Can an exogenous current modify endogenous mid-frontal theta activity and memory retrieval?
A *Stimulating* Endeavor

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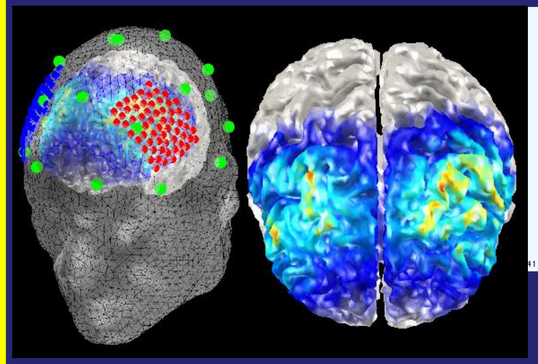
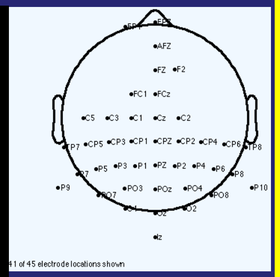
OVERVIEW

- Transcranial stimulation can test causal relationships between brain networks and human behavior[1,2], but few studies have simultaneously measured neural activity and behavior with stimulation.[3,4,5]
- Prior work showed pre-stimulus mid-frontal theta (4-8 Hz) associated with subsequent successful recollection (item + source retrieval).[6]
- We sought to recreate this effect with transcranial alternating current stimulation (tACS) at 5.12 Hz, measuring both neural activity, via electroencephalography (EEG), and memory, via a validated task[6].

APPARATUS

35 cm² electrodes, alcohol, conductive paste + gel, 64 ch EEG cap





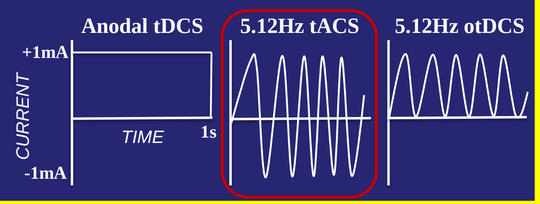
Medial prefrontal stimulation montage

Stimulation Types[1,2]

tDCS: ***direct current***

tACS (this study): ***alternating current***

otDCS: ***oscillating current plus DC offset***



WITHIN-SUBJECTS DESIGN

Incidental Encoding (20-30 min) -> tACS-EEG Setup (60-75 min) -> Retrieval/Stimulation (45-60 min) -> Takedown/Debriefing

Incidental Encoding

4 blocks X 50 nouns = 100 "Old"

Is this word pleasant?

SANDWICH

YES NO

OR

Is this word alive?

BUTTERFLY

YES NO

Retrieval/Stimulation

4 Blocks (~10 min each) X 75 Items, Old or New

5.12 Hz tACS on Blocks 1+3, off Blocks 2+4; EEG on all

Self-paced responses w/ fixed transition times

Test Item (Old/New), Source Recognition (Alive/Pleasant), + Confidence (Hi/Lo):

Have you seen this word?

BUTTERFLY

1/OldHi 2/OldLo 3/Maybe 4/NewLo 5/NewHi

ITEM

+

ISI

Which decision?

BUTTERFLY

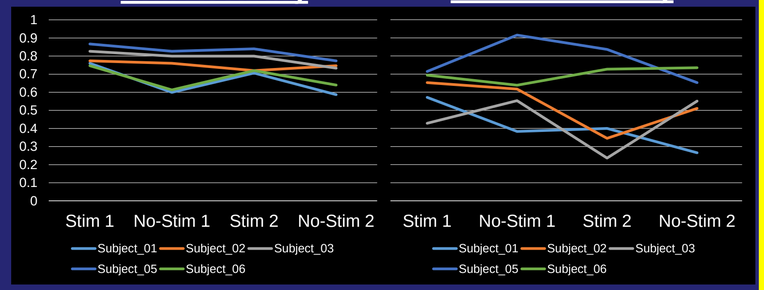
AliveHi AliveLo Maybe PleasantLo PleasantHi

