An fMRI Investigation of Medial Prefrontal Network Dynamics During a Context-Dependent Rule Learning Task

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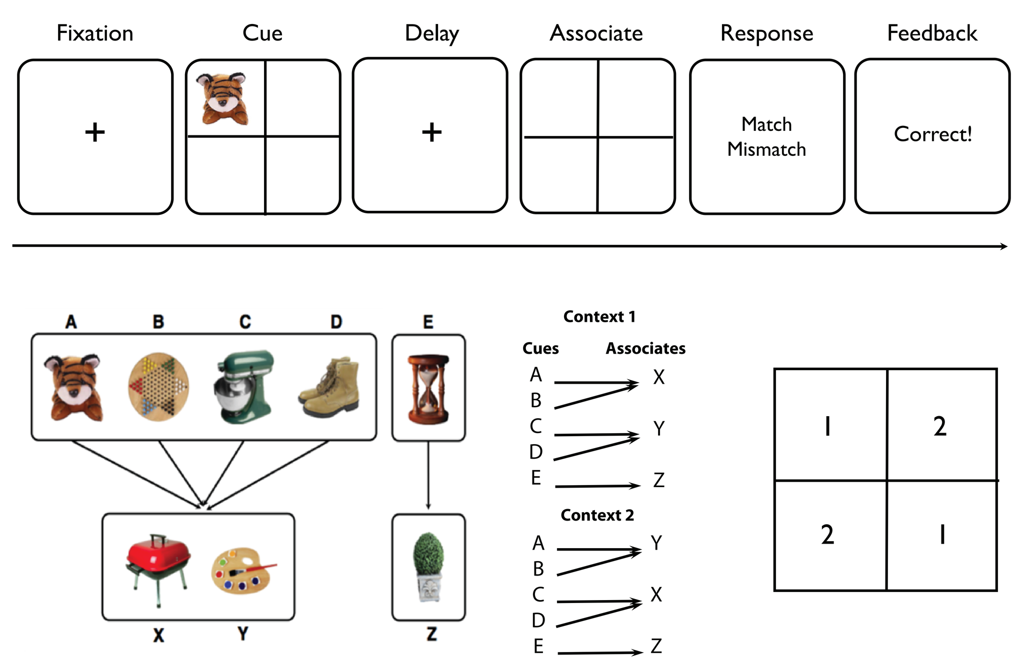
Background

The functional connectivity of brain networks dynamically changes during learning and can be measured with fMRI[1].

Previously, our lab scanned a cohort of 28 naive subjects while they learned a set of context-dependent paired associates. Performance varied greatly, with some participants inferring the rules almost immediately, and others performing poorly throughout scanning[9].

Medial prefrontal cortex (mPFC) and orbitofrontal cortex (OFC) are thought to incorporate information related to context and reward into new memories during a context-dependent task.



Context dependent rule-learning task. Sample trial and description of rules[9].

Goals:

1) Apply dynamic functional connectivity methods to an associative learning task.
2) Elucidate the connectivity patterns of medial prefrontal cortex and orbitofrontal cortex during learning and successful performance on the task.

