Electrophysiological mechanisms of tDCS modulation of executive functions

Abstract #22

Laura Dubreuil-Vall[1,2,3], Peggy Chau[2], Alik Widge[2], Giulio Ruffini[1], Joan Camprodon[2]

[1]Neuroelectrics, US;
[2]Department of Psychiatry and A. A. Martinos Center, MGH/HMS, US;
[3]Universitat de Barcelona, Catalonia, Spain

laura.dubreuil@neuroelectrics.com

MGH/HST Athinoula A. Martinos Center for Biomedical Imaging

MASSACHUSETTS GENERAL HOSPITAL

Harvard-MIT Health Sciences & Technology

INTRODUCTION

Cognitive deficits are common across neuro-psychiatric disorders and a primary cause of functional disability. Nevertheless, clinicians have limited therapeutic options to facilitate cognitive enhancement, particularly of executive functions. tDCS is emerging as a promising tool for the treatment of neuropsychiatric disorders, and dysexecutive syndromes in particular [1]. The successful development of novel therapies requires an understanding of its mechanisms of action and the key targets that, when engaged, drive the therapeutic response. In this sense, Event-Related Potentials (ERPs) recorded on the scalp have established scalp-recorded signatures of executive functions [2].

GOAL: to investigate the effect of tDCS over DLPFC (Left/Right/Sham) on executive functions and electrophysiology (ERPs).

METHODS

N=20 healthy adults (10 males, 10 females, age range 18-53 years) received three different tDCS stimulation sessions over three separate visits: sham, anodal tDCS on the right DLPFC (Anodal Right), and the left DLPFC (Anodal Left) using the Starstim device (Neuroelectrics, US). For each visit, participants performed the Flanker task and Multisource Interference Task with International Affective Picture System (MSIT-IAPS) before (PRE) and after (POST) receiving tDCS. We measured behavioral responses and EEG during the task, and calculated ERPs.

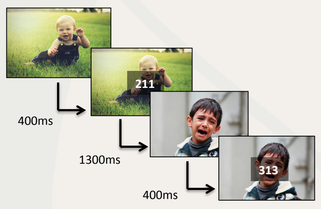

Figure 1. The MSIT-IAPS task consisted of 144 trials, with balanced distribution of images' Valences and Interference.

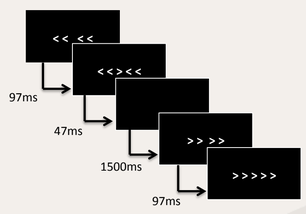

Figure 2. The Flanker task consisted of 144 trials with a ratio of 2 congruent trials for each incongruent trial.

tDCS montage

We used the hybrid 3cm^2 Ag/AgCl *Pistim* electrodes by Neuroelectrics with conductive gel to apply stimulation and record EEG. The duration of the stimulation was 30 minutes at 2mA, with a ramp up and down of 15 seconds. Montages consisted on:

- **Left stimulation:** Anodal F3, Cathodal Fp2.
- **Right stimulation:** Anodal F4, Cathodal Fp1.
- **Sham:** 15-second ramp up/down at the beginning and the end, no stimulation during 30 minutes.

Figure 3. Starstim, hybrid tDCS-EEG device.

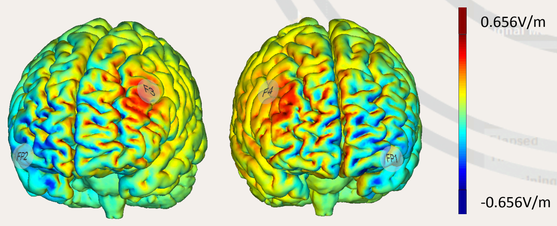

Figure 4. Modeling of the normal component of electrical field [3] for Left and Right stimulation.

Data analysis

- **ERPs:** EEG was offline processed following the steps in Figure 5. A linear mixed model with Subjects as a random intercept was used on single trials for the statistical analysis.

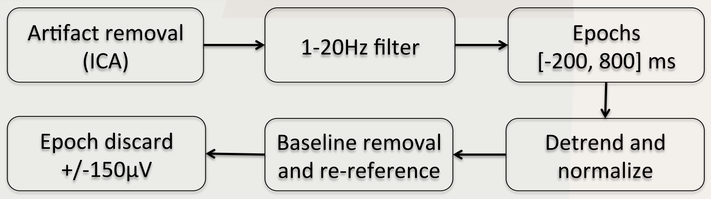

Figure 5. EEG offline processing flow

- **Behavioral:** Accuracy was analyzed using a two-way ANOVA with time point (PRE-POST) and tDCS condition as factors. Reaction Time (RT) was analyzed using a Generalized Linear Model with Mixed Effects (GLMM) with a Gamma distribution on a single-trial basis, with Subjects as a random intercept.

