Effects of robotic-assistance in ERP modulation for upper-limb exoskeleton control

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Introduction: Event-related potential (ERP)-based brain-computer interfaces (BCI) are being widely explored in robotic neurorehabilitation because there is increasing evidence that involving the patient in their control loop improves brain plasticity and motor learning[1]. In particular, exoskeletons can provide different assistance levels (AL), which can be optimized with ERP-based BCI [2]. However, it is not clear if and how brain activity is affected by different AL, or whether it is possible to use this modulation as a metric for assessing the performance of the robot and of the patient. In this work we investigate ERP modulation during a standardized motor task with different AL provided by FLOAT -a novel upper limb exoskeleton developed by our group [3]- to better understand the relationship between brain activity and AL in robotic neurorehabilitation.

Material, Methods and Results: 10 healthy right-handed subjects performed a reaching task using a touch panel as shown in Figure 1.1. The task was repeated in four different conditions: free movement (FM) and assisted by FLOAT exoskeleton providing low, medium, and high AL, respectively. High-density EEG was recorded and used to calculate ERP, which was compared across different AL. We found significant difference in the ERP amplitude 150-450 ms after reaching the target, when comparing FM with medium and high AL, while no significant differences were observed when comparing with low AL.

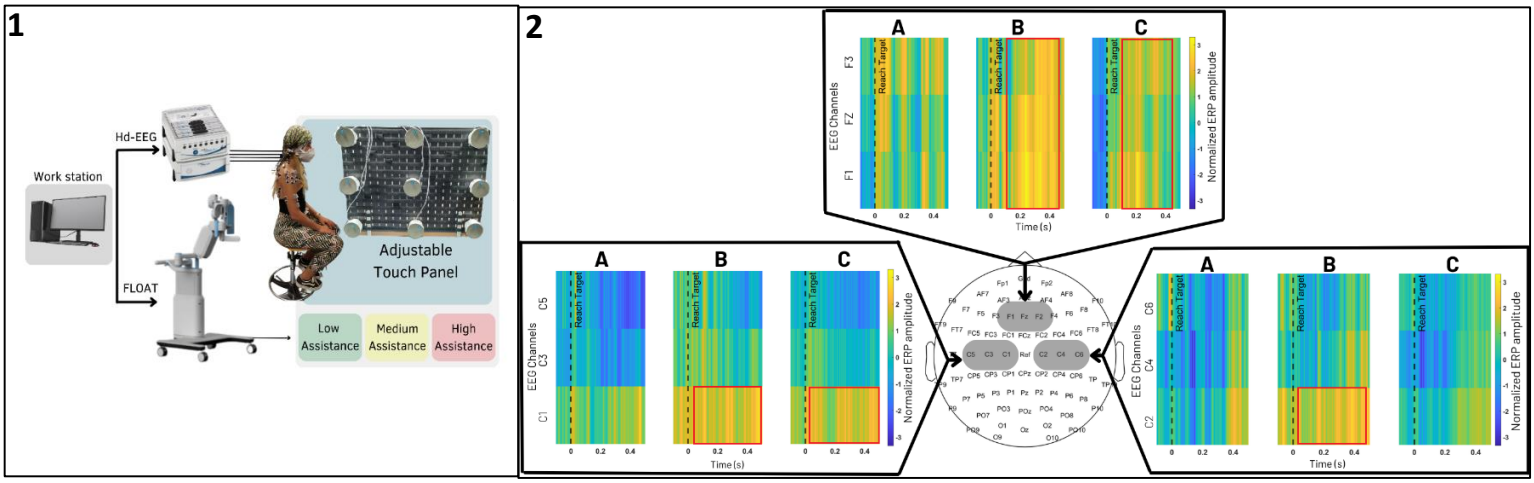

Figure 1. *1) Experimental setup.2) Differences in ERP amplitude between FM and A) Low AL, B)Medium AL, C) High AL, for the indicated EEG channels. Red squares indicate significant differences (p-value <0.05, computed with a cluster-based permutation using Montecarlo method).*

Discussion & Significance: We found differences in ERP modulation in different brain areas - associated with movement planning and execution - when performing the reaching task assisted by the robot (Figure 1.2). The fact that there is no difference between low AL and free movement could indicate that the motor scheme is unchanged during this condition, and thus, the two conditions are perceived as similar. Understanding the effects of different AL on brain activity could have important implications for BCI design: It can provide new insights about neural mechanisms of human-robot interaction that could be used to improve human-in-the-loop optimization strategies for neurorehabilitation.

References

[1] A. Colucci *et al.*, "Brain–Computer Interface-Controlled Exoskeletons in Clinical Neurorehabilitation: Ready or Not?," *Neurorehabilitation and Neural Repair*, vol. 36, no. 12, pp. 747-756, 2022.

[2] M. S. Al-Quraishi, I. Elamvazuthi, S. A. Daud, S. Parasuraman, and A. Borboni, "EEG-Based Control for Upper and Lower Limb Exoskeletons and Prostheses: A Systematic Review," *Sensors (Basel)*, vol. 18, no. 10, Oct 7 2018, doi: 10.3390/s18103342.

[3] S. Buccelli *et al.*, "A Gravity-Compensated Upper-Limb Exoskeleton for Functional Rehabilitation of the Shoulder Complex," *Applied Sciences*, vol. 12, no. 7, p. 3364, 2022.