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A non-invasive brain computer-brain stimulation interface to enhance motor rehabilitation

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Introduction: Rehabilitative brain-computer interfaces (BCI) improve motor function by inducing neuroplasticity [1]. Typically, these BCIs either use neurofeedback or neuromuscular electrical stimulation to induce neuroplasticity in the motor cortex, both of which don't directly stimulate the brain [1]. A rehabilitative BCI that directly stimulates the brain on movement-intention may cause greater motor cortex activity, amplifying the magnitude of Hebbian plasticity (Fig 1.). In this way, a direct brain stimulation BCI may induce greater neuroplasticity than standard rehabilitative BCI, enhancing motor recovery. Thus, we set out to develop and test the effects of a BCI that triggers a burst of gamma frequency repetitive transcranial magnetic stimulation (rTMS) when movement intention is detected (Fig 1.).

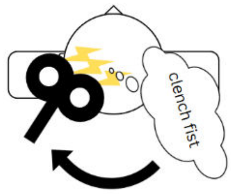

Figure 1: *Proposed Hebbian plasticity through co-incident movement-intention and brain stimulation.*

Material, Methods and Results: The BCI is trained on a participant's electroencephalography (EEG) data recorded during 30 trials of cued right-hand clenching. Specifically, the BCI uses 9 sensorimotor electrodes (FC3/z/4, C3/z/4, CP3/z/4) that are bandpass filtered between 8-40Hz. The data are split into noise [-3, -1] and movement [-1, 1] epochs. A common-spatial pattern (CSP) is fit to the epochs and a support-vector machine (SVM) is trained on the CSP transformed data. Five-fold cross-validation is then performed on the training data and the elbow of the receiver-operating characteristic (ROC) curve obtained from the fifth fold of cross-validation is used as the threshold in testing. We tested the BCI in pseudo-real-time using a 2s sliding window with a step-size of 83ms and a 2s window jump when the BCI detects movement regardless of whether movement truly occurred. We computed the true-positive and false-positive rates, where a true positive is defined as being within 1s of movement intention. Across 2 healthy adults and 2 fibromyalgia patients we achieved an average true-positive rate of 83% and false-positives/minute of 6.34/min with a mean latency of 123.7ms. In practice, real-time data will be streamed to a custom Python script running the tuned BCI that triggers an rTMS 100Hz triplet over the right-hand representation of the participant's motor cortex (Fig. 2).

Conclusion: We have successfully developed and obtained pilot validation data for a BCI that can trigger rTMS 100Hz triplets when movement intention is detected. This work introduces a novel form of rehabilitative BCI that directly and non-invasively stimulates the brain. This novel rehabilitative BCI has the potential to significantly enhance motor recovery through greater motor cortex plasticity. Our next steps are to test BCI performance in real-time and determine the effects of this BCI on motor cortex plasticity in healthy adults.

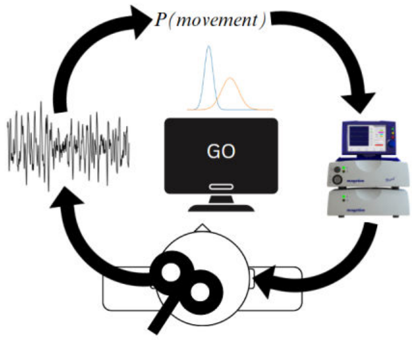

Figure 2: *Diagram of real-time implementation BCI-rTMS.*

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References:

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