The Neural Processes of *Statistical Learning*

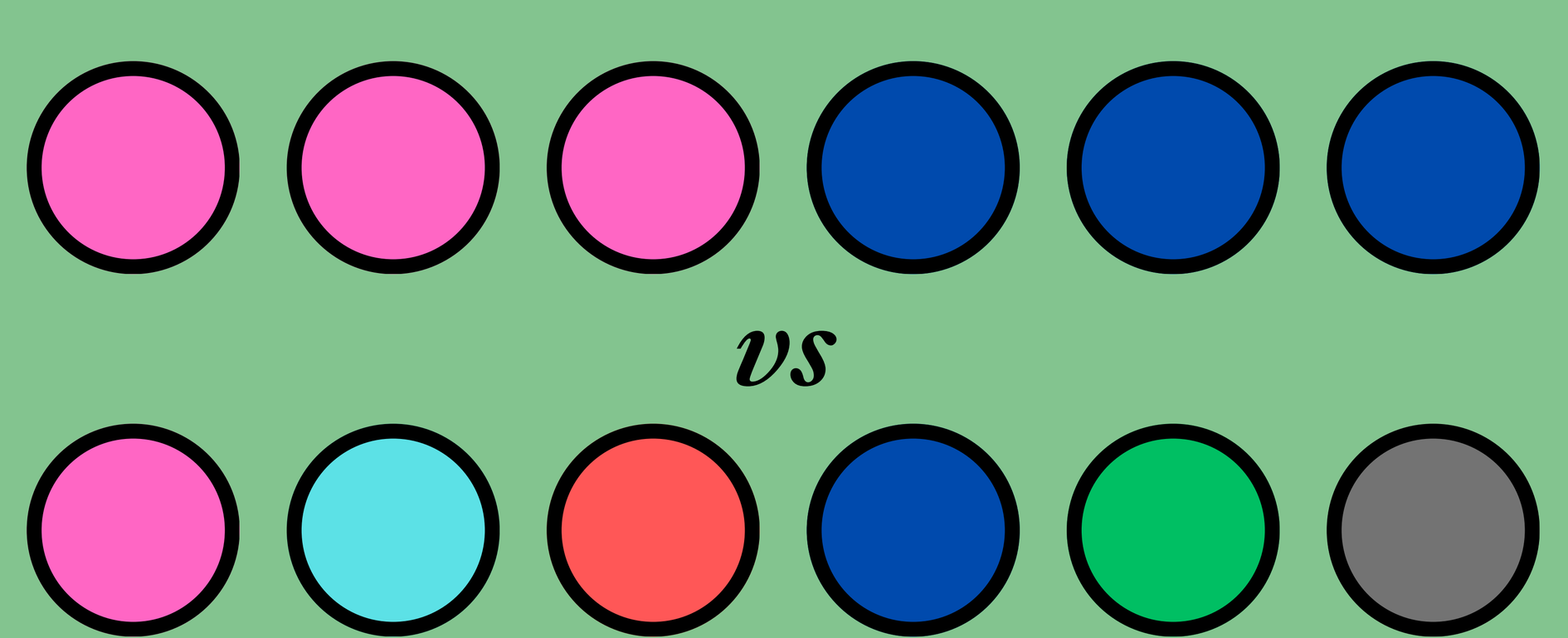
Will Decker
Julie M. Schneider, PhD
Christopher Cox, PhD

Department of Psychology
Department of Communication Sciences and Disorders

jdecke5@lsu.edu
juschnei@lsu.edu
chriscox@lsu.ed

Background

What is *statistical learning*?



- *Statistical learning* is the ability to extract units of information based on statistical regularities of the environment.
- Theory implicates *statistical learning* as a critical mechanism for language acquisition.[11]
- Recent works suggest *statistical learning* is not a unitary process, but occurs along varying spatial and temporal scales.[5]

