M1-tDCS MODULATES DYNAMIC EFFECTIVE CONNECTIVITY IN THE MOTOR NETWORK

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INTRODUCTION

- Vast literature on tDCS modulation of motor regions[1].
- Most evidence comes from motor-evoked potentials[2] and, in fewer cases, BOLD signal changes or functional connectivity[3].

→ Lack of mechanistic explanations on the specific effects of tDCS on cortical and subcortical networks.

- Evidence often obtained by comparing the changes after tDCS with baseline[4].

→ Little information on the temporal dynamics of tDCS

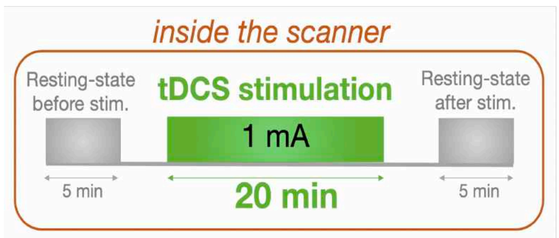
We investigated the ***temporal changes*** in ***effective connectivity*** across cortical and subcortical motor regions ***during*** tDCS.

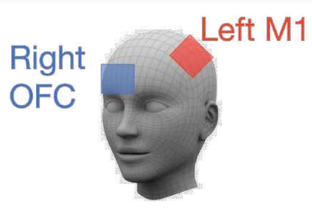
METHODS

- **Participants**: 21 right-handed healthy volunteers (8 Males, 13 Females), aged 18 - 32 (M = 22.1; SD = ± 3.9)
- **Design:** Within-subjects; 3 tDCS sessions: anodal, cathodal, sham (counterbalanced)

tDCS stimulation

- **Procedure:** online tDCS inside MRI scanner
- **Montage**: left M1 (active) and right orbitofrontal area (reference)
- **Duration:** 20 minutes
- **Intensity:** 1 mA



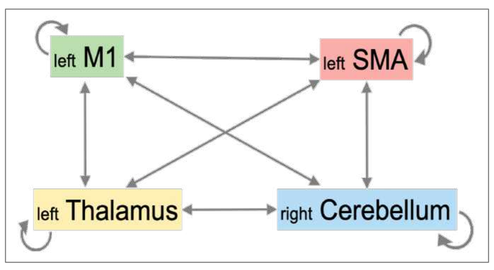


MRI

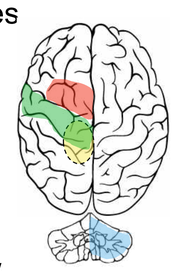
- Resting-state fMRI during tDCS
- **Preprocessing:** standard pipeline (SPM12) + denoising (Tapas PhysIO toolbox) via modelling of physiological noise

ANALYSIS

Regions of interest: left M1, SMA, thalamus and right cerebellum (ROI coordinates were taken from task data)



1. **Spectral DCM:** effective connectivity estimation from the rs-fMRI data through Bayesian Model Inversion and Comparison
2. **Hierarchical PEB:** Bayesian Model Comparison, Reduction and Averaging to test for group differences

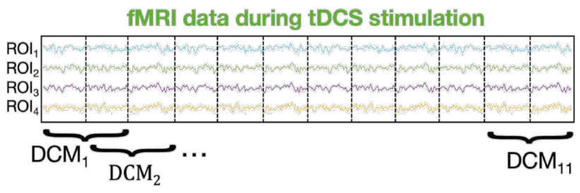


Whole time-series:

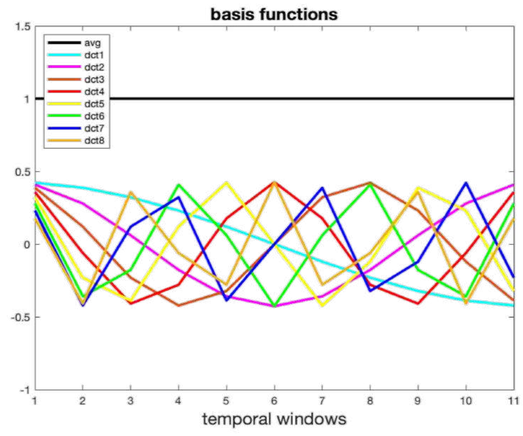
1. Individual spDCMs for each participant and session
2. Group PEB with contrasts: a) [tDCS - sham]; [anodal - cathodal]
   b) [anodal - sham]; [cathodal - sham]

Sliding Windows:

1. Individual spDCMs for each participant, session and time-window
2. **PEB1:** basis functions designs across time windows for each participant and session (multiple designs tested – the design with most positive Free Energy index best fits the data)
3. **PEB2:** average across participants for each polarity
4. **PEB3:** group effects with same contrasts as whole time-series analysis



