Effects of tDCS neurostimulation on Flight Simulator Performance

Jesse Mark[1], Hasan Ayaz[1-5], Daniel Callan[6]

1. **School of Biomedical Engineering, Science, and Health Systems, Drexel University, Philadelphia, PA USA**
2. **Drexel Solutions Institute, Drexel University, Philadelphia, PA USA**
3. **Department of Psychology College of Arts and Sciences, Drexel University, Philadelphia, PA USA**
4. **Department of Family and Community Health, University of Pennsylvania, Philadelphia, PA USA**
5. **Center for Injury Research and Prevention, Children's Hospital of Philadelphia, Philadelphia, PA USA**
6. **AI Brain Integration Laboratory, Advanced Telecommunications Research Institute International, Kyoto, Japan**

Humans have a limited capacity for cognitive workload, and performing complex jobs such as piloting a plane, performing surgery, and operating advanced machinery can push this capacity to the limit [1]. When attention needs to be split between several different focal points in order to succeed, or during high pressure situations where time is critical or safety is at risk, people may suffer from inattentional deafness, and unintentionally ignore what may otherwise be obvious signs of impending failure [2]. This can lead to a loss of time, money, or even life. There is an unmet need to utilize neuroergonomic methods to intervene and enhance operators' performance to meet operational demands. Here, we have used transcranial direct current stimulation (tDCS) applied to the right dorsolateral prefrontal cortex to improve task performance.

Flight simulators are a well-studied medium for research involving mental workload, training, and learning, and have been widely utilized for functional neuroimaging studies [3-5]. Previous research has found that tDCS stimulation applied to the prefrontal cortex, specifically the right dorsolateral prefrontal cortex (DLPFC), is effective in inducing task-related changes in brain activity and performance in working memory and flight simulator tasks [6]. In the research presented here, we analyzed the behavioral effects induced by tDCS during flight simulator tasks [7].

Our study used a single-blind, three session, dual-task format with concurrent flight simulator landing tasks and an auditory response and working memory task. Twenty-six college-aged students (age 18-22, 8 female) from Japanese universities with experience piloting gliders were recruited for this study. Participants were outfitted with a Neuroelectrics Starstim high definition tDCS with three electrodes to localize stimulation to the 10-20 location AF8 over the right DLPFC. Thirty minutes of stimulation at 1.5 mA was provided during the second session for the stim group, whereas the sham group only received 30 seconds of ramp-up stimulation.

The landing task consisted of 24 trials per session, each trial averaging 45 seconds. Participants piloted a plane using a three-axis flight stick in the right hand and were instructed to land on a runway as smoothly as possible; the simulator used was programmed in X-Plane 11. Each trial either had wind present or absent, representing hard and easy difficulties, as well as two possible runways that were wide or narrow, also representing easy and hard respectively. Audio stimuli played during each trial for the memory response task. Each stimuli was presented an average of once per two seconds, and consisted of a pseudorandom callsign containing a basic color and number combination (e.g. Blue 4, Green 9). Subjects were instructed to memorize the parity of the number following every "Red" stimulus, and respond with a button press to each following red callsign number based on whether the parity was a match or mismatch (i.e. Red 5 followed by Red 7 is a match, but Red 2 is a mismatch). Responses were required in half of all trials, but auditory stimuli played every trial. These three conditions—wind, runway, and auditory task—were counterbalanced across all trials and sessions.

For this analysis, flight performance data in sessions 2 and 3 were baselined per subject to session 1 to remove any existing pre-study biases. Generalized linear mixed models were processed using session and tDCS condition as factors (Figure 1) with subject as random. The models displayed high significance in total trial time factors of session ($F_{1,1200} = 16.14$, $p < 0.001$) and tDCS ($F_{1,23.9} = 5.20$, $p < 0.05$), as well as their interaction ($F_{1,1200} = 4.16$, $p < 0.05$). The speed at landing was found to be significantly affected by tDCS condition ($F_{1,24} = 7.82$, $p < 0.01$), as well as by the runway difficulty included as a cofactor ($F_{1,1198} = 10.4$, $p < 0.01$). Finally, the total air deviation in the pitch and yaw directions were significant for both session ($F_{1,1204} = 20.46$, $p < 0.01$) and interaction of session and tDCS ($F_{1,1204} = 14.6$, $p < 0.001$).

Participants in both conditions displayed a decrease in the time to land from session 2 to 3, as expected, indicating an improvement in performance over practice, as they were able to land earlier. However, the tDCS stimulation group had both overall lower times as well as a greater improvement in time (sharper decrease) between sessions 2 to 3. This suggests that tDCS improves performance both during and directly following application. The same pattern is true for the pitch and yaw deviation, with a large decrease in deviation, indicating better performance, is seen between sessions 2 to 3. Last, tDCS stimulation participants had significantly higher speed at landing in both sessions than sham subjects. A higher speed at landing indicates that airspeed was not unnecessarily lost during the approach to runway and that there was a lower probability of stalling.

From this preliminary analysis, we have seen clear improvement in piloting ability correlated with right prefrontal tDCS stimulation during complex task performance. These improvements last even after active stimulation has ended, and in follow-up experiments we will determine the persistence of long-term improvement. In this experiment, we additionally used fMRI to record brain activity concurrently with tDCS stimulation, which will be used to analyze changes in neuron activation and long-term potentiation effects. These results suggest that neurostimulation can improve performance and increase the efficiency of skill acquisition.

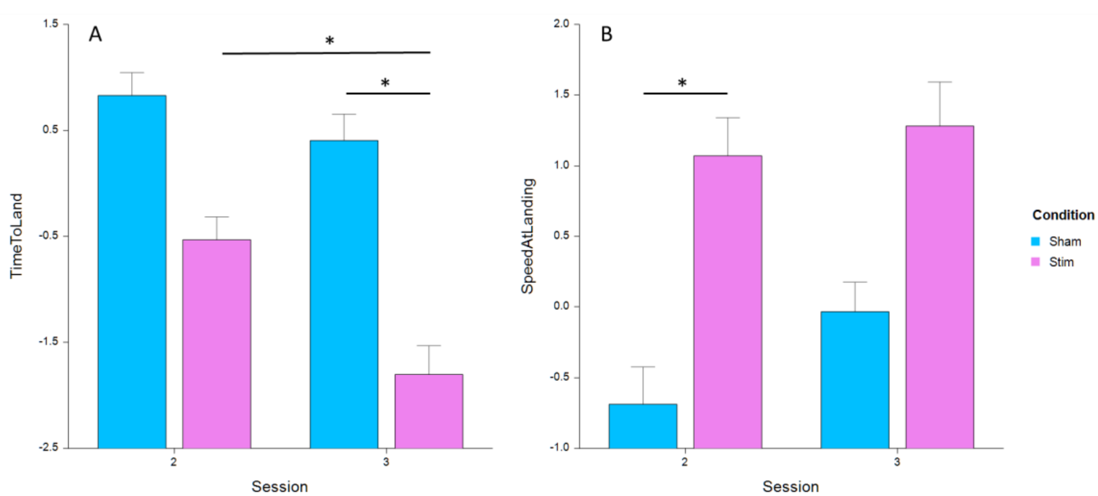

Figure 1: (A) The time to land, baselined to session 1 performance. (B) The speed at landing, baselined to session 1 performance. Asterisks indicate Bonferroni corrected post-hoc significance $p < 0.05$.

References:

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