Computational formalization

$$P(Y \mid X) = \frac{P(X \cap Y)}{P(X)}$$

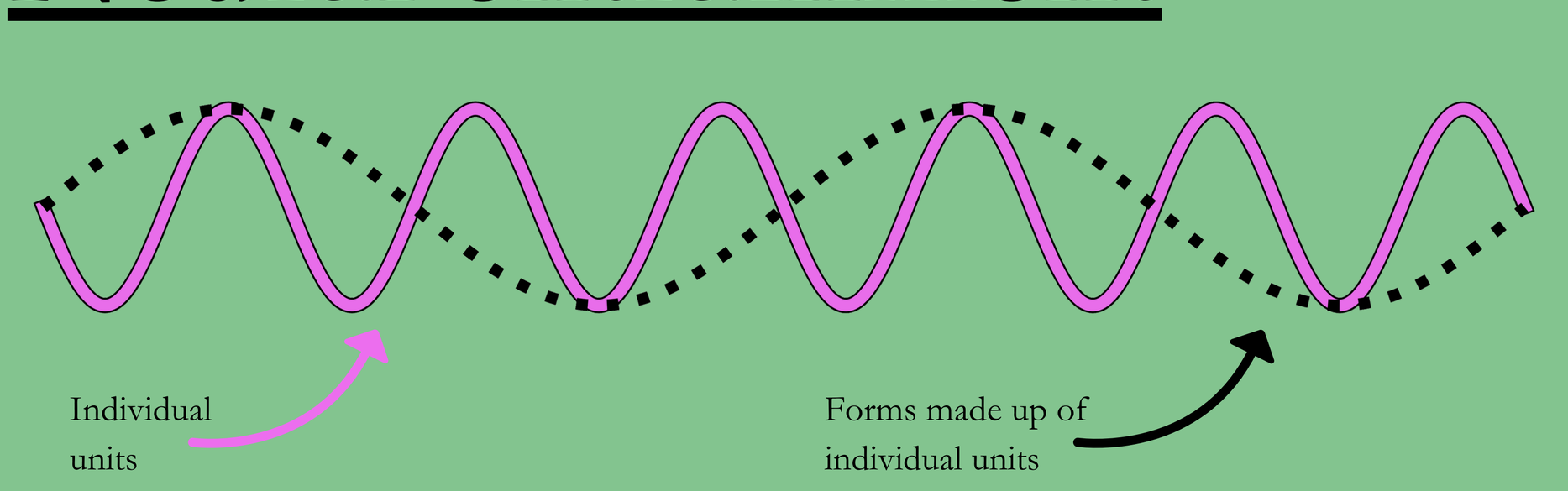
Likelyhood stimulus **Y** will co-occur with **X** given the frequency of stimulus **X.**[6]

Linguistic example

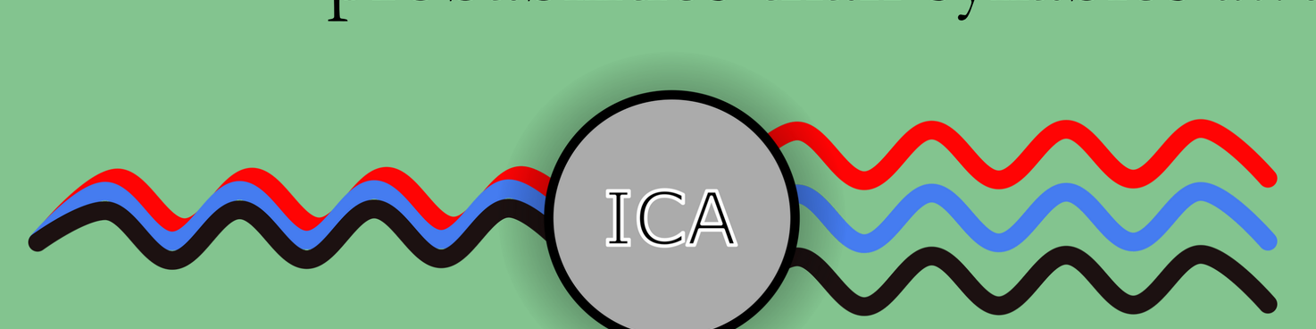
Cool dads

Syllables *within* words have higher transitional probabilities than syllables *across* words.