FLANKER TASK RESULTS

In the Flanker task, the effect of tDCS stimulation on Reaction Time is significantly different for Incongruent and Congruent trials (Interaction PRE-POST/Left-Sham/Congruent-Incongruent p=0.04):

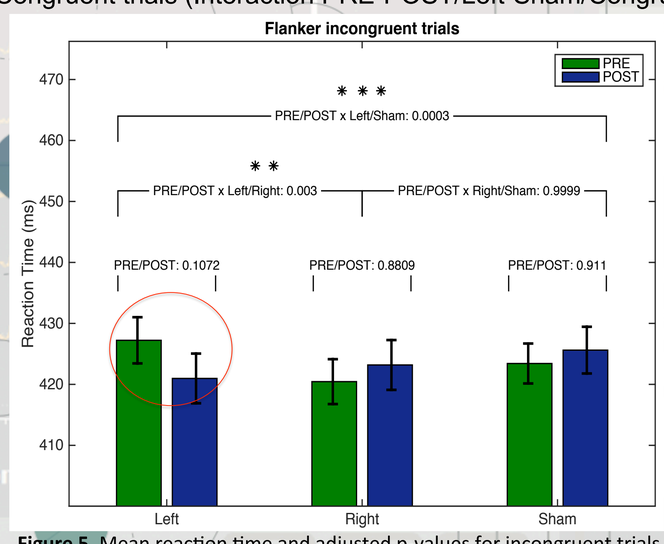

Figure 5. Mean reaction time and adjusted p-values for incongruent trials.

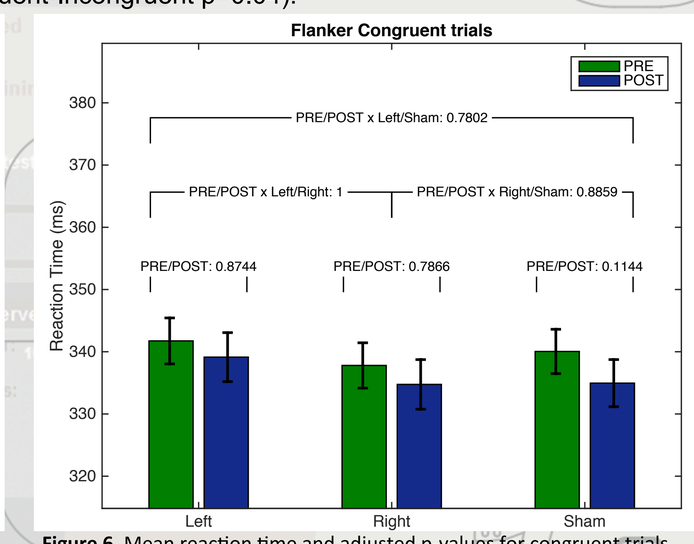

Figure 6. Mean reaction time and adjusted p-values for congruent trials.

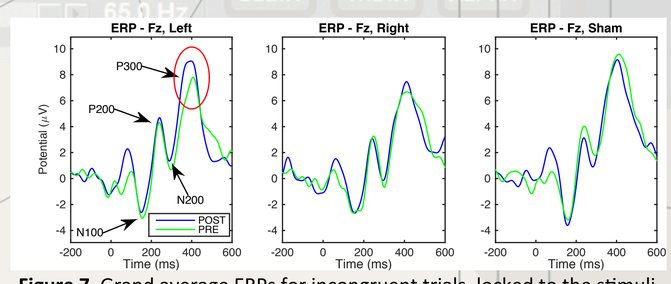

Figure 7. Grand average ERPs for incongruent trials, locked to the stimuli.

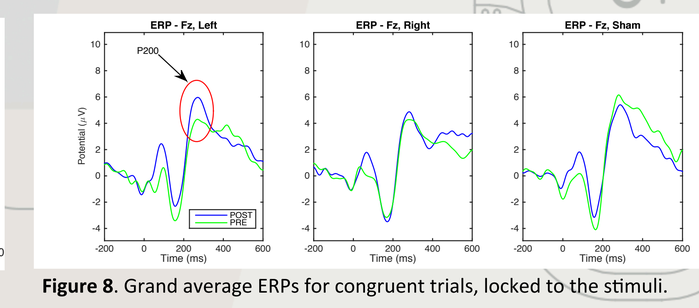

Figure 8. Grand average ERPs for congruent trials, locked to the stimuli.