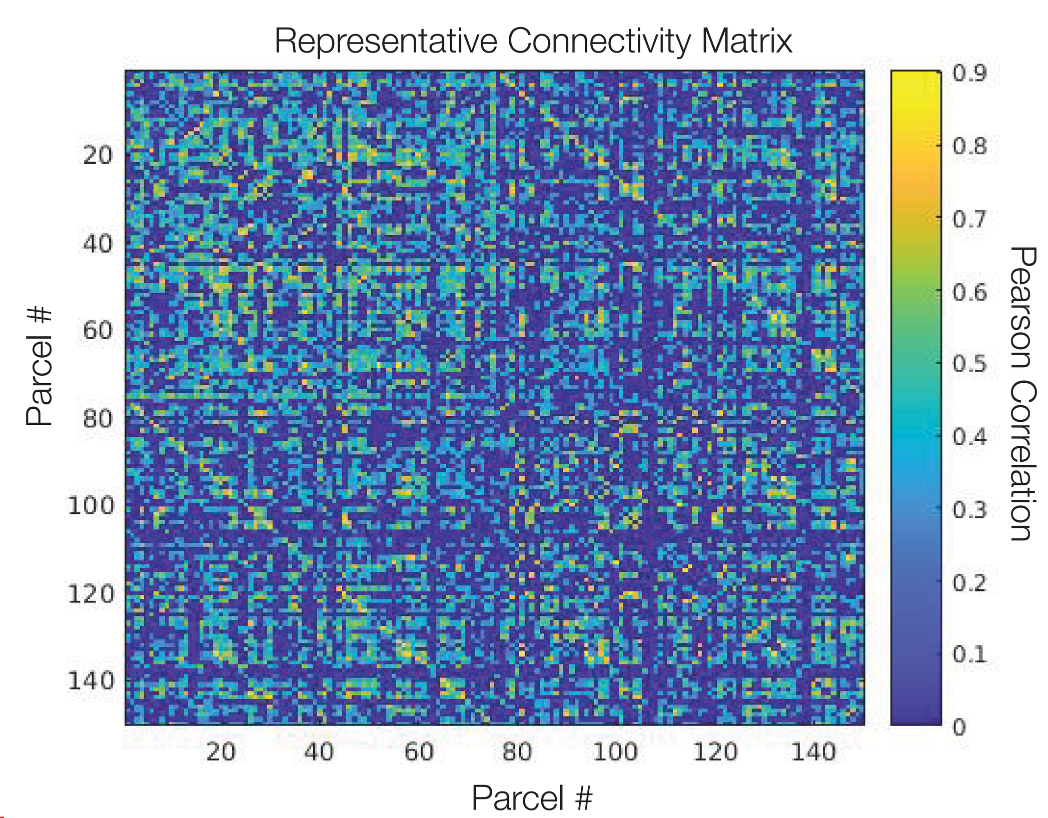
Methods: Dynamic Functional Connectivity

The brain was parcellated into 150 regions using the Destrieux Atlas[6].

Connectivity matrices were generated for each subject by calculating the Pearson correlation between the BOLD timecourses for each pair of regions.

Correlations were corrected for multiple comparisons using the Benjamini-Hochberg method, and insignificant correlations were masked to zero[8].

A sliding window analysis was used to calculate 40 connectivity matrices for each subject (each matrix represents a step through time).



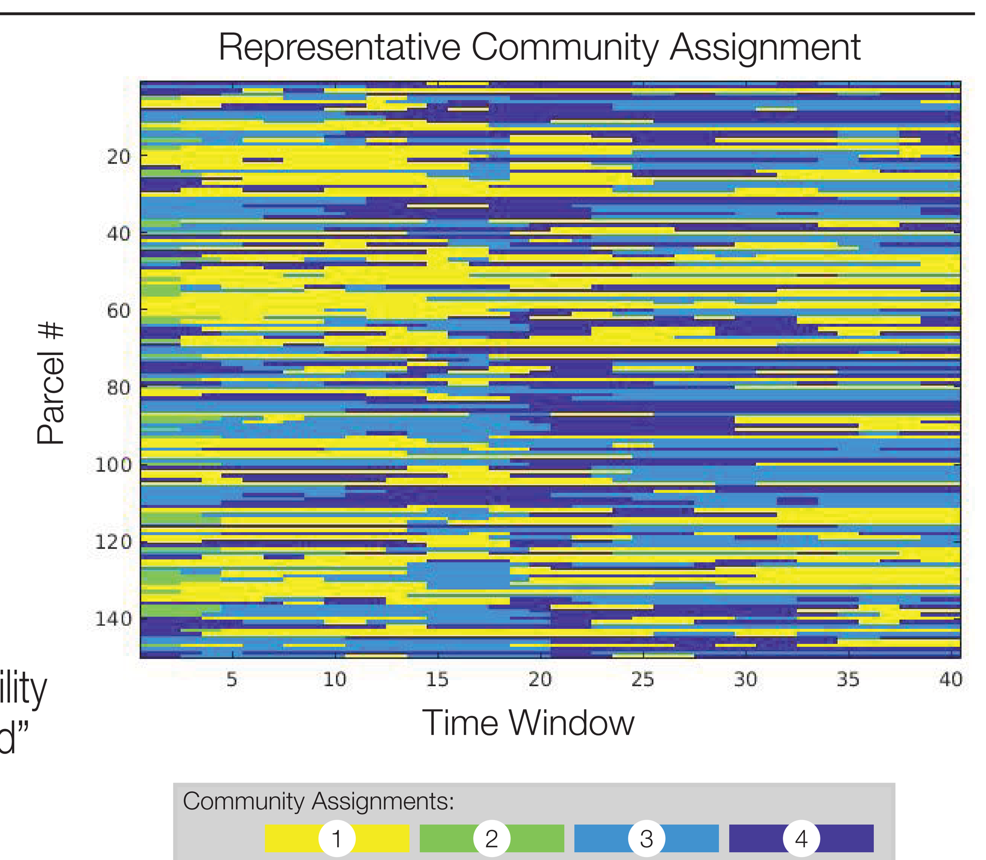
Methods: Community Detection and Node Flexibility

