DOI: 10.3217/978-3-99161-050-2-148

Error-Positivity Amplification with Alternating-Current Stimulation Augments Perceptual Skills to Detect Errors

Deland Liu[1]*, Michael Solomon[2], Holland Ernst[3], Frigyes Samuel Racz[4], Hannah Lee[1], José del R. Millán[1,3,4]*

[1] Chandra Family Dept. of Electrical and Computer Engineering, [2] Dept. of Neuroscience, [3] Dept. of Biomedical Engineering, [4] Dept. of Neurology. The University of Texas at Austin, Austin, TX, USA

Introduction Accurate perception of visuo-motor errors is crucial for sensorimotor learning and corrective actions [1]. Our ongoing research has identified the error positivity (Pe) component of the error-related potential (ErrP) as a neural correlate of perceptual ability for visuo-motor errors [2]. We hypothesize that 20 minutes of transcranial alternating current stimulation (tACS) at a personalized θ frequency, targeting the frontocentral region, will increase Pe amplitude. To test this hypothesis, we evaluated the effects of tACS in a classic 1D error monitoring task involving discrete cursor jumps that induce expectation mismatches [3]. We expect similar Pe enhancement in a more cognitively demanding 2D continuous task, where visuo-motor perturbations introduce mismatches (Fig. 1a). Importantly, we also postulate that tACS will improve participants' perception of visuo-motor errors.

Material, Methods and Results Twenty-six healthy volunteers were randomised into two groups: 13 in the active stimulation group and 13 in the active control group (100-400 Hz transcranial random noise stimulation, tRNS). Stimulation was applied using a 4×1 montage (FCz: 2 mA; AF3, AF4, C1, C2: -0.5 mA). Participants attended two days, each consisting of one pre-stimulation and three post-stimulation sessions. On Day 1, they performed the 1D discrete task [3] with 100 trials (30% erroneous) before and after 20 minutes of personalized θ-tuned tACS or tRNS at rest. Post-stimulation sessions occurred immediately, 15, and 30 minutes later. Day 2 followed the same structure, with participants completing two runs of the 2D continuous task [2] per session. Each run included 36 trials where participants used a joystick to control a cursor along a straight trajectory. In 30% of the trials, the joystick-to-cursor mapping was altered with a small 6° visuo-motor rotation. Participants reported perceptual decisions via joystick button presses after each trial. Results showed that in the 1D task, tACS increased Pe amplitude, becoming significant at 30 minutes post-stimulation, with no effect in the control group (Fig. 1b). At this time point, tACS also enhanced Pe amplitude in the 2D continuous task, alongside improved error perception, while the control group showed no changes (Fig. 1c-d). Moreover, between-group comparisons showed significant differences in Pe amplitude and error perception in favor of tACS.

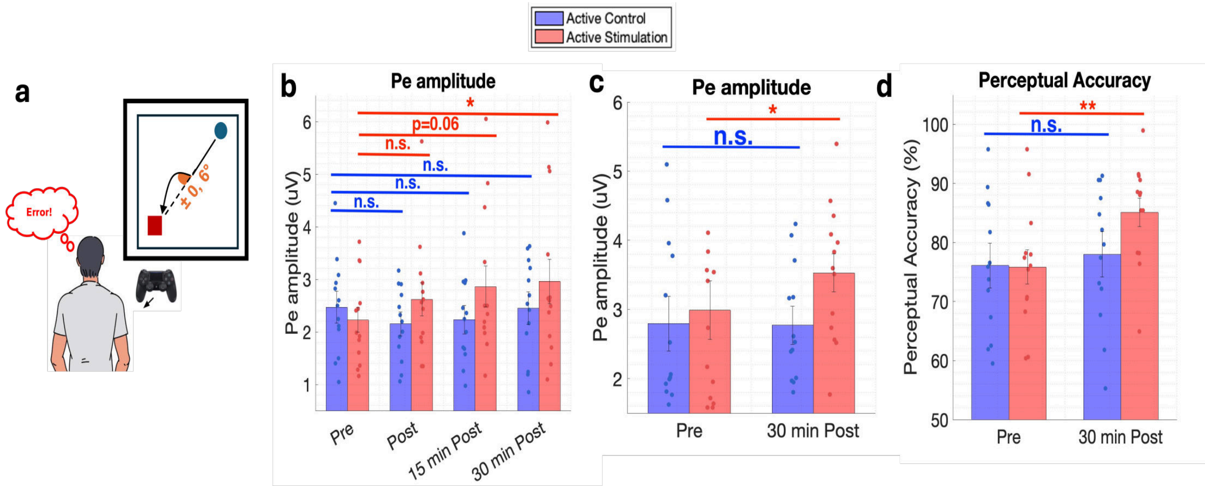

Figure 1: **a** *The 2D continuous visuo-motor error perception task.* **b** *Pe amplitudes at four time points (pre-, immediately post-, 15 min post-, and 30 min post-stimulation) in the 1D task.* **c** *Pe amplitudes at pre- and 30 min post-stimulation in the 2D task.* **d** *Perceptual accuracies at pre- and 30 min post-stimulation in the 2D task. Data for the active group (red, n=13) and control group (blue, n=13) are shown in panels b-d.* $*P < 0.05$, $**P < 0.01$, *n.s.* $P > 0.05$.

Conclusion The proposed brain stimulation approach offers a non-pharmacological, non-invasive foundation for addressing perceptual impairments in elderly and clinical populations, avoiding drug side effects and accelerating perceptual learning compared to conventional methods.

Acknowledgements and Disclosures Authors thank participants and declare no conflict of interest.

References

[1] S. T. Albert and R. Shadmehr, "The neural feedback response to error as a teaching signal for the motor learning system," *Journal of Neuroscience*, vol. 36, no. 17, pp. 4832–4845, 2016.

[2] D. Liu, F. Iwane, M. Zhang, and J. d. R. Millán, "Brain-computer interface training fosters perceptual learning," in *10th Int. BCI Meeting*, 2023.

[3] R. Chavarriaga and J. d. R. Millán, "Learning from EEG error-related potentials in noninvasive brain-computer interfaces," *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 18, no. 4, pp. 381–388, 2010.

*2501 Speedway Ave, Austin, TX 78712, USA. E-mail: deland.liu@utexas.edu, jose.millan@austin.utexas.edu

Published by Verlag der Technischen Universität Graz