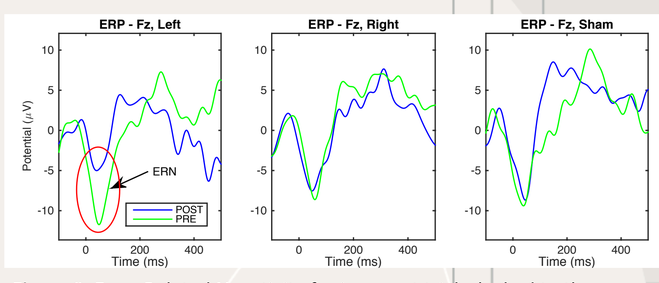

Figure 9. Error Related Negativity for incorrect trials, locked to the response.

- For **incongruent** trials, Anodal Left tDCS lead to faster RT and an increase in P3 amplitude –related to attention–, while Sham lead to no significant changes.
- For **congruent** trials, there were no significant changes in RT for any of the stimulation conditions, but P2 amplitude was increased after Left stimulation.
- **Error-Related Negativity** (ERN) amplitude was significantly decreased after Left stimulation compared to Right and Sham, suggesting a decrease in error monitoring, which may be translated into an increase in self-confidence that may explain the improvement in RT.

MSIT-IAPS TASK RESULTS

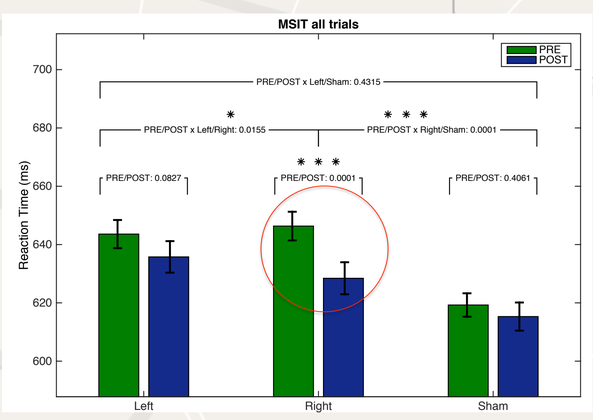

Figure 10. Mean reaction time and adjusted p values for MSIT trials.

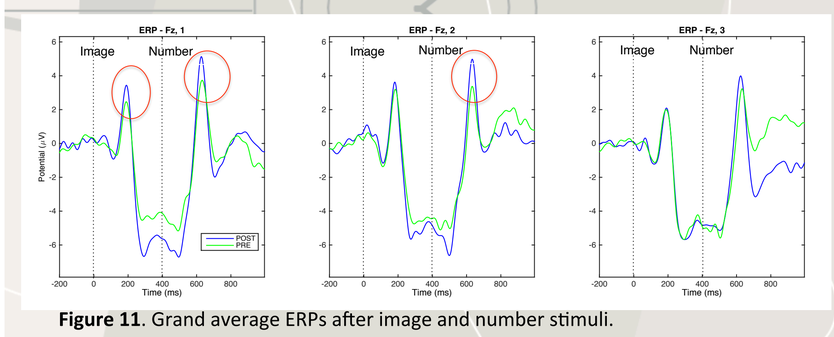

Figure 11. Grand average ERPs after image and number stimuli.

- The effect of tDCS stimulation is not significantly different for Interference and Non-Interference trials, nor for Positive/Neutral/Negative trials.
- For all trials, Right stimulation lead to a significant decrease in RT and an increase in P2 amplitude, related to attention.

CONCLUSIONS

Our results show that ERPs related to executive functions are modulated by anodal tDCS applied over DLPFC in healthy adults. This modulation is correlated with significant changes in the behavioral performance, suggesting tDCS as a possible method to modulate executive function. This presents ERPs as potential biomarkers and therapeutic targets for pro-cognitive treatments.

Future work includes the adaptation of task difficulty to each subject baseline; the use of multi-channel tDCS montages to target the fronto-parietal network with increased focality, and the analysis of other EEG features that may be useful as potential biomarkers, such as ERP latency, power and connectivity between regions.

REFERENCES

[1] Sarkis RA, Kaur N, Camprodon JA. Transcranial direct current stimulation (tDCS): modulation of executive function in health and disease. Curr Behav Neurosci Rep. 2014; 1:74–85.

[2] LY. Deouell et al. Executive Function and high-order cognition: EEG studies. Encyclopedia of *Neuroscience* (2009).

[3] G. Ruffini, M. D. Fox, O. Ripolles, P. C. Miranda, A. Pascual-Leone. Optimization of multifocal transcranial current stimulation for weighted cortical pattern targeting from realistic modeling of electric fields. *NeuroImage* (April 2014).