To track, the changing connectivity of each brain region over time, we used each subject's connectivity matrices in a multilayer Louvain community detection algorithm[3].

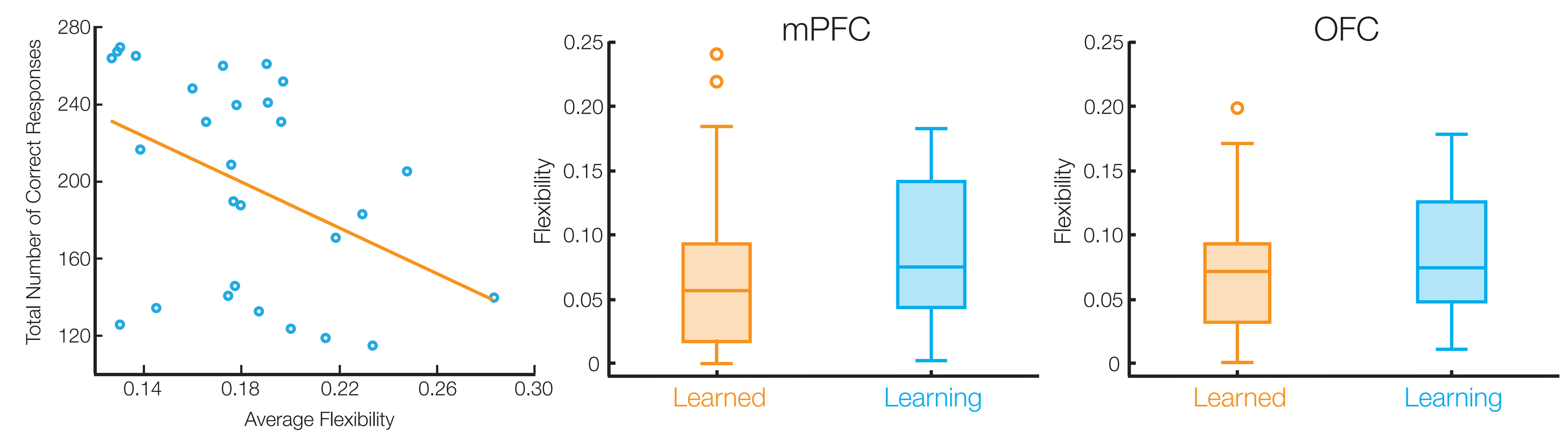
The community detection algorithm was repeated with 100 different sets of initial conditions and the most popular community assignments were labeled for each region at each timepoint.

For each subject, the **flexibility** of each node was calculated as the number of times a node switched communities, over the number of possible switches.