Neural entrainment

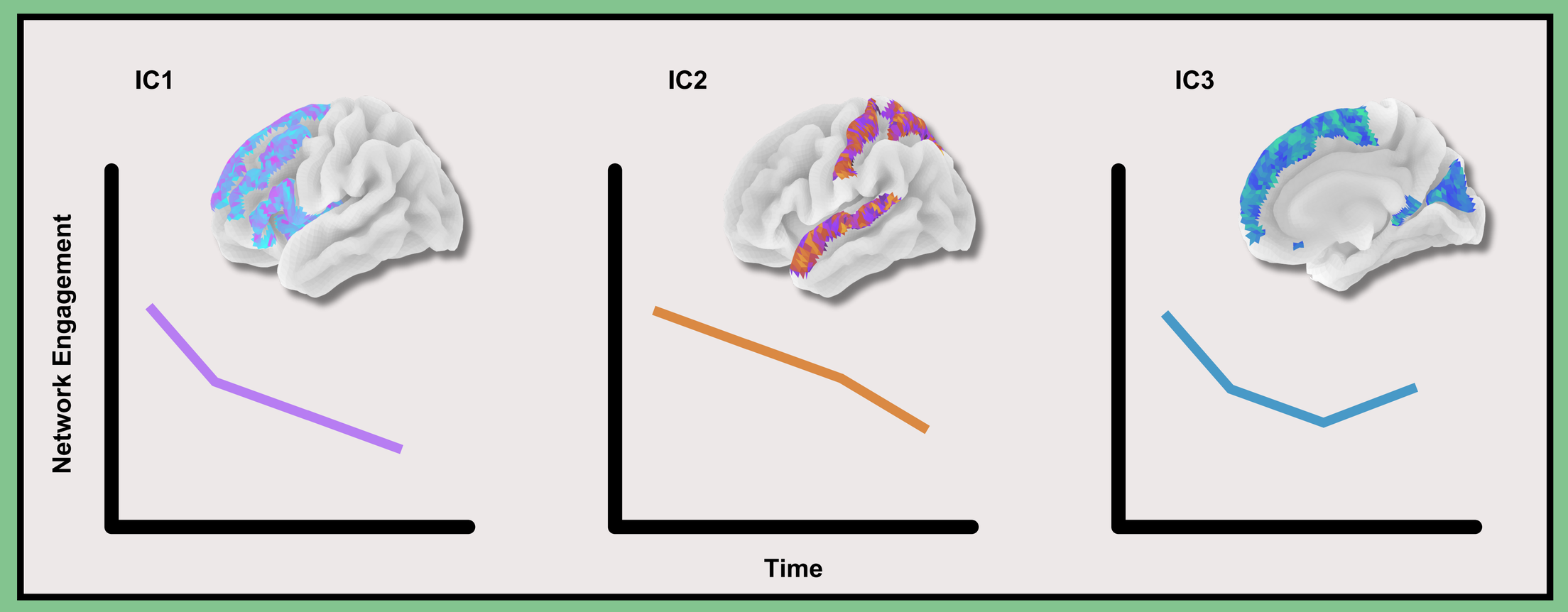


ICA



- Relevant "components" of brain activity can be extracted using temporal independent component analysis (ICA).[4,9]

- Brain activity oscillates at the same frequency of rhythmic stimuli as a function of *statistical learning.*[2]
- The methods used to detect neural entrainment (e.g., M/EEG) have low spatial resolution.

