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Assessing the impact of transcranial Direct Current Stimulation (tDCS) on the enhancement of race driving skills

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Introduction: Transcranial Direct Current Stimulation (tDCS) is a non-invasive brain stimulation approach where DC currents are delivered to the brain tissue through electrodes placed on the user's scalp, modulating cortical excitability [1]. Although tDCS seems to be a promising motor training approach, very few studies have addressed the impact of tDCS on learning complex motor skills like race driving [2]. The identification of neuromarkers associated to motor learning has begged the question whether the underlying brain plasticity mechanisms can be manipulated to give rise to faster and/or more effective training of race drivers using tDCS.

Material and Methods: Eleven novice participants were included in a study aimed at investigating the potential role of tDCS in learning to race. We recorded electroencephalography (EEG) and electrooculography (EOG) at 512 Hz using an ANT Neuro eego 64-channel EEG system while subjects were driving in a racing simulator (rFactor2). Twenty minutes of Active or Sham tDCS (PlatoWork by PlatoScience, Copenhagen, Denmark) was applied before the race-driving task. Subjects were randomly and blindly assigned to one of two tDCS groups (6 Active, 5 Sham). Balance of identified confounding factors (age, gender, driving proficiency, corrected vision) was ensured using Frane's allocation algorithm. The Active tDCS group received anodal stimulation with fixed electrode positioning designed and parameterized to assist learning by increasing neural excitability over prefrontal brain regions associated with learning. Sham stimulation simulated the same sensation without giving rise to cortical excitability. Each participant went through 10 experimental sessions (20 laps/session). Lap time was adopted as the variable for evaluating the learning outcome. Telemetry data were saved for further analysis at 100 Hz sampling rate. The role of tDCS in learning to race was evaluated through a mixed-design ANOVA with lap time gain as the response variable (average lap time of the last 2 sessions subtracted from that of the first 2 sessions), the between-subject factor was tDCS treatment (Active, Sham), and the within-subject factor was time (in sessions, with 10 levels). We also inspected the average, standard deviation, and significance (with unpaired, two-sided Wilcoxon rank sum tests) of the lap times per group and session.

Results and Discussion: The ANOVA showed no significant effect of tDCS on lap time gain ($F=0.63$, $p=0.76$). However, the session-wise lap time comparisons between the two groups suggest that tDCS may in fact play a role in learning to race. On average, Active tDCS subjects performed in the last session significantly better (by almost 3 s) than the Sham ones (Active: 89.4±9.5 vs Sham: 92.0±10.5, $p<10^{-17}$), although performance is balanced in the first session. The difference in favour of Active tDCS becomes more pronounced over sessions and is statistically significant in session 2 and throughout sessions 5-10 (see Figure 1). Interestingly, the Active tDCS group exhibits better outcomes in sessions where intense learning takes place (i.e., when the average lap improvement across all subjects is greatest). Overall, unlike all other confounds examined, the tDCS factor is the only one that is balanced at training onset and superior for the Active group at training offset, suggesting a contribution of anodal tDCS on race skill acquisition. Of note, we posit that the marginal (non-significant) superiority for the Active group observed already in session 1 should be attributed to tDCS-related learning benefits taking effect already within the 20 laps executed by subjects in the first session. It can thus be claimed that anodal tDCS seems to play a positive role in race driving learning, although the effect was not strong enough as to manifest in our ANOVA of total lap time gain in this small subject cohort.

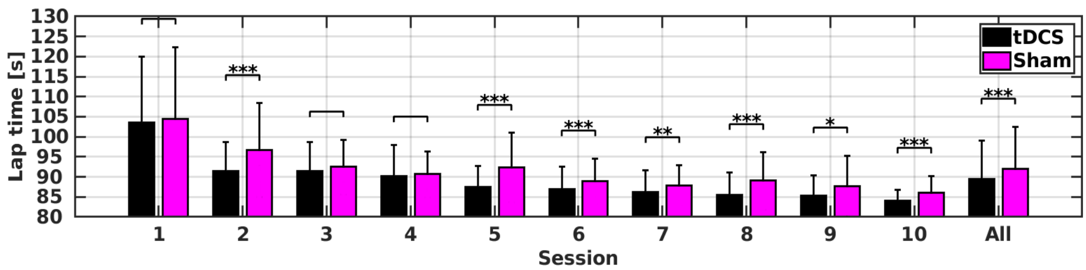

Figure 1. Average pooled lap time per session compared between two groups (Active vs Sham tDCS).

Significance: We provide preliminary evidence in favour of the hypothesis that tDCS can support learning of race driving. Future work will focus on confirming this hypothesis and delineating such effects with larger populations, as well as on studying the relationship of various EEG markers of plasticity with the learning outcomes.

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