and arrow-cue-feedback utilizing Event-Related (de)Synchronization (ERD/ERS) demonstration, respectively. Imagery data (left/right hand/foot) from 12 healthy college participants (age 20~22, five females) were collected (15 trials/task/run) and randomly allocated for each designated protocol. A processing framework was implemented using a conventional Lasso-based sparse Filter Bank Common Spatial Pattern (SFBCSP) for feature extraction/selection and Linear Discriminant Analysis (LDA) for classification to assess the baseline performance. Average ROC (5-fold cross-validation) was calculated for the upper-limb binary model of each run with different non-overlapping time segments. Statistical non-parametric tests were used for within-group and cross-group comparative analysis. **Results:** In within-group analysis, average performance between run1 & run2 is as follows: G1 (52.7% & 44.8%); G2 (62.0% & 57.8%); G3 (52.5% & 67.7%) where G3 group yielded significant improvement (run2 > run1, $p<0.05$), while no statistical difference had been found within the G1 or G2 group. In cross-group analysis, an average performance combining all runs of G1, G2 and G3 are 48.8%, 59.8%, and 60.1%, respectively, where it showed significant differences in G1&G2 ($p<0.05$) and G1&G3 ($p<0.05$) but not in G2&G3. In the after-run self-assessment analysis, while few elements strongly correlated with the overall performance, no significant difference was found between the image-cue and arrow-cue groups. **Conclusion:** The preliminary result highlights that different instructions (arrow/image cue & feedback) may affect the within-session performance between runs while reporting no evidence of changing the subject's psychological factors. The statistical analysis also suggests that verbal feedback with arrow-cue can enhance the model's efficacy, which can be further explained by orienting the alpha-band ERD/ERS response. Future studies may explore other human-based factors considering the motor response-ability within the larger target group of users, potentially advancing BCI application in a personalized paradigm.