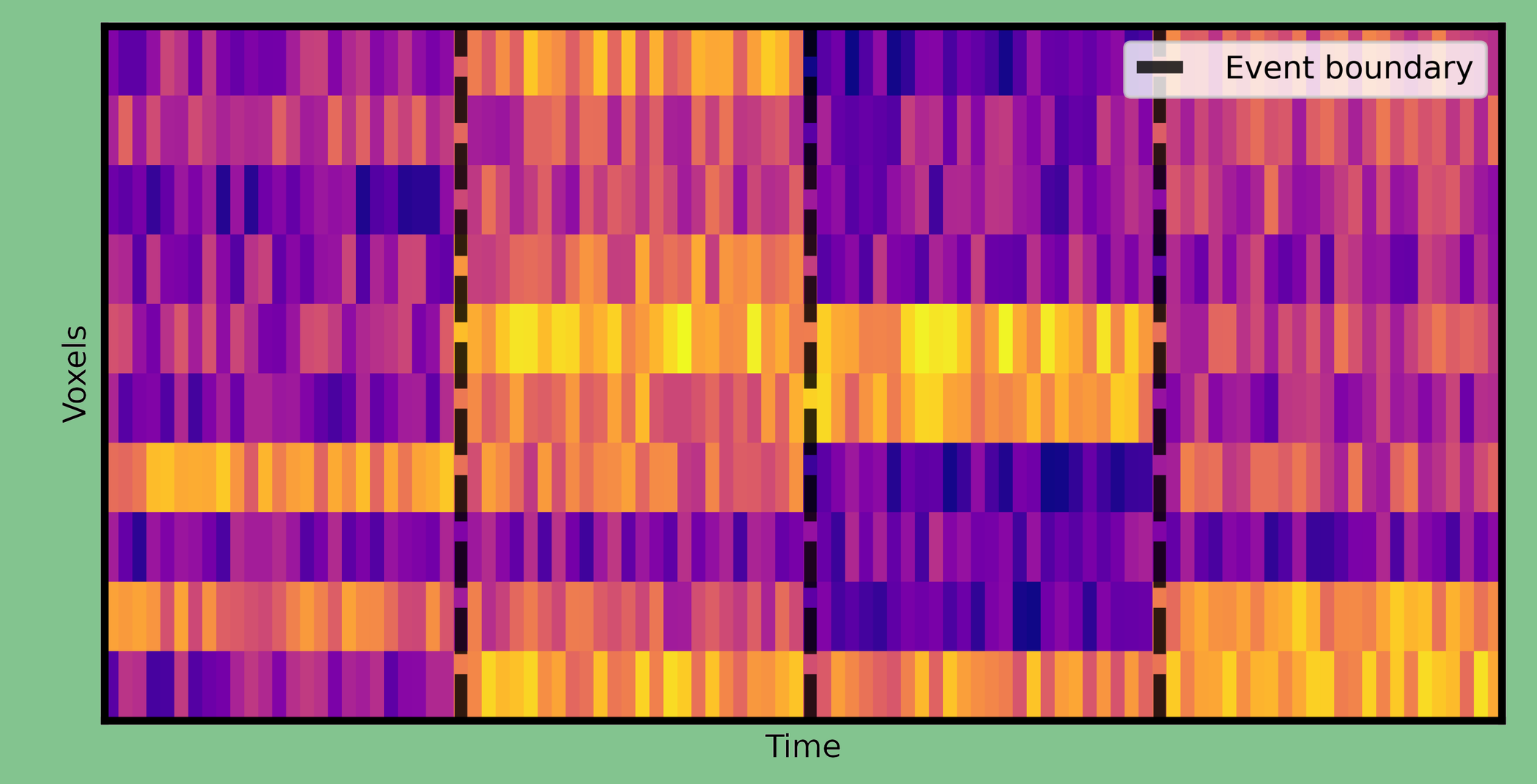


Can we comprehensively characterize *statistical learning* in the brain as it unfolds over time with fMRI?

Methods

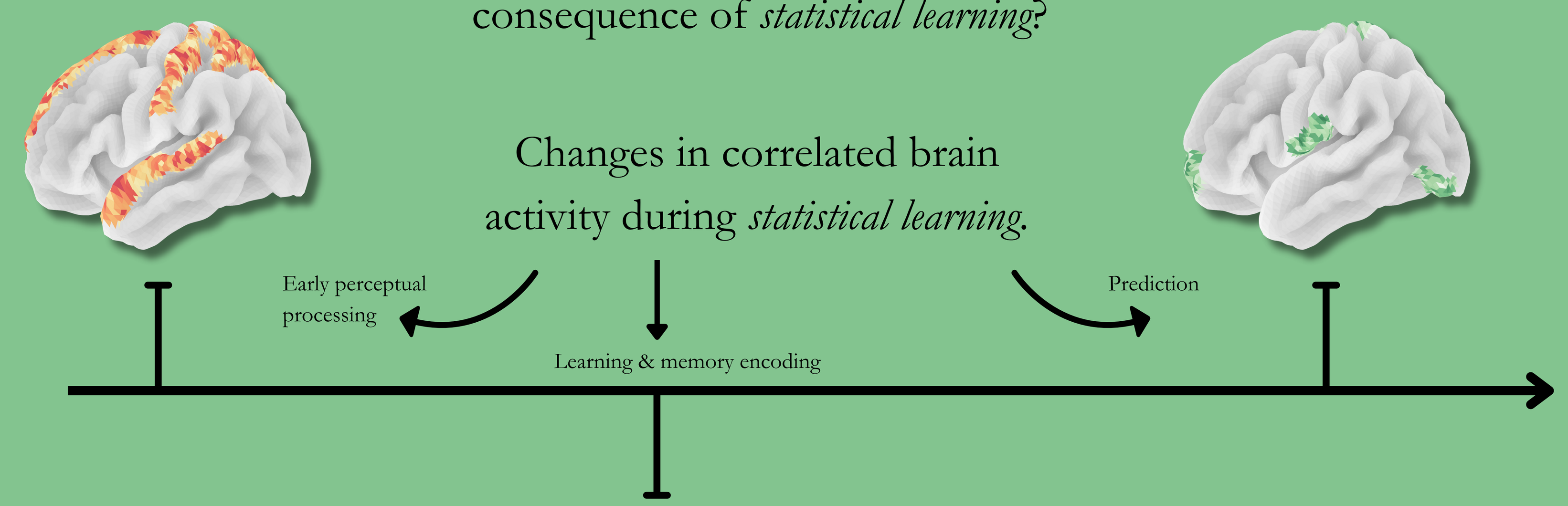
Event Segmentation

- Brain activity is *not random.* It can exists in various states.[1,14]
- Can we uncover different event-states of *statistical learning?*

