# Alpha-frequency Transcranial Alternating Current Stimulation (tACS) Modulates Dynamic Brain States and Facilitates Sustained Attention

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## Introduction

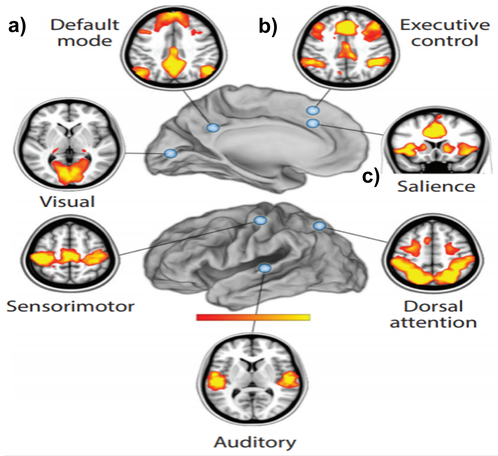



**Figure 1.** Visualization of activity of Intrinsic Connectivity Networks.

- Default mode Network (DMN) - dominant during rest, maintains vigilance and introspective attention.
- Executive control network (ECN) - Top-down control of external attention, anti-correlated with DMN.
- Salience network (SN) - Switching networks, detecting and orienting to salient stimuli.

## Experimental Questions

1. How are these large-scale networks coordinated over time in brain states during sustained attention?
2. Can enhancing alpha oscillations affect states and improve sustained attention in the face of distractors?

## Methodology

**Approach:**

- Identify and define states from network BOLD fluctuation (Bayesian machine learning)
- Brain-behavior association: state metrics & sustained attention performance
- Alpha-tACS to experimentally manipulate alpha

**Participants:**

- 40 participants
  - After exclusions:
    - Active condition: n = 12
    - Sham condition: n=15

**Experimental Paradigm**

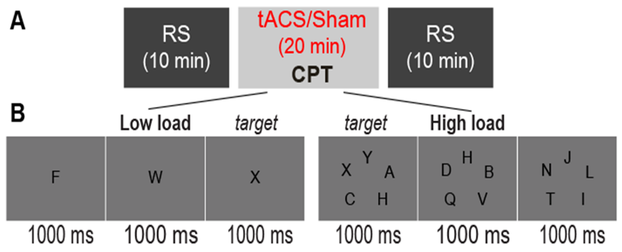



**Figure 2.** Overview of continuous performance task (CPT).

## Results

Transcranial Alternating Current Simulation (tACS) **increased** alpha oscillations and facilitated sustained attention.

**Figure 3.** tACS improves task accuracy in high load.

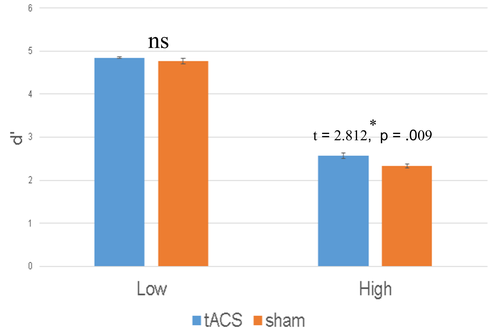



**Figure 4.** tACS differences in alpha oscillation in Active vs Sham conditions.

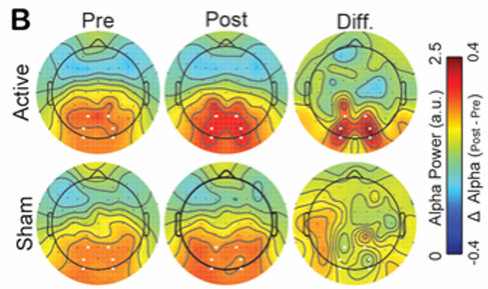



**Figure 5.** Task accuracy had a statistically significant moderately negative correlation with mean lifetimes in High S1.

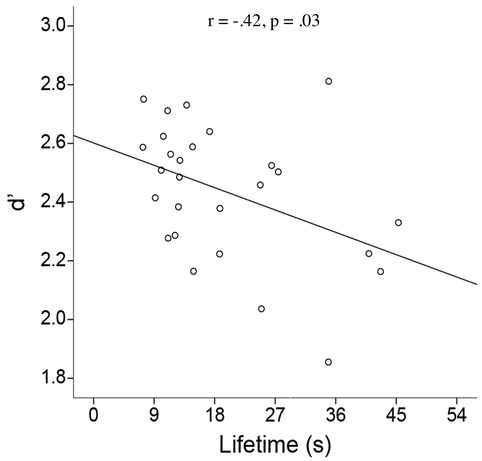
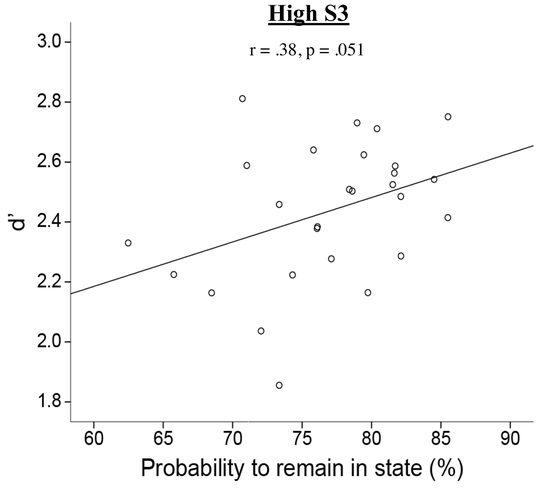