SOURCE

BEHAVIORAL RESULTS

- N = 6
- 2 F, 4 M
- Age 22-32 yo
- Subject 4 (F) omitted due to technical errors
- **No apparent effect of stimulation on memory**

Item Accuracy



Mean = 0.74, SD = 0.06

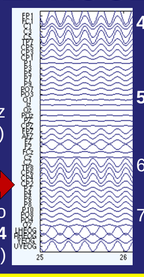
Source Accuracy

Mean = 0.57, SD = 0.14

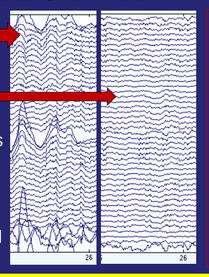
EEG PREPROCESSING (EEGLAB/MATLAB)

1. Remove stim-blocked/bridged channels (18 removed for Sub1-5, 20 for Sub6)
2. Bandpass filter at 1-55Hz (Window-sinc, Hamming)
3. **If Sham/Stim-Off, add sine wave**

   Spatiotemporally similar to tACS artifact (so step **4** may be uniformly applied)



4. ****Artifact template subtraction[3,7]**
5. **PCA+SASICA** Remove residual artifacts
6. Rereference, de-mean data
7. Epoch -2000 to 2000 ms around each stimulus



****Moving Weighted Average Subtraction**

A. *Divide block into 6400-sample segments*

B. *For each sample in a segment, create sample average over 10 adjacent segments*

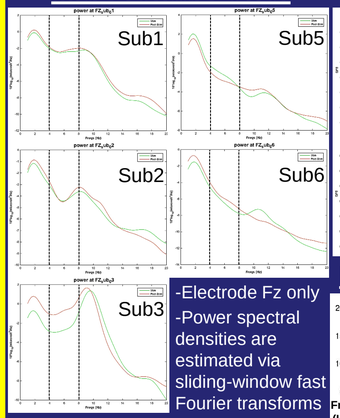
C. *Beta-weight sample averages via least-squares regression vs raw data*

D. *Subtract weighted averages from each sample*

EEG RESULTS

No apparent effect of stimulation on theta mid-frontal power or GFS

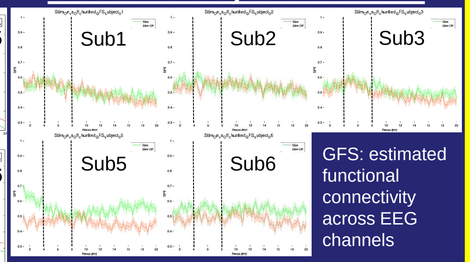
Mid-Frontal Power



-Electrode Fz only

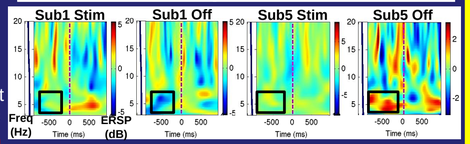
-Power spectral densities are estimated via sliding-window fast Fourier transforms

Global Field Synchronization



GFS: estimated functional connectivity across EEG channels

Event Related Spectral Perturbation



Power/GFS: ***Stim-On*** *= green,* ***Stim-Off*** *= orange,* ***Theta (4-8 Hz)*** *= dotted lines.* ***ERSP: Prestimulus theta*** *= black boxes*

-Frequency-domain wavelet analysis at electrode Fz for successful recollections (correct item+source>item-only)

-Stimulation-associated increase in Fz prestimulus theta in some subjects (e.g. Sub1), but not others (e.g. Sub5)

DISCUSSION

- We observed some stimulation-related increases in prestimulus theta ERSP, though other neural or behavioral effects were absent.
- We successfully removed the tACS-EEG artifact, demonstrating the simultaneous stimulating-and-recording apparatus may be used further.
- This was a useful pilot, but more subjects and experiments are indicated.
- Transcranial stimulation (tACS, anodal tDCS, otDCS) may be a promising tool to improve memory and learning. This is an exciting new field, and further research is forthcoming.

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