Cognitive control beyond executive functions
pre-pilot study

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1 Introduction

Organism-wide coordination during daily life relies on information integration and processing units reflected in specific patterns of brain activity and functional connectivity (FC). While cognitive control (CC) is primarily attributed to the fronto-parietal network (FPN; often termed the Central Executive Network, CEN) (Cole et al., 2013), the role of alternative modulatory systems and the mechanisms underlying FC-mediated state transitions remain unclear. Investigating abnormal FC and cortico-striato-thalamo-cortical (CSTC) disconnectivity in psychopathology offers promising diagnostic and therapeutic targets.

These questions are particularly relevant in major depressive disorder (MDD), where meta-analytic evidence links the disorder to hypoconnectivity within frontoparietal control systems and hyperconnectivity within the default-mode network (Kaiser et al., 2015). Using synchronized EEG-fMRI during rest and varied task conditions, we aim to identify non-FPN sources of CC and confirm the CSTC circuit's modulatory role. Further, in MDD, we will determine if FC alterations stem from structural changes, imbalanced cognitive-neural states, or CSTC dysfunction, mapping the correlation of these mechanisms and neuro-behavioral variability circuit dysfunctions to specific individual patient subgroups (Lee et al., 2024).

Currently, our pre-pilot phase focuses on protocol verification and troubleshooting to improve temporal efficiency, ensure participant comfort, and maximize data validity.

2 Methods

The primary methods for data collection are EEG and fMRI. The data is acquired using EEG caps equipped with 128 electrodes and a 3T MRI scanner. During both EEG and fMRI recordings, participants are presented with a experimental script comprising resting-state and movie-viewing conditions.

Participant comfort is ensured through the use of ear protection, blankets, continuous monitoring and an emergency response button during fMRI. Protocol optimization includes aligning experimental scripts with scan durations and standardizing task instructions.

3 Results

As the project remains in the pre-pilot phase, we are not able to provide any empirical results. However, procedural improvements have been achieved, such as reduction in EEG cap preparation time by approximately one hour. This was possible by distribution of the assignments and their parallel conduction. We have also managed to remove some artifacts that were present in the first scans.

4 Discussion

Our focus for now is on methodological adjustments rather than hypothesis testing. We are working on improvements of the protocol to make it ready for the next stage.

Ensuring participant comfort and safety remains an important concern, especially since the study will include individuals with MDD, for whom participation in an fMRI environment could lead to increased stress or discomfort.

We are also evaluating options for installation of a secondary display to allow simultaneous monitoring of the experimental script.

Ongoing efforts to optimize the protocol, particularly the alignment of scripts with scan timing and the development of cognitive tasks are crucial for the success of pilot and further stages of the study.

References

Cole, M. W., Reynolds, J. R., Power, J. D., Repovs, G., Anticevic, A. and Braver, T. S. (2013). Multi-task connectivity reveals flexible hubs for adaptive task control. *Nature Neuroscience*, 16(9):1348–1355.

Kaiser, R. H., Andrews-Hanna, J. R., Wager, T. D. and Pizzagalli, D. A. (2015). Large-Scale Network Dysfunction in Major Depressive Disorder: A Meta-analysis of Resting-State Functional Connectivity. *JAMA Psychiatry*, 72(6):603–611.

Lee, K., Ji, J. L., Fonteneau, C., Berkovitch, L., Rahmati, M., Pan, L., Repovš, G., Krystal, J. H., Murray, J. D. and Anticevic, A. (2024). Human brain state dynamics reflect individual neuro-phenotypes. *bioRxiv: The Preprint Server for Biology*, pp. 2023.09.18.557763.