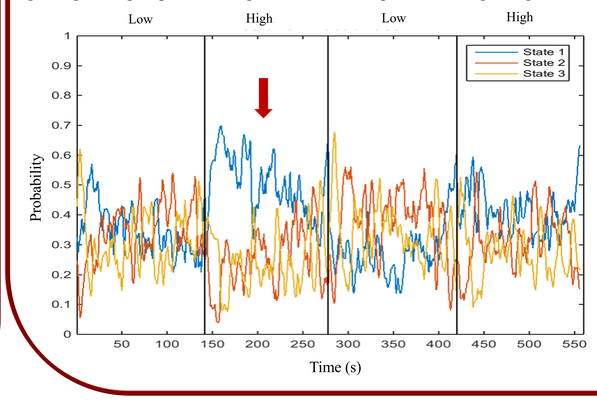

**Figure 6.** Task accuracy had a statistically significant moderately positive correlation with the percent probability to remain in High S3.

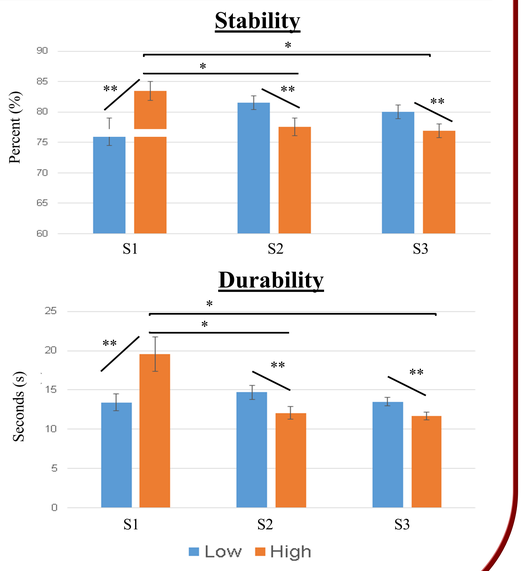



**Three Dynamic Brain States**

| S1 | S2 | S3 |
|---|---|---|
| Inefficient<br>Low activation | Efficient<br>DMN & VN | Efficient<br>SN & ECN |

**Figure 7.** Temporal dynamics of States 1, 2, and 3. Likelihood any given participant is going to be at a specific State averaged across all participants.

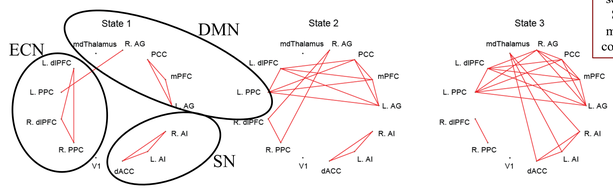



## Revealed Dynamic Brain States:

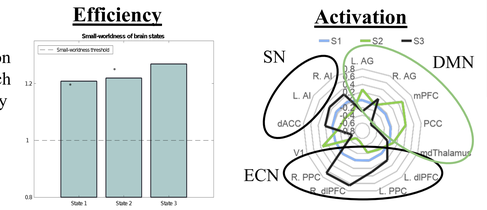
**Binary Connectivity**

**Figure 10.** Visualizations of Binary Connectivities between ICNs.




Closer functional connectivities as seen in S2 and S3 represent more effective communication.

**Figure 11.** Visualization of how much state activity deviates from the norm.




No deviations from the norm in S1 show the lack of communication in binary connectivity

Show that State 1 is not impactful or helpful in sustaining attention.

## Discussion

Large-scale networks are coordinated over time in brain states during sustained attention.

- ICNs vary by hidden state
- Distractors influence states
  - Equal distribution in low load
  - S2 & S3 yield to S1 in high load
- Behavioral relevance
  - S1: detrimental effect on sustained attention
  - S3: beneficial effect on sustained attention

**Figure 12.** Enhancing alpha oscillations may affect states and improve sustained attention in the face of distractors.


## References

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