- Window size: 200 s
- Overlap: 100 s



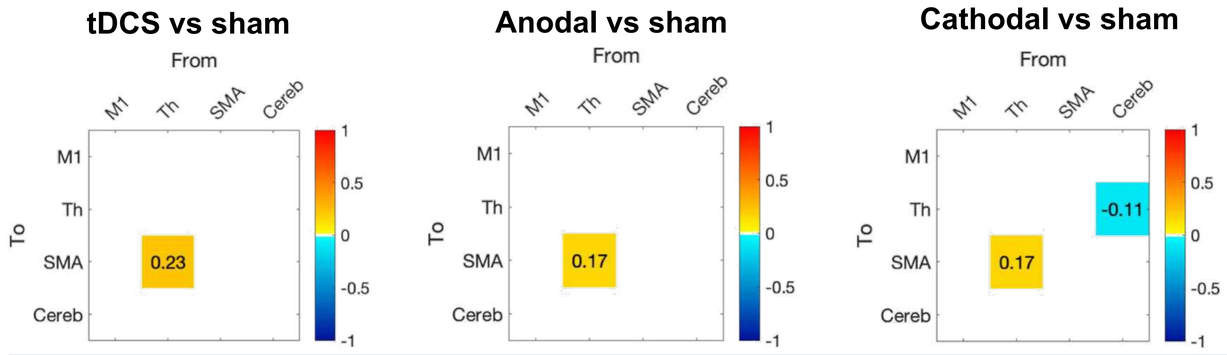
PEB1 winning model: a discrete cosine transform (DCT) with 8 bases.

In this plot, each coloured line is a cosine function with a specific rate of oscillation.
On the x axis are the 11 sliding time-windows, on the y axis the values assigned to each of them in PEB1.

