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Adaptive Closed-Loop Neurofeedback Brain-Computer Interface for Treatment of Laryngeal Dystonia

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Introduction: Laryngeal dystonia (LD) is a task-specific focal dystonia characterized by involuntary spasms of laryngeal muscles that selectively impair the production of speech but not whispering, crying, or laughing. A recent EEG study [1] showed apparent differences in brain activity between speaking and whispering in LD patients compared to healthy individuals. In a double-blind, sham-controlled study, we aimed to build on the selectivity of speech impairment in LD for the development of a non-invasive adaptive closed-loop neurofeedback-based brain-computer interface (NF-BCI) for the treatment of this disorder.

Material, Methods, and Results: Eighteen LD patients participated in the study, divided into two groups: nine in the active condition and nine in the sham condition. The personalized EEG-based NF was displayed using the head-mounted virtual reality (VR) goggles and included real-life scenarios with various auditory and visual complexity and high vocal demand to elicit LD symptoms. Over five consecutive days, each patient participated in two one-hour NF-BCI sessions daily, during which they were trained to modulate abnormally increased EEG activity associated with impaired speaking to the levels associated with normal whispering. All patients assessed changes in their symptom severity after each session using a Likert-item questionnaire, ranging from -5, Worsened to +5, Improved. In addition, patients assessed their level of comfort, engagement, concentration, controllability, and responsiveness during NF-BCI sessions. Repeated-measures Friedman ANOVA corrected for ties was used to examine the differences in symptom severity and the overall performance during NF-BCI between the active and sham LD groups.

We found that patients who received active NF-BCI had a statistically significant improvement of their voice symptoms compared to patients who had sham NF-BCI ($Chi^2 = 9.99$, $p = 0.002$). Patients with active NF-BCI had significantly greater controllability of NF-BCI than patients with sham condition ($Chi^2 = 10.05$, $p = 0.002$) but had no difference in their comfort, engagement, concentration, or responsiveness during the training (all $Chi^2 \leq 2.6$, $p \geq 0.10$).

Conclusion: By integrating personalized EEG modeling, neurofeedback, and VR, this first study of adaptive closed-loop BCI intervention in LD patients demonstrated the feasibility of the treatment of this disorder, opening new opportunities for patients with LD and other focal task-specific dystonias.

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