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Toward EEG discrimination of fingers movements during motor imagery vs passive movement

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Introduction: BCIs based on finger motor imagery (MI) show promising potential but limited performance, due to the proximity of the cortical areas dedicated to the fingers of the same hand and the low signal-to-noise ratio of EEG, which results in overlapping signals [1]. To delve into this challenge, previous studies have demonstrated that calibrating BCIs using passive movement may offers a more efficient alternative to MI, particularly by reducing the cognitive and physical load on participants [3]. The goal of our study is to determine whether passive finger movements can induce significantly stronger modifications in the motor cortex compared to when those same movements are imagined.

Material, Methods and Results: Twenty-six healthy participants completed a 2-hour experiment where they: (1) performed MI and (2) experienced passive movements (applied by a custom-built exoskeleton), while their EEG data was recorded using 20 active electrodes (g.USBAmp, g.tec). The motor tasks involved flexion and extension of the index, middle and ring fingers independently, as well as simultaneous movements of all 3 fingers. The sequence of conditions and tasks was randomized, with 30 trials per movement type per condition. Signal from 24 participants was filtered using notch filter and a 0.5-40 Hz band-pass filter. Automatic artifact rejection, independent component analysis and common average reference were applied to limit artifacts. Time-frequency representations were computed using Morlet wavelets. Significant effects ($p \leq 0.05$) were identified with a non-parametric cluster-based paired t-test, and averaged across participants (see Fig. 1).

In the α (8-12 Hz) and sub-part of β (20-25 Hz) bands, a greater number of significantly stronger event-related desynchronizations (ERDs) were observed during the passive movement tasks than during the MI tasks. A repeated measures ANOVA on ERDS values between 8 to 36 Hz and 1 to 5 s after task onset revealed a significant effect of the experimental condition ($F = 19.77$, $p < 10^{-3}$, $\eta^2 = 0.12$) and the movement type ($F = 8.16$, $p < 10^{-3}$, $\eta^2 = 0.02$) on these values. However, the interaction between condition and movement is not significant ($F = 0.87$, $p = 0.45$, $\eta^2 = 10^{-2}$), indicating two independent factors.

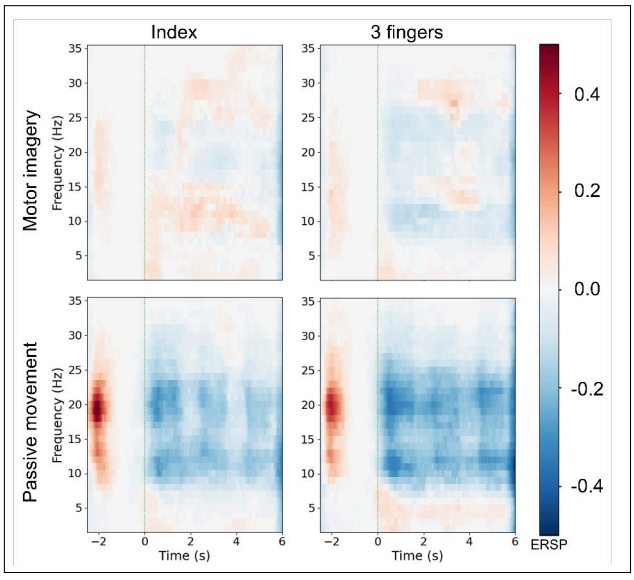

Figure 1: *Grand-averaged ERSP at C3 for MI and passive movement tasks for right index finger and three-fingers movements.*

Conclusion: In accordance with the literature, passive movements consistently elicited stronger contralateral ERD in the motor cortex compared to MI [2]. Interestingly, significant ERSP differences were found between the different finger movements. Future analyses will examine whether training classifiers on MI data or movement data results in the greatest accuracy when tested on MI data.

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