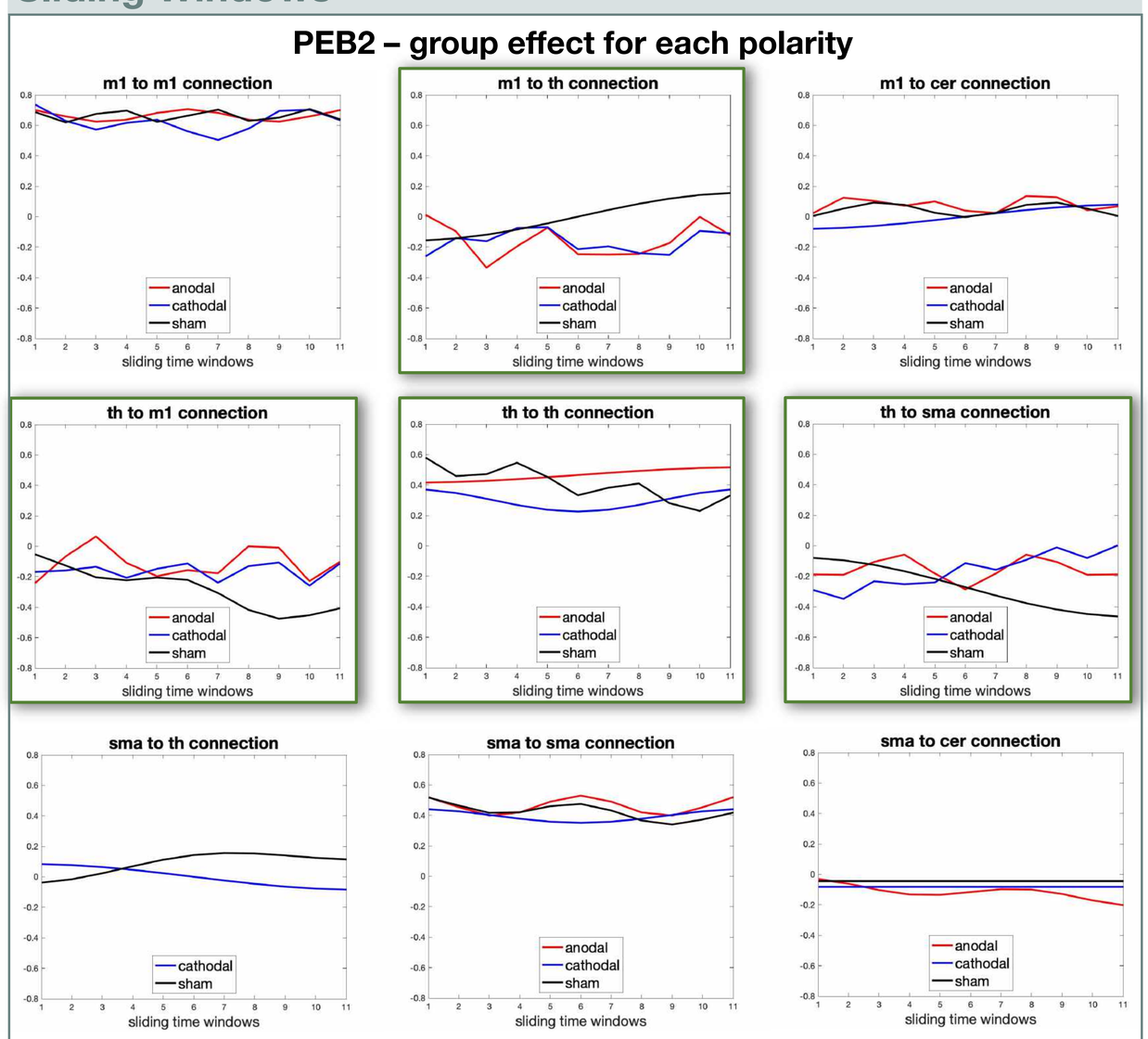
RESULTS

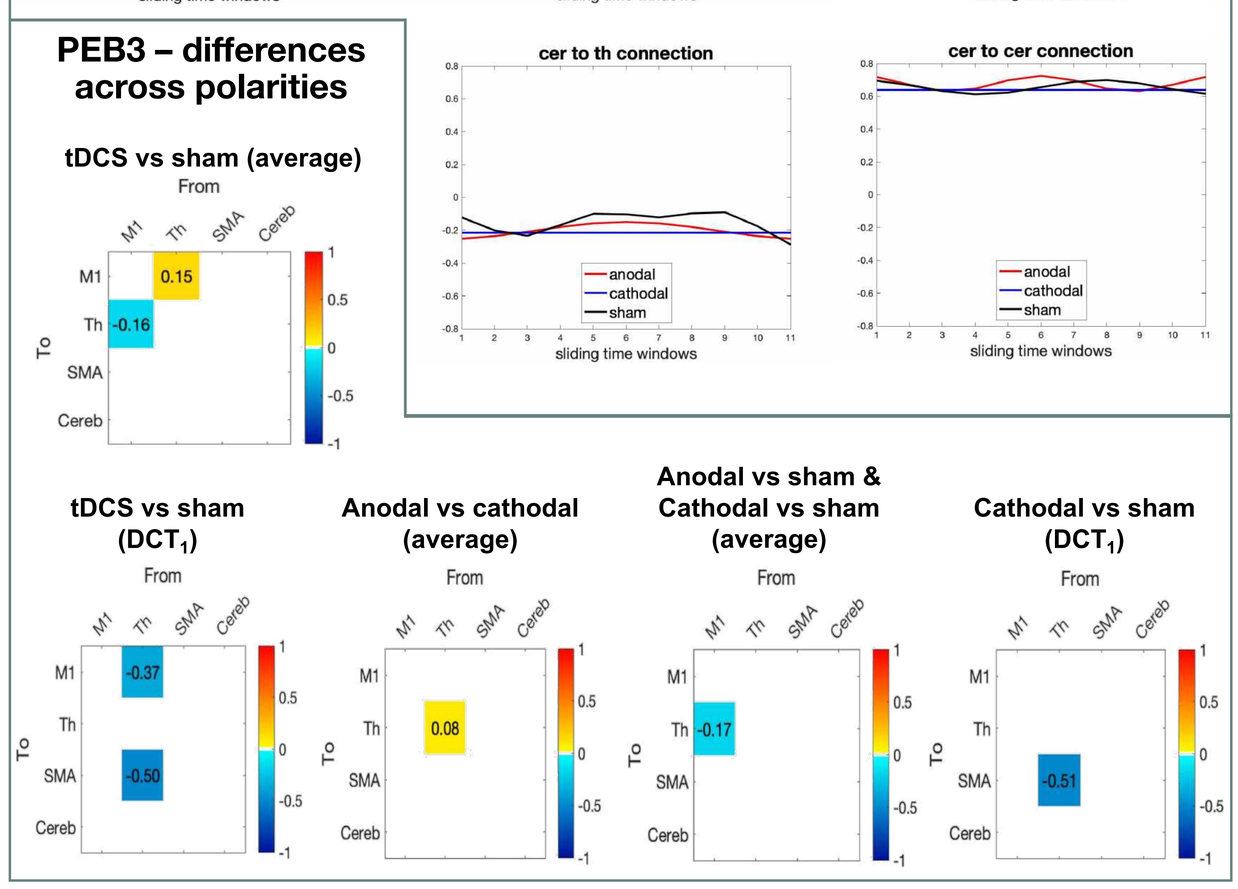
Estimated parameters after model comparison - thresholding based on Free Energy (Pp > 0.95)

Whole time-series



Sliding Windows





CONCLUSIONS

- Real tDCS (anodal & cathodal) elicits online changes in effective connectivity.
- The effects extend beyond the stimulated site and have different temporal patterns in different regions.
- Cosine oscillations best explain the data: tDCS perhaps follows the resting-state fluctuations
- Different thalamic and M1 connectivity between real tDCS and sham → inhibition in M1-Th and Th-SMA nodes; excitation in Th-M1 node; overall, these nodes are characterised by faster oscillations during real tDCS with respect to sham.
- The thalamus is affected in a polarity-specific manner (more inhibition in anodal tDCS).
- In conclusion: when at rest, anodal and cathodal M1-tDCS appear to clearly affect thalamic connectivity with an oscillatory (cosine) trend.

REFERENCES

[1] Kobayashi, M., Pascual-Leone, A. (2003). The Lancet Neurology 2, 145–156.
[2] Nitsche, M.A., Paulus, W. (2001). Neurology 57, 1899–1901.
[3] Polanía, R., et al. (2011). NeuroImage 54, 2287–2296.
[4] Jang, S.H., et al. (2009). Neuroscience Letters 460, 117–120.

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