Representation of item and context specific information during memory retrieval in the human brain

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Introduction

Neural theories of episodic memory propose that memory retrieval is a result of the reactivation of patterns of activity present during the encoding of a specific memory. Context-like signals have been observed in neural recordings from the medial temporal lobe of rats[1] and humans[2-3]. Retrieved-context models[4-5] propose that this neural signature represents the reactivation of the spatiotemporal context of an encoded event, allowing for the subjective experience of "mental time travel." The aims of the present work are to determine whether it is possible to distinguish between patterns of fMRI activity that may represent context specific information despite the inherent autocorrelation in the observed neural signal. We further seek to identify signal that represents item specific information.

Methods
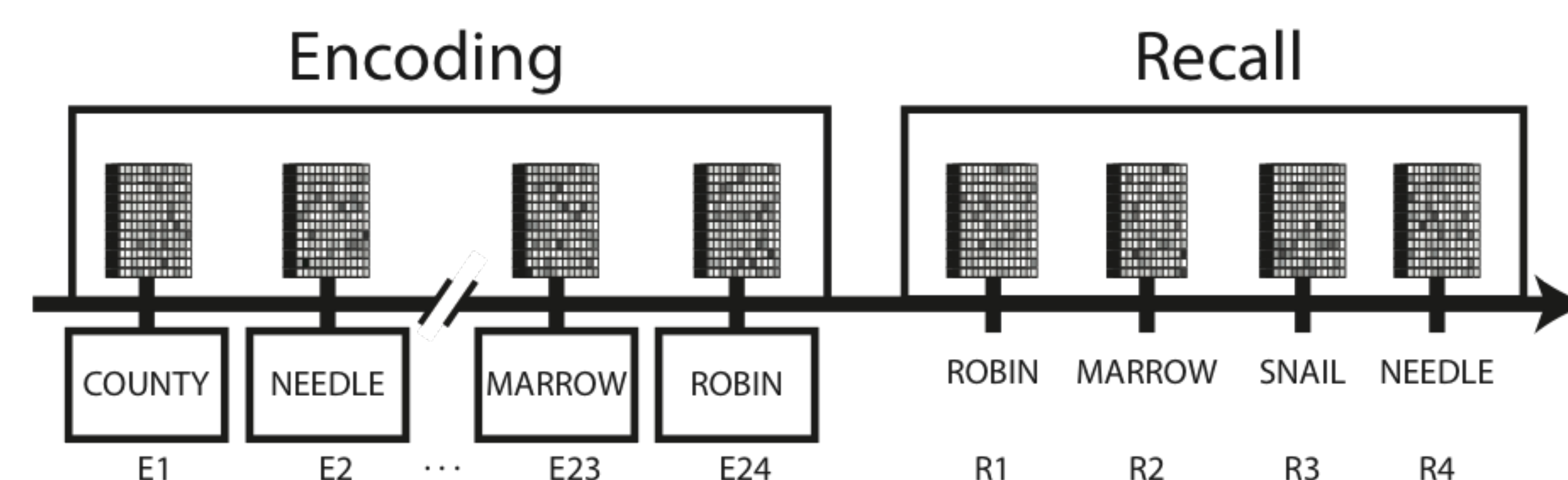