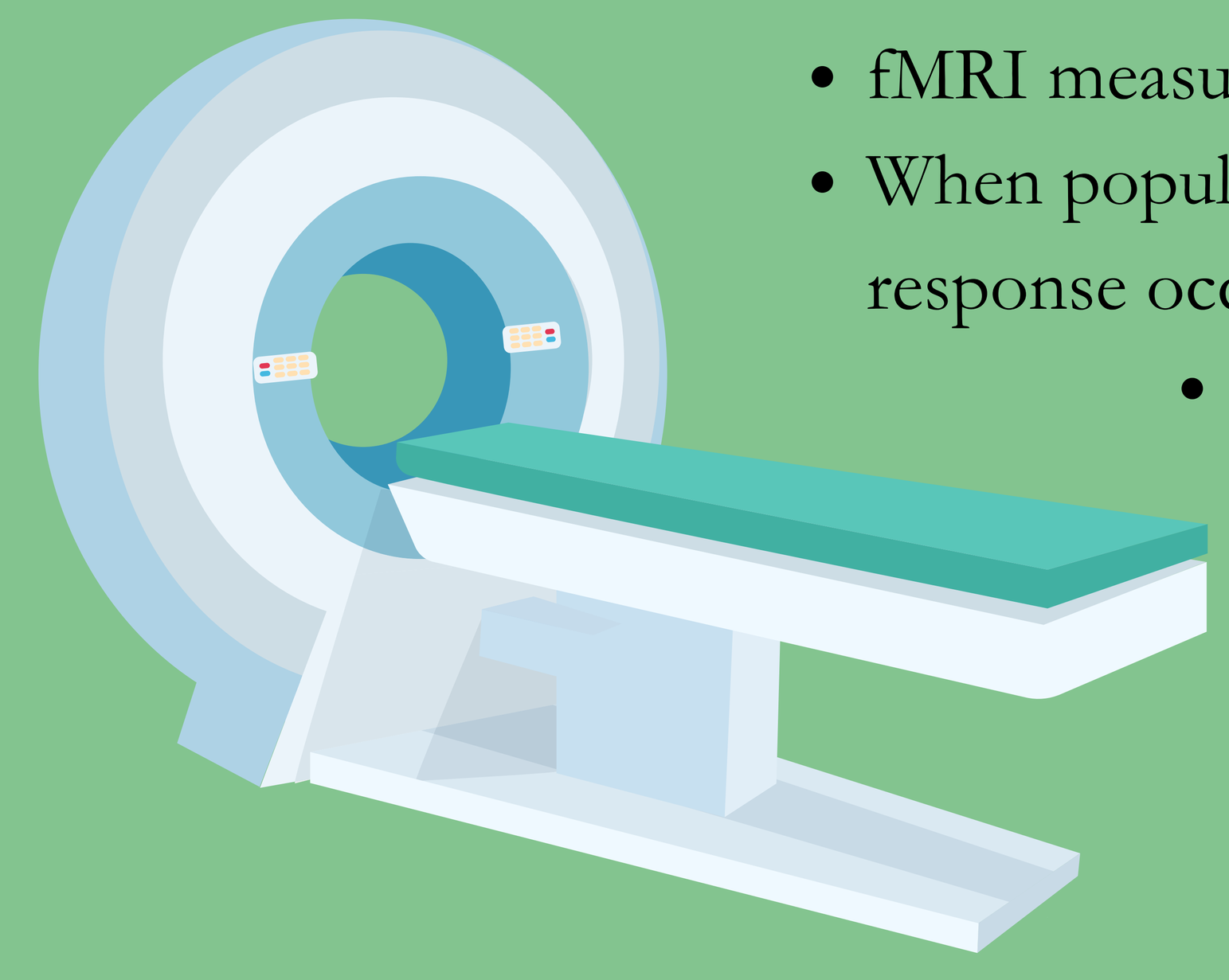


Dynamic Functional Connectivity

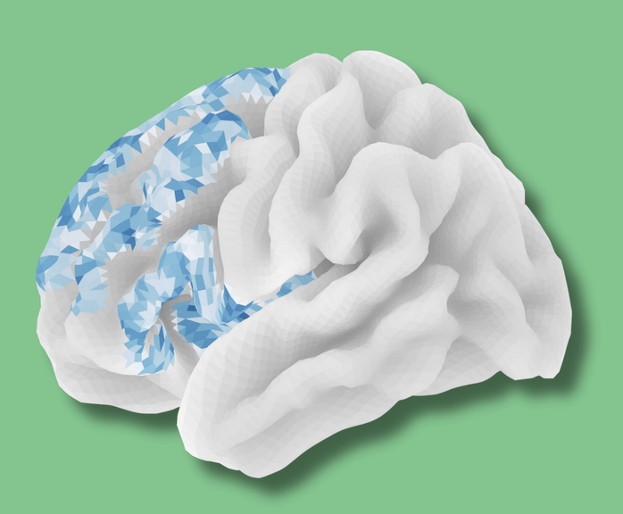
- Brain regions are "functionally" connected; their activity is highly correlated despite being spatially distinct.[3]
- Can we reveal changes in functional connectivity as a consequence of *statistical learning?*



