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EEG and EMG-Controlled Hand Exoskeleton for Training Neural Activation Following Stroke*

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***Abstract*— We describe the design and development of a platform for training neural activation patterns throughout a movement, from initiation to termination, to promote hand rehabilitation in stroke survivors. Brain and muscle activation are used to control a soft-hard hybrid hand exoskeleton. The platform will be used both for therapy and to carry out motor control studies to better understand hand impairment following stroke.**

***Clinical Relevance*— Upper extremity impairment following stroke is a common outcome that greatly reduces quality of life. Training of brain and muscle activation combined with robotics represents an exciting new approach to hand rehabilitation for these patients. Furthermore, the device can be used as an experimental instrument to further understanding of the neural control of movement following stroke, thereby facilitating development of novel therapies.**

I. Introduction

Chronic hand impairment is a common outcome for stroke survivors, greatly affecting activities of daily living and quality of life. We have previously shown that stroke survivors have trouble creating proper grasp postures, often frustrating attempts to position their hands around objects. These deficits are compounded by delays in grip initiation and termination that impair reaction time, grip stability, and object release. The impairments result primarily from aberrant neural activation patterns, observed in both brain (EEG) and muscle (EMG).

Unlike movement, brain and muscle activation cannot be directly observed. Using technology to provide feedback of EMG [1] and EEG signals [2], however, has shown promise for stroke therapy. The goal of this work is to combine both EEG and EMG control to facilitate practice creating proper neural activation patterns throughout the movement, from initiation to termination. In accordance with others [3], we have observed that event-related desynchronization (ERD) within certain frequency bands in EEG signals precedes movement initiation and termination, while EMG signals correspond to active task performance. Accordingly, we have developed a novel platform which utilizes both EEG and EMG control of a hand exoskeleton to facilitate therapeutic practice of hand movement.

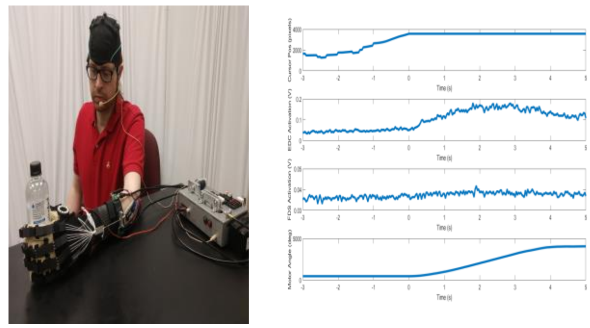

Figure 1. (Left) Complete EEG and EMG-controlled hand exoskeleton system. (Right) Averaged signals for one healthy user during exoskeleton-assisted hand extension. From top to bottom: BCI2000 cursor position for a 1D CursorTask, EDC activation, FDS activation, and motor position.

II. System Design

For this platform (Fig. 1), the user controls a hand exoskeleton, derived from the VAEDA Glove [1], which employs cable-driven actuation to assist extension and resist involuntary flexion of all five digits simultaneously. The exoskeleton can be controlled by a combination of EEG, EMG, and voice signals. In typical use, voice commands are used to set the desired action (e.g., hand closing), while EEG signals trigger initiation and termination of exoskeleton task performance and EMG signals control speed and extent of device movement.

An Arduino Due with a custom PCB controls the device by reading analog and digital inputs and providing output command signals to the servomotor. EEG signals are processed in real-time using BCI2000. The Arduino Due and BCI2000 communicate using a UDP protocol. A user-friendly graphical user interface (GUI) was developed in MATLAB to allow a therapist to easily integrate the device into a patient's normal therapy sessions.

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