DOI: 10.3217/978-3-99161-050-2-034

Exploring Early Predictability of Grasping Movements with non-invasive EEG

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Introduction: Grasping is a complex neural process integrating motor control and intention. In brain-computer interface (BCI) research, interpreting human intentions to control assistive devices is a key focus. Electroencephalography (EEG) serves as a critical tool for studying grasping, but traditional methods like movement-related cortical potentials and spectral power analysis often perform poorly [1]. Few studies have explored neural activity during the planning phase to predict grasp types early [2,3]. This study investigates the predictability of four grasp types—power, tripod, lateral, and cylindrical—during the planning phase.

Materials, Methods, and Results: We recorded EEG data (64 channels) from 10 healthy participants (3 males, 7 females, age 27.3 ± 3.7) during a reach-grasp-relocation task (Fig. 1A-C). Each participant performed 30 repetitions per grasp type across five directions. EEG preprocessing included bandpass filtering (0.1–45 Hz), artifact removal, re-referencing, and independent component analysis. We epoched from -2.3 to 0.9 seconds relative to movement onset, capturing peak motor planning activity [4]. Features were extracted using Common Spatial Patterns (CSP) [3], xDAWN spatial filter [3], and wavelet transform, paired with machine learning classifiers (LDA, LR, RF, SVM) and validated via 10-fold cross-validation. Data were tested for normality and 3-way ANOVA was used to assess performance with different parameter configurations.

We evaluated classifiers performance across two EEG configurations (64- vs 5-channel) and three feature sets. We found (Fig 1C) that xDAWN outperformed CSP and Wavelet, and CSP outperformed wavelet. RF and SVM outperformed LDA and LR. The 64-channel setup significantly improved performance over the 5-channel configuration, highlighting the benefits of broader spatial coverage. Statistical analysis revealed SVM using xDAWN and 64-channel setup as the best configuration.

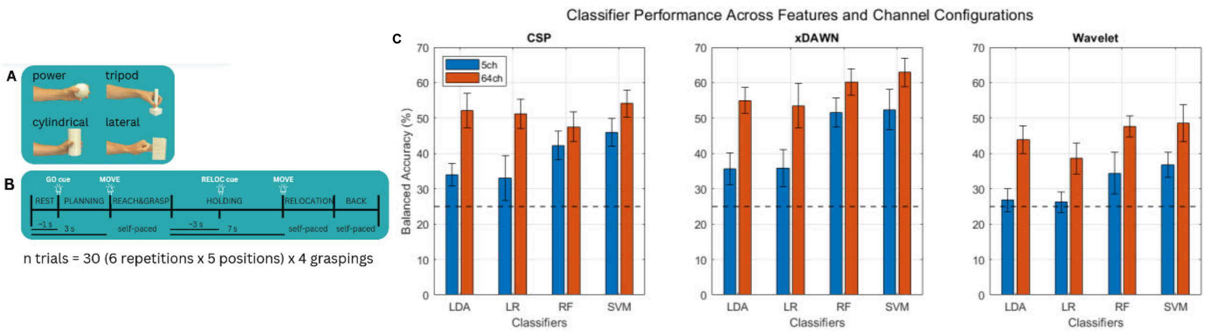

Figure 1: A) Experimental paradigm. B) Grasping types. C) Balanced accuracy for classifying four grasps using three feature extraction methods (CSP, xDAWN, Wavelet) across two electrode configurations (5-channel and 64-channel). Performance is shown for four classifiers: Linear Discriminant Analysis (LDA), Logistic Regression (LR), Random Forest (RF), and Support Vector Machine (SVM). A dashed line indicates the chance level (25%).

Conclusion: This study demonstrates EEG's ability to differentiate grasp types during the planning phase, offering valuable insights into motor control. These findings could inform methodologies for investigating grasp and for assistive technology development. Future research is needed to validate these results and optimize prediction strategies.

Acknowledgments and Disclosures: The authors thank N. Boccardo, M. Canepa, M. Mozzon, and A. Salvia for their support in experimental design and technical implementation. Authors have no conflicts of interest.

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