

BCI controlled neuromuscular electrical stimulation enables sustained motor recovery in chronic stroke victims

R. Leeb^{1,2,#}, A. Biasucci^{2,#}, T. Schmidlin¹, T. Corbet², P. Vuadens³, JdR. Millán^{2,*}

¹Center for Neuroprosthetics (CNP), École Polytechnique Fédérale de Lausanne, Sion, Switzerland;

²Chair in Brain-Machine Interface (CNBI), École Polytechnique Fédérale de Lausanne, Geneva, Switzerland;

³SUVACare - Clinique Romande de Réadaptation, Sion, Switzerland

Equal contributions; * Campus Biotech, Chemin des Mines 9, CH-1202 Geneva, Switzerland; E-mail: jose.millan@epfl.ch

Introduction: Recently, it has been shown that brain-computer interfaces (BCI) can be used in stroke rehabilitation to decode motor attempts from brain signals and to trigger movements of the paralyzed limb [1]. Among other available practices in rehabilitation, neuromuscular electrical stimulation (NMES) is often used to directly engage muscles on the affected parts of the body during physical therapy. Nevertheless, the benefits of a combined approach, to directly link the brain intention with a muscular response, are not yet fully validated. In this abstract, we report first results of a BCI-NMES system for stroke rehabilitation.

Material and Methods: Up to now, we enrolled 18 chronic stroke victims (minimum 10 months past the incident) suffering from an impairment of the upper limb in a randomized controlled clinical trial. Half of the subjects were assigned to the BCI group and half to a “sham” group, whereby the criteria such as motor impairment –measured via the Fugl-Meyer scale for upper extremity (FM) score–, age, time since incident and lesion location were balanced. Generally, the experimental protocol consisted of three different phases: (i) patients underwent a pre-evaluation to check the motor capabilities, to characterize the initial state of the brain and to calibrate the BCI classifier (see BCI details in [2]). (ii) In the following weeks, they were trained with an online BCI twice a week for 10 sessions (45 to 90 minutes including setup). (iii) Finally, they performed a post-experimental screening to determine changes in EEG patterns and in motor functions following the treatment, and a 6-month follow-up to evaluate the sustainment. Patients in the BCI group received NMES of the extensor digitorum muscles triggered by the BCI detecting the intention of movement at the cortical level (modulation of the sensorimotor rhythm in the contralateral motor cortex). For patients in the sham group the NMES was not correlated with the brain activity. All subjects were asked to attempt to open their paretic hand (full sustained finger extension) with the aim of activating the NMES upon detection of a suitable sensorimotor rhythms (Fig. 1-a). Subjects in the two groups (BCI and sham) received comparable amount of NMES.

Results: Remarkably, subjects in the BCI group improved their motor function (post minus pre) by 8.6 ± 5.0 FM points (which is more than the minimal clinical change of 5.25 FM points), while those in the sham group improved only by 2.4 ± 3.4 FM points (Fig. 1-b). As expected, the features used by the BCI classifier were mostly located over the affected hemisphere and the motor cortex (see topographic presentation in Fig. 1-c).

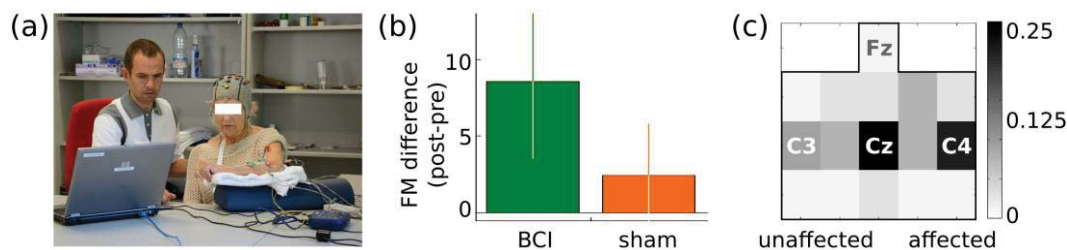


Figure 1. (a) Experimental BCI-NMES setup with the patient and the physical therapist. (b) Improvement in the Fugl-Meyer scales for the upper extremity for the BCI and the sham group (mean \pm standard deviation). (c) Topographic presentation of the ratio of used BCI features (EEG channels might have been flipped so that the lesioned hemisphere appears always on the right side).

Discussion: We hypothesize that the motor improvement in the BCI group (in contrast to the sham group) is triggered by the tight timed and functional link between the intended action in the brain, and the executed and perceived motor action, through the activation of the body’s natural efferent and afferent pathways.

Significance: In our randomized controlled trial, we demonstrate that the modulation of sensorimotor rhythms driving contingent neuromuscular stimulation is more effective than sham stimulation with active motor attempt, and that the proposed therapy dosage produces a clinically important recovery in chronic stroke survivors having a moderate-to-severe motor impairment.

References:

- [1] Ramos-Murguialday A, et al. Brain-machine interface in chronic stroke rehabilitation. *Ann Neurol*, 74(1):100-108, 2013.
- [2] Leeb R, et al. Transferring brain-computer interfaces beyond the laboratory: Successful application control for motor-disabled users. *Artif Intell Med*, 59: 121-132, 2013.