EEG Classification of Grasp Force – Neural Correlates of Weight During Object Lifting

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Introduction: Restoration of general motor function and arm control is the number one priority of patients with Spinal Cord Injury. Since interacting with the environment is a crucial aspect of everyday life, having an intuitive prosthetic is of the utmost importance for the quality of life. Recent studies have found promising results for decoding reaching and grasping from neural signals [1, 2], but the target object weight and the amount of pressure applied have not been investigated as much, while being an important aspect of interacting with objects.

Methods: In this study, 11 participants are tasked with grasping and lifting objects with differing weight (50 and 250 gr) and shape (spherical and cylindrical). Additionally, the expected object weight is tested by creating catch-trials where the object weight is different from the previous trial but has the same shape. We record EEG signals and identify new neural correlates by looking at Movement Related Cortical Potentials (MRCP) below 5Hz and Event Related (De)synchroization (ERD/S) in the centro and centro-parietal regions. With this EEG data we identify neural correlates for object shape, weight, known and unknown weights, catch-trials, and how the correlates change throughout the stages of a movement. Finally, we use Machine Learning methods to create multiclass decoders based on the MRCP, and apply them over different stages of the movement.

Results: The analysis revealed clear MRCPs, show a response in lower frequency ranges in response to the movement, and a strong ERD pattern in the centro and parietal regions. Clear ERDs related to the movement were found relating to the movement onset, but no significant differences between the object weights. We found evidence for the presence of Centro Parietal Positivity when participants are presented with a new object as well as after lift onset in catch-trials.

Most notable is the above chance-level decoding accuracy of object weight in the reaching stage (acc. 51.3%), which increases during the lifting stage (acc. 56.6%). Furthermore, our work shows how heavier objects can be classified more accurately than lighter objects.

Conclusion: We show the role of different well-known neurophysiological signals during grasping and lifting of objects and how object weight can be decoded from an EEG signal around the lifting stage of a grasping movement. The proposed paradigm and neural correlates discovered help gain insight into the motor cortex' contribution in grasping control, but is also useful for the development of neuroprosthetics and exoskeletons that support stroke and Spinal Cord Injury patients.

References

[1] A. I. Sburlea et al., "Disentangling human grasping type from the object's intrinsic properties using low-frequency EEG signals," *Neuroimage: Reports*, Jun. 2021.

[2] A. Schwarz et al., "Decoding natural reach-and-grasp actions from human EEG," *Journal of Neural Engineering*, Dec. 2017.

Highlights:

- We propose estimating the weight of an object from EEG as an approach to make reliable neuroprosthetics, and propose a novel paradigm to study this.
- We study neural correlates to discern between heavy and light objects, known and unknown weights, spherical and cylindrical objects, and four movement stages using Movement Related Cortical Potentials and Event Related Desynchronizations.
- We train Machine Learning models to determine the weight and shape of the object from EEG signals over four different movement stages, showing that object shape can be identified already in the fixation stage (acc. 53%), while object weight can be identified starting in the reaching state (acc. 51.3%), but better better in the lifting stage (acc. 56.6%).