Functional Magnetic Resonance Imaging

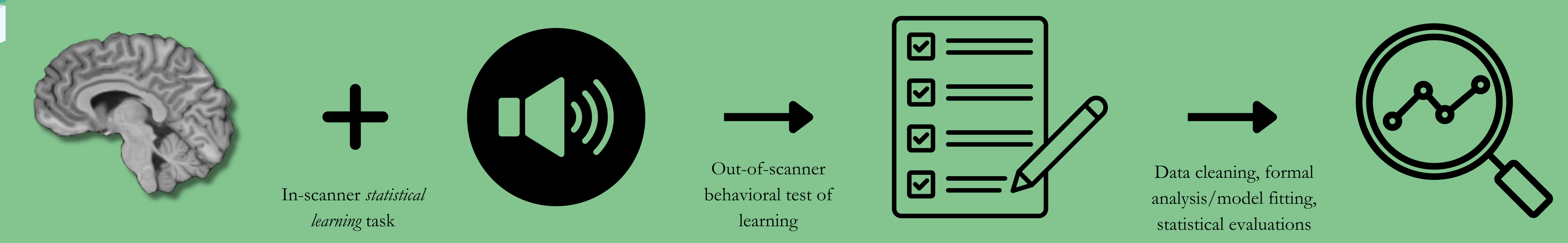


- fMRI measures changes in blood flow inside the brain.
- When populations of neurons are firing, a haemodynamic response occurs, facilitating neural activity.
  - Hemoglobin contains magnetic properties which can be monitored in the fMRI scanner.



Are their systematic profiles of correlated neural activity at different times during learning?

