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Brain-computer interface for treatment of focal dystonia

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Introduction: Dystonia is a neurological disorder that causes involuntary muscle contractions leading to uncontrollable movements and abnormal postures. Current treatment options are limited to temporary symptom management [1]. Recent characterization of dystonia as a neural network disorder [2, 3] opened opportunities for the development of novel treatments for targeting disorder pathophysiology.

Methods: We developed a closed-loop neurofeedback-based BCI and tested it in 10 patients with laryngeal dystonia (LD; 5 M/5 F, age 57.1±12.3 years). The BCI included a high-density EEG system and a machine-learning platform (regularized LDA) to provide near real-time visual feedback of ongoing EEG activity, which was based on differences between symptomatic speaking and asymptomatic whisper, in a virtual reality (VR) environment (Fig 1A). Using individual feedback, each patient was trained to actively modulate and match their neural activity during symptomatic speaking to that of asymptomatic whisper. Each patient participated in 2 training sessions for 5 consecutive days. BCI-induced changes in neural activity were assessed by contrasting source power activations in the beginning vs. end of daily BCI intervention and using discriminative power (R^2) between speech and whisper spectral power across the entire length of intervention.

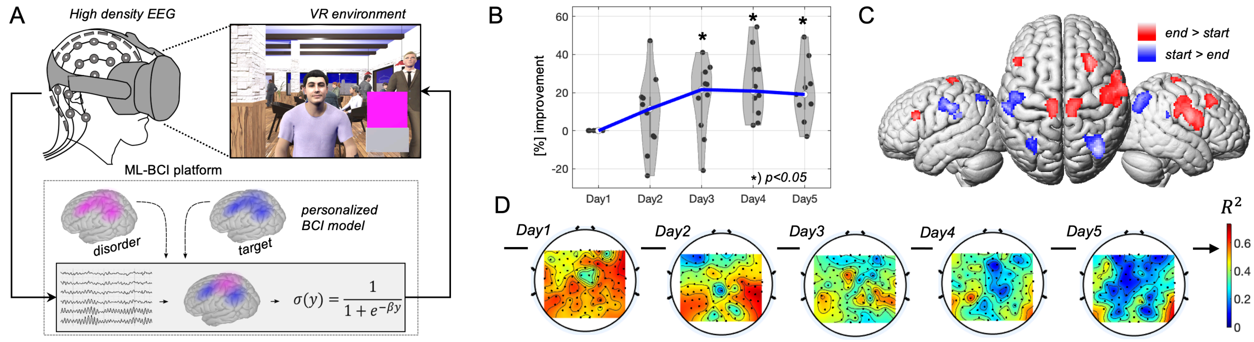

Figure 1. (A) BCI intervention paradigm in LD patients. (B) Controllability of feedback over the course of 5-day intervention. (C) Group BCI-induced gamma-power modulation; (D) Daily changes in gamma-power during symptomatic speaking compared to asymptomatic whisper.

Results: Patients demonstrated the significant ability to gain and maintain the control of their neural activity during BCI training using the near real-time visual feedback (Fig 1B). Most prominent BCI-induced neuromodulation was found in the gamma frequency band (30-50 Hz) and included a reduction of abnormal activity in the left primary sensorimotor and bilateral parietal cortex and an increase of activity in the right primary sensorimotor and bilateral premotor cortex (Fig 1C). Gamma-power differences between speech and whisper were gradually reduced from Day 1 to Day 5 (Fig 1D). In a 7-day follow-up after BCI intervention, 7 out of 10 patients reported improved voice quality and ease of speaking.

Discussion: The BCI intervention directly modulated brain regions associated with LD pathophysiology, which was associated with symptom reduction throughout the training and at a follow-up.

Significance: Closed-loop BCI interventions targeting disorder pathophysiology may be a novel treatment option for patients with laryngeal dystonia.

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