Chapter 33
Stroke Rehabilitation and Parkinson's Disease Tremor Reduction Using BCIs Combined With FES

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ABSTRACT

This article describes how Stroke and Parkinson's disease are two illnesses that particularly affect motor functions. With the advancements in technology, there is a lot of research focusing on finding solutions: to contribute to neuroplasticity in the first case, and to reduce symptoms in the second case. This manuscript describes the design of a brain-computer interface system (BCI) system paired with an electrical muscle stimulation suit for stroke rehabilitation and the reduction of tremors caused by Parkinson's disease. The idea is to strengthen the sensory-motor feedback loop, which will allow a more stabilized control of the affected extremities by taking into account the patient's motivation. To do so, his brain signals are measured to detect his intention to attempt to execute a movement, in contrast to the classical approach where the movement executions are imposed. A first feasibility study was completed. The author's next step is planning to test the system first with healthy subjects and finally with patients.

INTRODUCTION

This manuscript describes the design of a non-invasive EEG-based Brain-Computer Interface (BCI) system for motor recovery of stroke patients and for tremor reduction in patients with Parkinson's disease. Patients suffering from these diseases present motor impairments that prevent them to fully live

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their daily lives. In the case of stroke, some motor functions can be recovered some time after the stroke given a suitable rehabilitation therapy. Parkinson's disease symptoms on the other hand tend to worsen as time passes.

Several rehabilitation methods, such as Robot-assisted arms, Functional Electrical Stimulation (FES) and BCI combined with exoskeleton are examples of technology-based rehabilitation therapies (Ramos-Murguialday et al., 2012) being used, some with more success than others are. Nevertheless, in the end, the most important factor in the success of a rehabilitation therapy is the patient himself. Indeed, most of these therapies require the patient to perform the same movement multiple times. In the long term, the patient will lose interest since he gets bored by repeating the same exercise several times. This increasing boredom will consequently affect his motivation. Bhagat et al. (2014) demonstrated that a lack of the latter would limit the effectiveness of the rehabilitation process.

Lew et al. (2012) successfully extracted brain signals signatures indicating volitional upper limb movement intention from healthy persons, and detected the intention as early as 1500 ms before the movement onset. Bhagat et al. (2014), Ramos-Murguialday et al. (2015) and Yilmaz, (2015) performed similar experiments with stroke patients. Those studies suggest that it is possible to develop closed-loop brain-machines interfaces driven by the user's voluntary movement intention (Spüler et al., 2014). Plus, FES-based therapy has proven to be very promising for motor recovery during stroke rehabilitation (Noma et al., 2014).

Here, a system that combines BCI with a VisionBody suit that provides Electrical Muscle Stimulation (EMS) is proposed. The VisionBody suit is chosen to facilitate real-world applications. This suit, originally used in fitness and sports, provides Electrical Muscle Stimulation through electrode pads - located in the arms, legs, breast, etc. - directly to the skin in direct proximity to the muscles to be stimulated. The impulses delivered by these electrodes mimic the action potential coming from the Central Nervous System, causing the muscles to contract.

Our aim is to overcome patients' boredom and lack of engagement to the rehabilitation tasks by allowing them to execute voluntarily the required movements and detecting those intentions using their brain signals. As soon as an intent to move is being detected, the VisionBody suit will be used to deliver the electrical stimulation to the patient's muscles to assist him in the movement production in the case of stroke, and to suppress tremors that may occur while executing a movement in the case of Parkinson's disease. Otherwise, if no intention to move is detected, no support for the movement via Functional Electrical Stimulation (FES) will be provided. By doing so, it is intended to strengthen the sensorimotor feedback loop in order to stabilize the control of the affected extremities. A more positive engagement is then expected from the patients. This has the potential to increase the functionality of the affected limbs, and reduce fatigue by minimizing the energy consumption, the ultimate goal being the improvement of the daily lives of the patients.

The manuscript is organized as follows: first, an overview of stroke and Parkinson's disease is presented, followed by some rehabilitation techniques and treatments used for the two illnesses; then, the tools and methods used for the experiment were presented along with some results.