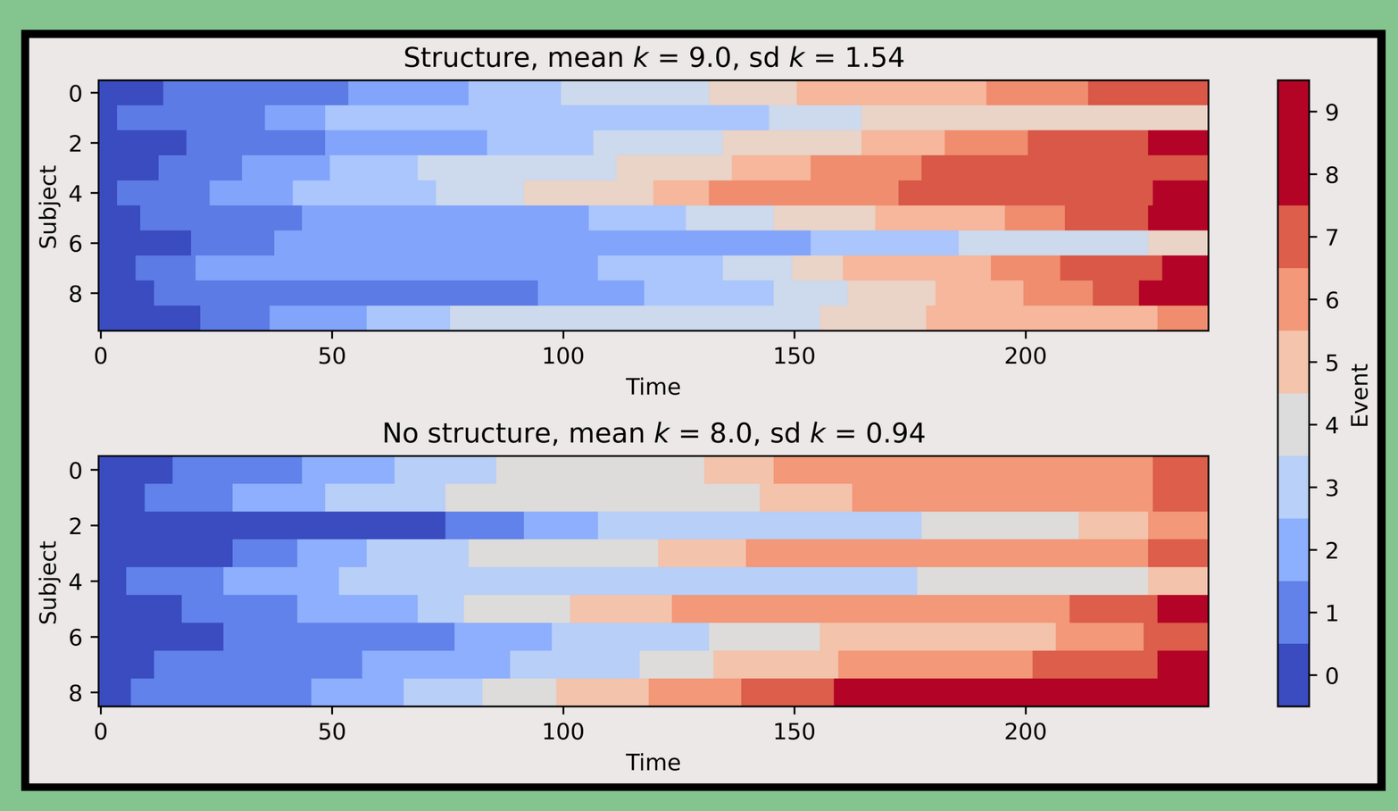
Procedures

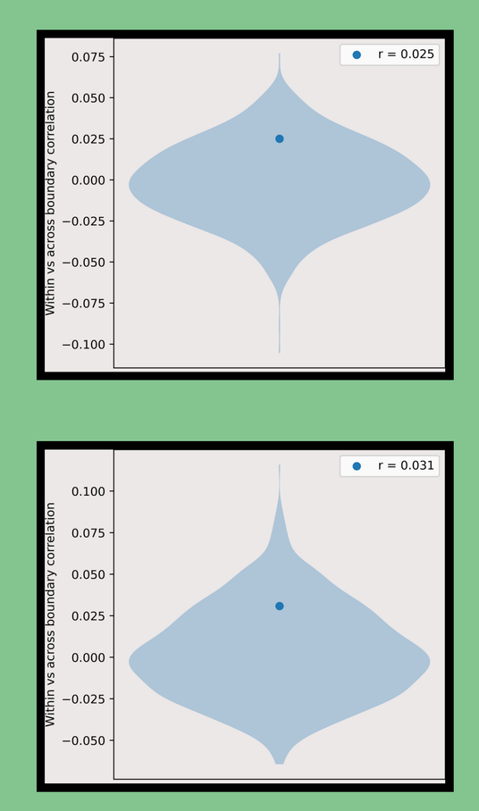


Results & Discussion

Event Segmentation

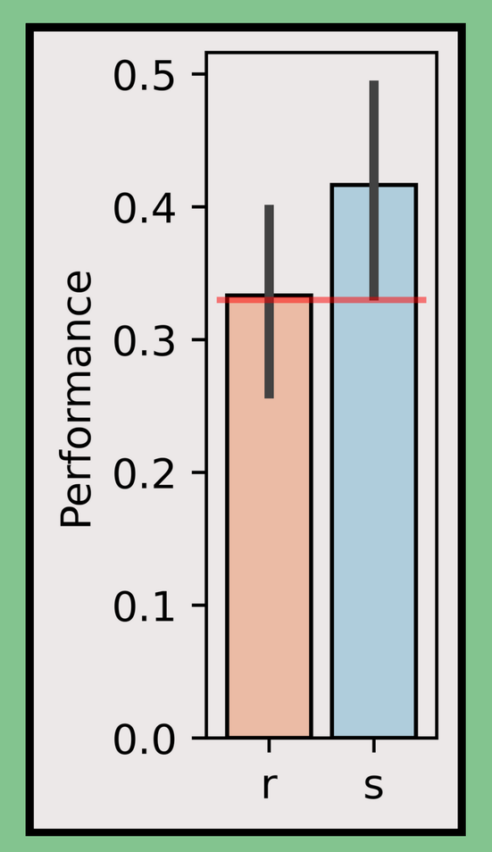
- An adapted Hidden Markov Model (HMM) was used to calculate event structure from the continuous fMRI timeseries.[1,8]





- Although behavioral results confirmed that learning occurred, subjects' neural data is more variable when learning than when not. This could be due to dimensionality reduction approach. Or....
- These group differences demonstrate the heterogeneity of learning: brain data is more variable when learning compared to not learning.[7,12]

