 DOI: 10.3217/978-3-85125-962-9-215

Transcutaneous Electrical Spinal Stimulation Fosters Motor Imagery Skill Acquisition

Hussein Alawieh[1*], Deland Liu[1*], Jonathon Madera[2], Satyam Kumar[1], Frigyes Samuel Racz[3], Ann Majewicz Fey[2], José del R Millán[1,3]

[1] Dept. of Electrical and Computer Engineering, The University of Texas at Austin, Austin, Texas, USA; [2] Dept. of Mechanical Engineering, The University of Texas at Austin, Austin, Texas, USA; [3] Dept. of Neurology, The University of Texas at Austin, Austin, Texas, USA; * These authors contributed equally

*2501 Speedway Av., Austin, Texas 78712, United States of America. E-mail: **hussein@utexas.edu**

Introduction: Non-invasive brain computer interfaces (BCIs) present promising solutions for patients with neuromuscular impairments allowing them control over assistive devices [1]. BCIs are commonly controlled through the imagination of limb movements — motor imagery (MI), which relies on voluntarily modulated sensorimotor rhythms (SMRs). However, a major challenge is the non-stationarity of SMRs, which require longitudinal feedback training for MI skill acquisition. There had been several approaches aimed at increasing the excitability of the sensorimotor networks and thus the quality of SMRs through incorporating electrical stimulation as feedback [2], but less focus has been given to the inhibitory circuits involved in MI. In this study we use transcutaneous electrical spinal stimulation (TESS), which has been shown to exhibit inhibitory effects on the cortex [3], prior to BCI training to promote faster and better BCI skill acquisition.

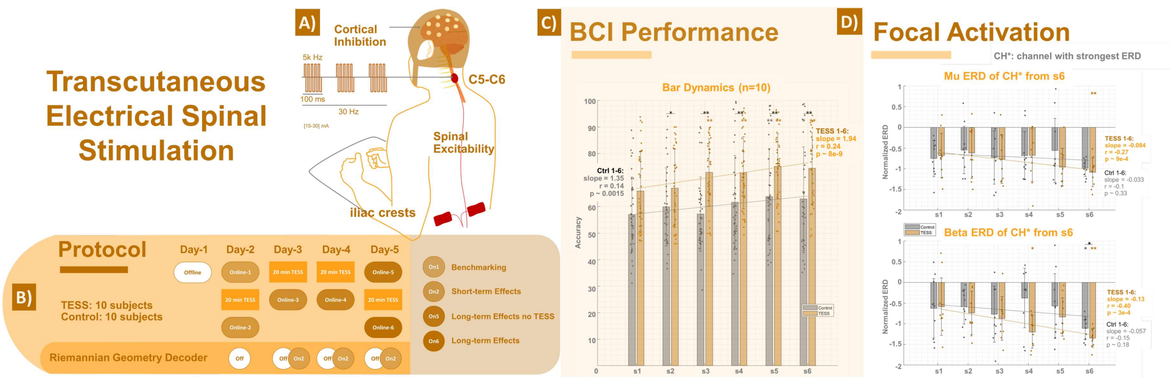

Figure 1: A) Illustration of setup, B) Protocol Design, C) Comparison of BCI performance between TESS group (orange) and Control group (grey), D) Comparison of the degree of ERD focality of the Mu and Beta bands across the two groups.

Material, Methods, and Results: Twenty healthy participants trained over 5 days to control a binary BCI (left vs right MI, Fig. 1B). Participants were randomly split in two groups, where 10 subjects received 20 minutes of TESS before each BCI session. Consistent with previous work [3], TESS was delivered at the C5-C6 level with parameters shown in Fig. 1A. After the longitudinal training, we found significant improvement in BCI performance, measured by the percentage of time participants were in control of the bar task (Fig. 1C). Notably, the TESS group had significantly better performance compared to the control starting on the second session ($p < 0.001$, n=40) until the end of training (TESS: $74.4\% \pm 13.5\%$, Control: $62.9\% \pm 19.5\%$, $p < 0.01$, n=40, LME). The performance in the TESS group was also accompanied with a statistically significant increase in focal activation in the mu and beta bands as shown in Fig. 1D.

Discussion: The BCI performance over the training sessions provide supporting evidence to the hypothesis that pre-training TESS promotes the acquisition of the MI skill and supports better BCI control. The emergence of more focal ERD patterns with TESS is consistent with the expected focal activation/surround inhibition phenomenon during MI.

Significance: In contrast to previous work, our findings highlight the role of inhibition in MI skill acquisition. We propose that using TESS to induce cortical inhibition before focally activating the motor cortex with MI promotes the acquisition of the MI skill for better BCI control. This not only has implications for replacing lost functions, but also for rehabilitation.

References

Jonathan R Wolpaw, José del R Millán, and Nick F Ramsey. Brain-computer interfaces: Definitions and principles. In José del R Millán and Nick F Ramsey, editors, Handbook of Clinical Neurology, volume 168, pages 15–23. Elsevier, 2020.

[2] T. Corbet, I. Iturrate, M. Pereira, S. Perdikis, and J. D. R. Millán, Sensory threshold neuromuscular electrical stimulation fosters motor imagery performance, *Neuroimage*, 176: 268-276, 2018.

[3] F. D. Benavides, H. J. Jo, H. Lundell, V. R. Edgerton, Y. Gerasimenko, and M. A. Perez, Cortical and subcortical effects of transcutaneous spinal cord stimulation in humans with tetraplegia, *Journal of Neuroscience*, 21(13): 2633-2643, 2020.