To compare flexibility and connectivity during the learning and learned stages of the task, we repeated the entire process, but generated connectivity matrices and flexibility measurements for each scan run. Each run was categorized as "learning" or "learned" based on individual subjects performance.



Results: Dynamic Changes to Functional Connectivity During Associative Learning

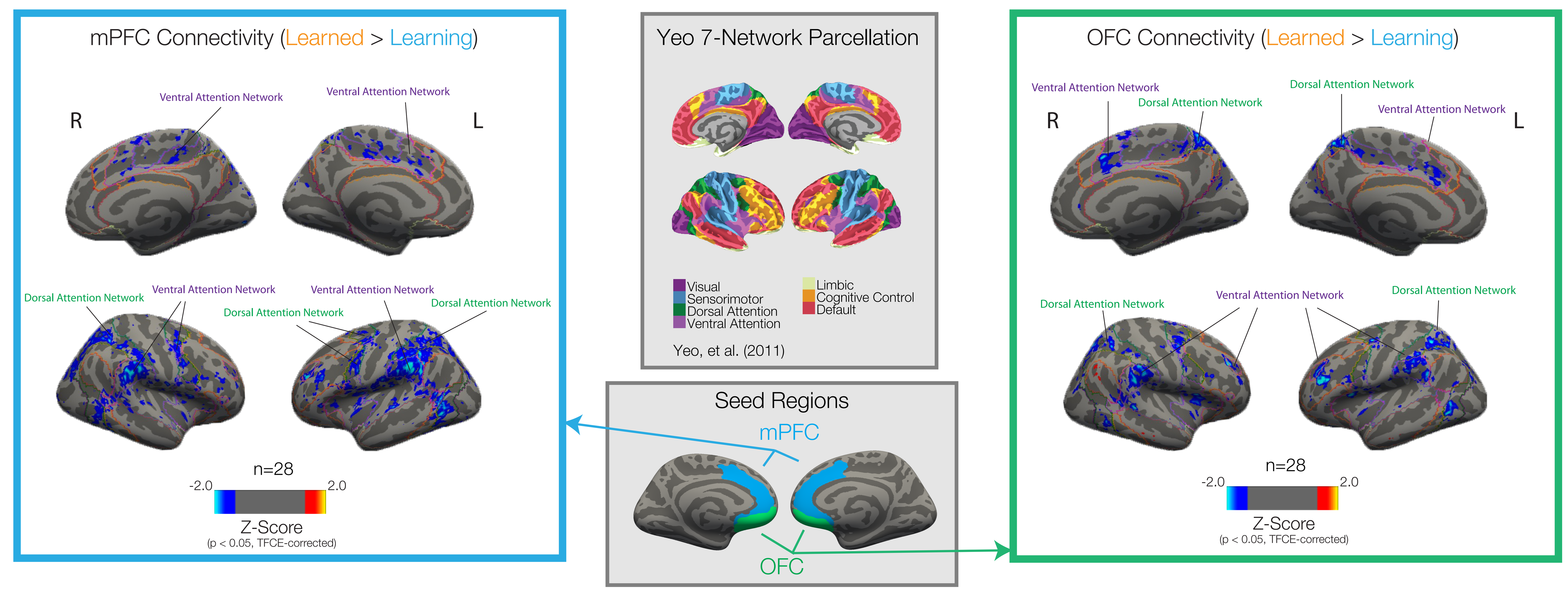


Average flexibility of all brain regions was negatively correlated with individual subjects' performance on the context-dependent rule learning task.

Both the mPFC and OFC demonstrated greater flexibility during learning compared to when subjects had successfully learned the task.

These results suggest that node-connectivity is flexible during learning, and becomes rigid after learning.

Results: Attentional Networks are More Functionally Connected to mPFC and OFC During Learning



Discussion

1) Analysis of node flexibility suggests that node connectivity is flexible during learning, but becomes rigid when the task is learned.

2) Results suggest that medial prefrontal cortex and orbitofrontal cortex have increased functional connectivity with attentional networks during learning.

References

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