ACCELERATION OF PROCEDURAL LEARNING WITH TRANSCRANIAL DIRECT CURRENT STIMULATION (tDCS)

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I have no financial relationships to disclose.

I will discuss the following off-label use and/or investigational use in my presentation:
Introduction

• Manpower Problem:
  – Some jobs (Image Analysis) must be done by humans
  – Many tasks in the military are procedure based
Non-Invasive Brain Stimulation?

• Began as neurological therapeutic treatment
  - Two Primary Methods:
    • Transcranial Direct Current Stimulation
    • Transcranial Magnetic Stimulation

Healthy Controls – Improved Cognitive Performance
Introduction

Transcranial Direct Current Stimulation

Sham (2 mA, 30 sec)  Active (2 mA, 30 min)

Up-modulate neural activity
(decrease membrane potential, increase spontaneous firing)

Down-modulate neural activity
(increase membrane potential, decrease spontaneous firing)

(from Purpura & McMurtry, 1965)
Can we accelerate nondeclarative (skill) learning?

- Previous research – enhancement simple motor procedural learning with motor cortex stimulation (Galea & Celnik, 2009)
- Wanted to examine more complex motor procedural task

**Strategy**

Enhance motor skill
Excite – Motor Cortex

Depress competing memory
Inhibit – Prefrontal Cortex
Skill Learning

Warship Commander Task

Day 1: Learning (20 minutes)

Day 2: Testing (20 minutes)

<table>
<thead>
<tr>
<th>Skill Acquisition</th>
<th>Anodal - Motor Cortex</th>
<th>Cathodal - Prefrontal Cortex</th>
<th>Anodal - Motor &amp; Cathodal Prefrontal</th>
<th>Sham - Motor &amp; Sham - Prefrontal</th>
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</thead>
<tbody>
<tr>
<td>Group 1 (n=10)</td>
<td></td>
<td></td>
<td>Group 3 (n=10)</td>
<td>Group 4 (n=10)</td>
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<tr>
<td>Skill Consolidation</td>
<td>Group 2 (n=10)</td>
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</table>
The Sequence of training and testing blocks with notations for Active and Sham TDCS.

**Active Groups**

- **Day 1**
  - Baseline: 1 wave, 12 Aircraft, 75 sec
  - Training 1: 3 waves, 12 aircraft/wave, 3 min 45 sec
  - Training 2: 3 waves, 12 aircraft/wave, 3 min 45 sec
  - Training 3: 3 waves, 12 aircraft/wave, 3 min 45 sec
  - Training 4: 3 waves, 12 aircraft/wave, 3 min 45 sec

- **Day 2**
  - Test 1: 3 waves, 12 aircraft/wave, 3 min 45 sec
  - Test 2: 3 waves, 12 aircraft/wave, 3 min 45 sec
  - Test 3: 3 waves, 12 aircraft/wave, 3 min 45 sec
  - Test 4: 3 waves, 12 aircraft/wave, 3 min 45 sec

**Sham Group**

- **Day 1**
  - Baseline: 1 wave, 12 Aircraft, 75 sec
  - Training 1: 3 waves, 12 aircraft/wave, 3 min 45 sec
  - Training 2: 3 waves, 12 aircraft/wave, 3 min 45 sec
  - Training 3: 3 waves, 12 aircraft/wave, 3 min 45 sec
  - Training 4: 3 waves, 12 aircraft/wave, 3 min 45 sec

- **Day 2**
  - Test 1: 3 waves, 12 aircraft/wave, 3 min 45 sec
  - Test 2: 3 waves, 12 aircraft/wave, 3 min 45 sec
  - Test 3: 3 waves, 12 aircraft/wave, 3 min 45 sec
  - Test 4: 3 waves, 12 aircraft/wave, 3 min 45 sec

**Active TDCS:** 2 mA for 20 min.  
**Sham TDCS:** 2 mA for 30 sec.
Results
Score

Ave % Change from Baseline in Score

- M
- C
- M+C
- Sham
Results
Correct Button Presses

Average Difference in Correct BP

- M
- C
- M+C
- Sham
Results
Incorrect Button Presses

Ave Change from Baseline

M  C  M+C  Sham
Discussion

• Cathodal over DLPFC immediately following training improves rate of learning
  – Dominance of declarative memory system in complex task
  – C-tDCS shifts dominance to non-declarative system

• Allows better consolidation

• Anodal over motor cortex aids learning in this task during training
  – Improves procedural motor component of task – i.e. clicking buttons
Conclusions

- **TAKE AWAY FINDINGS:**
  - Either excitation of the motor cortex during training or inhibition of the prefrontal cortex during consolidation lead to an acceleration of procedural learning.
  - Although not significant, it appears that a combination of the two stimulation paradigms may lead to greater improvements than one technique alone.

- **FOR FUTURE RESEARCH:**
  - Investigate effects of tDCS over multiple days. Determine whether additive effects exist
  - Determine duration of improvement - test one week and two weeks following training
Questions?

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