Effects of Transcranial Direct Current Stimulation (tDCS) on Operator Vigilance: A Double-Blind, Sham-Controlled Study

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Introduction

Problem:

- Society is increasingly reliant on automation
- Monitoring such systems is essential but tedious
- Vigilance decrement in human operators creates significant safety risks[1]

Proposed Solution:

- Transcranial direct current stimulation (tDCS) is safe, portable, and relatively inexpensive
- Previous work suggests anodal tDCS applied to left dorsolateral prefrontal cortex (dlPFC) can improve task vigilance[2,3]

Methods

Design

- 21 healthy young adults completed 2 sessions
- Active or sham tDCS; order counterbalanced
- 7 or 14 days between sessions, same time/day

Task

- Computerized version of Mackworth clock test[4]
- ~8% of 3600 trials required response
- Evenly distributed across three 10-minute blocks

Stimulation

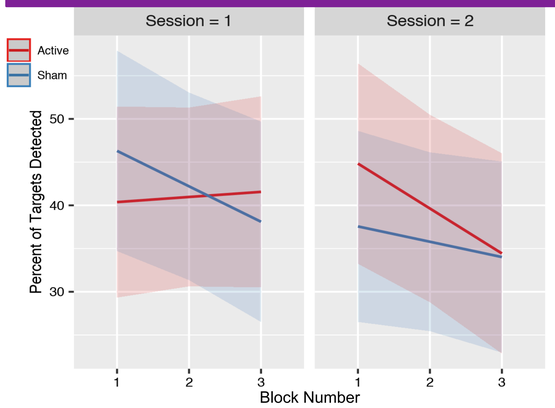
- Neuroconn DC-Stimulator Plus
- 5 x 7 cm sponge-covered rubber electrodes
  - Anode: F3 (left dlPFC)
  - Cathode: Fp2 (contralateral forehead)
  - 2 mA x first 20 minutes of task

Statistics

- Linear mixed effects model (subjects = random)

Results

Performance Accuracy



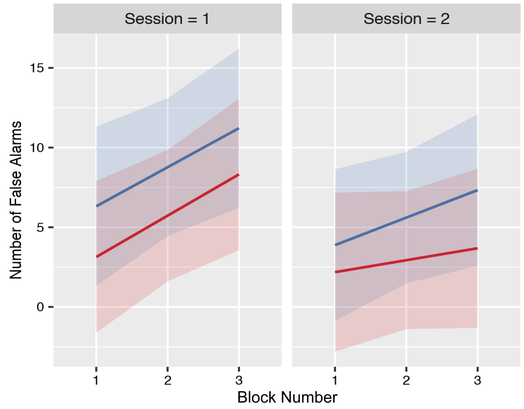
Correct Responses (True Hits)

Main Effects

- Session: $p = 0.022$
- Block: $p = 0.015$

Interaction

- Session * Block * Stimulation: $p = 0.049$



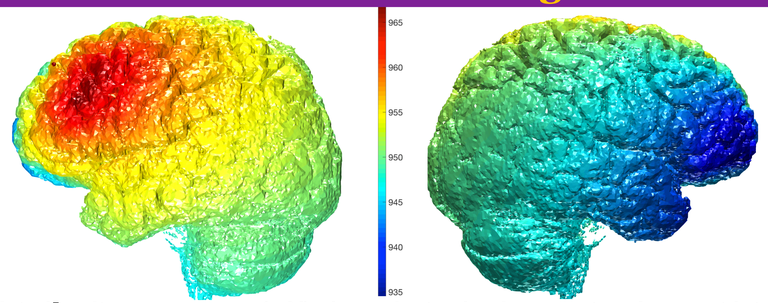
Incorrect Responses (False Alarms)

Main Effects

- Session: $p = 0.004$
- Block: $p = 0.003$
- Stimulation: $p = 0.009$

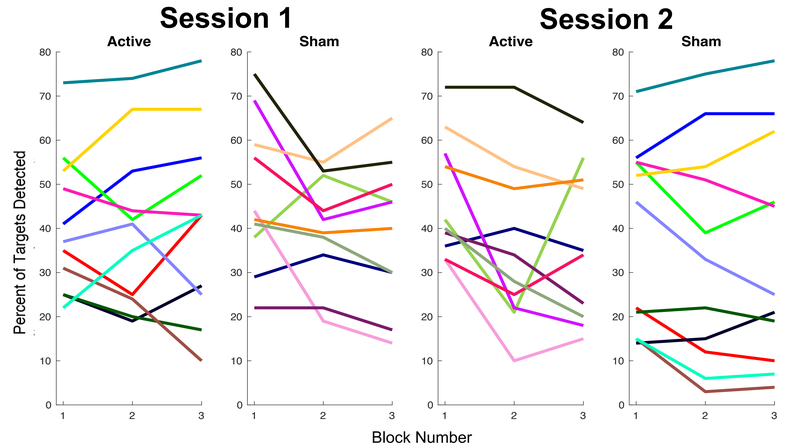
Fitted regression models for correct (above) and incorrect (below) responses.

Current Modeling



Simulated[5] voltage measures (mV) given electrode placement and current intensity.

Individual Responses



Individual performance for true hits. Color-coding conserved across plots.

Discussion

- Findings suggest future promise for enhanced operator vigilance
- Some effects likely obscured by:
  - Interaction between attention and task familiarity
  - Individual variability in tDCS response
- Modulating stimulation via real-time feedback may yield more consistent, optimal vigilance performance
  - Neural vigilance marker: Sensitive to endogenous/exogenous factors affecting attention
  - Dynamic stimulation parameters: Online adaptation of intensity/waveform based on individualized traits and states

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Acknowledgments

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