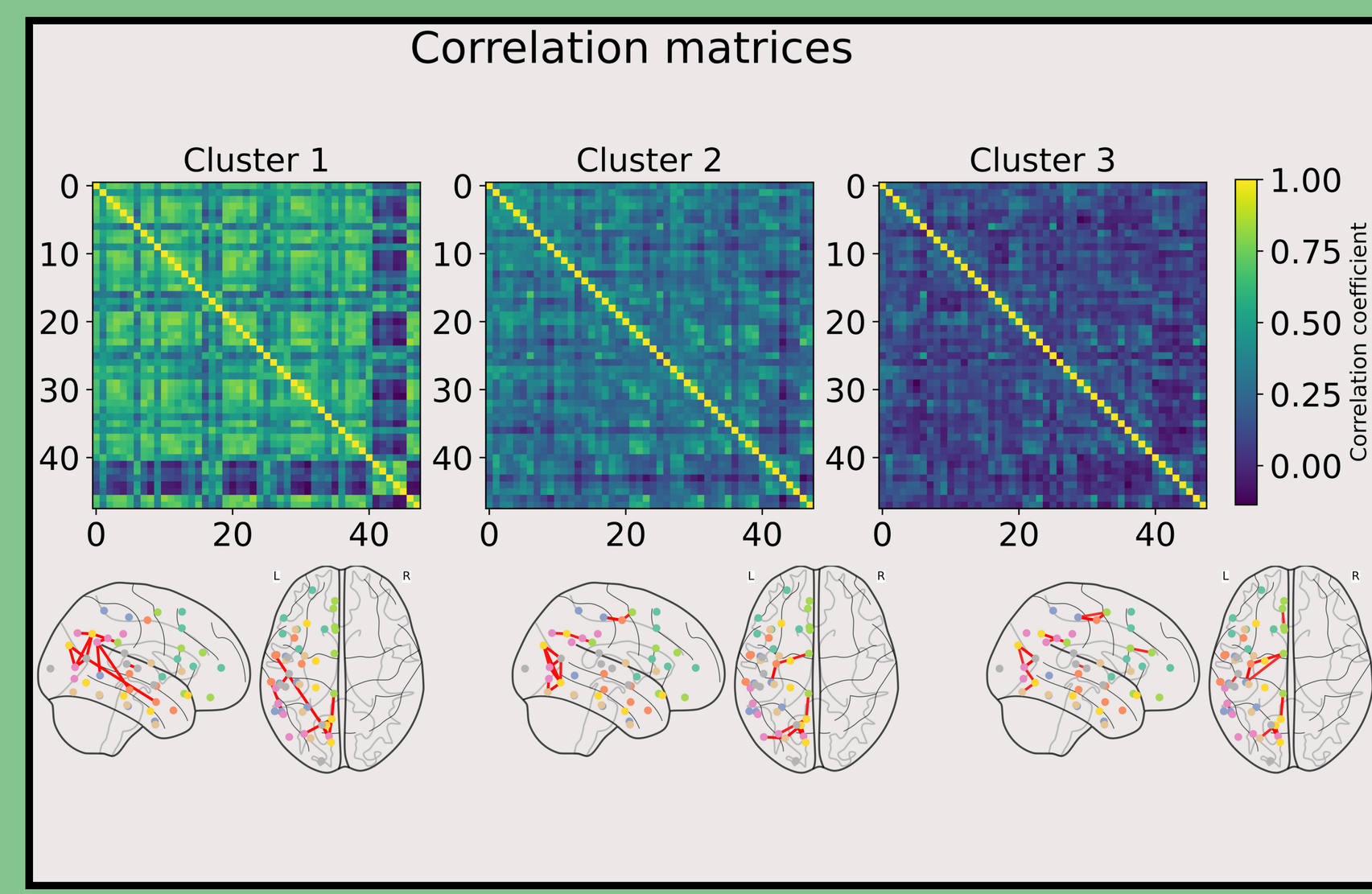
Behavior



- Individuals learned the structure.

Dynamic Functional Connectivity

- Using a sliding window approach, we calculated dynamic functional connectivity for the structured group using Pearson's ***r***.[13]
- Overall reduction in FC is inline with previous work.[10]
- Cluster one shows particular emphasis on auditory cortex.



- Left lateralization and general patterns bolster the idea that domain-specific perception *and* higher-order processing scaffold *statistical learning.* This is grounded in theoretical work.[5,7]

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Ack.

Thank you to the **LEND Lab** and **ReLearn Lab** for their continued support.

Some brain plots were generated with my open source Python module, **roipy.** Check it out!

```
$ pip install roipy
```

All code for formal analyses is hosted on GitHub. Scan the QR code.

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