20 subjects performed a variant of the free-recall task while functional magnetic resonance imaging data were collected on a Philips 3T MRI scanner. Subjects studied 6 lists of 24 items, presented for 3 sec duration. Recall periods lasted 75 sec. Patterns of activity associated with the encoding and retrieval of individual events were estimated using a single-trial general linear model implemented in SPM8.
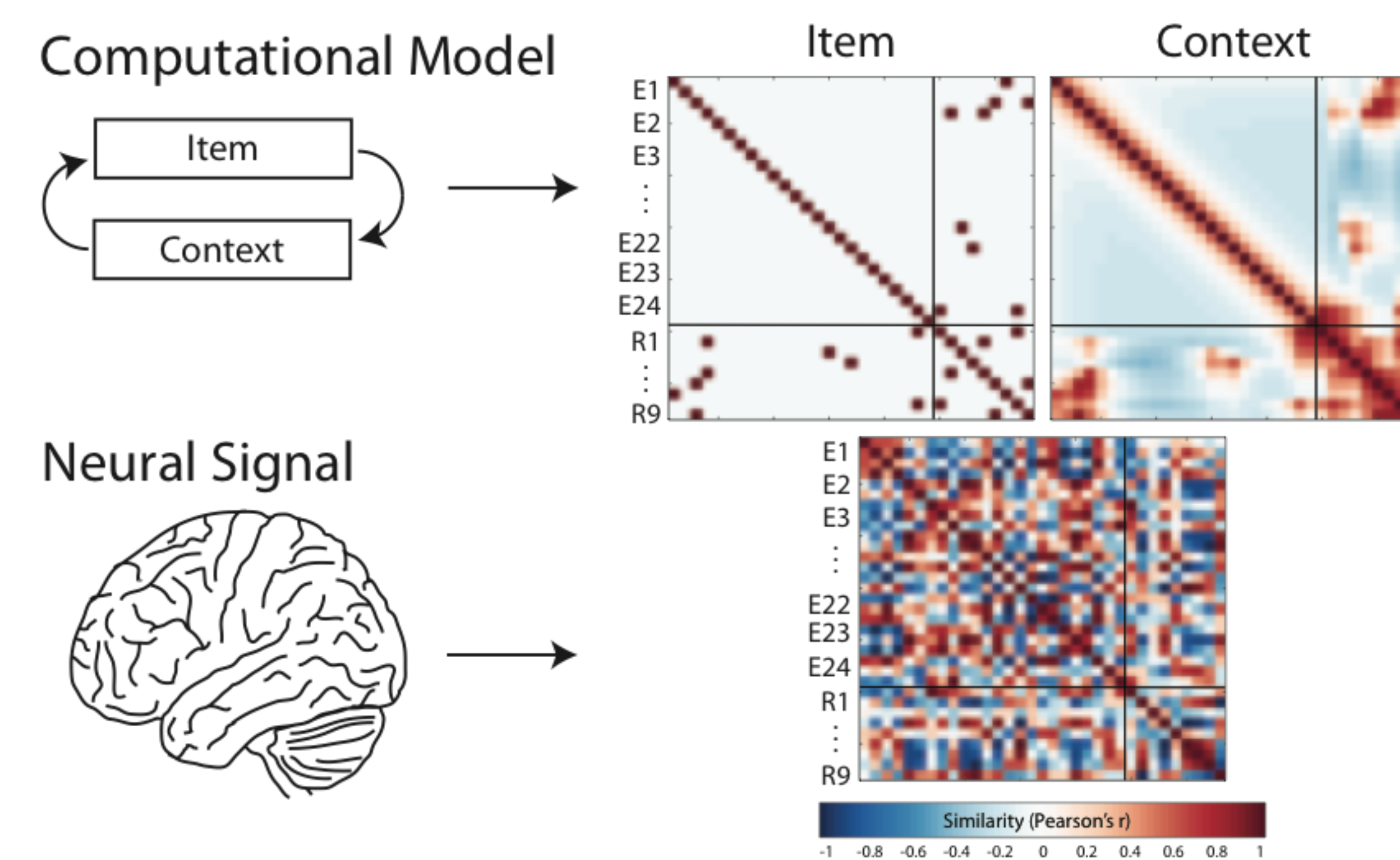
Pattern similarity matrices were constructed by computing Pearson's r between each pairwise combination of encoding and retrieval patterns constructed from either the model or neural data. Neural patterns were created from 74 a priori regions of interest, defined using the Automated Anatomical Labeling toolbox[6]. To test the capacity for patterns of neural activity to reflect a context-like signal, second-order similarity between neural and model based representations was computed using Spearman's ρ. Permutation testing of second-order similarity scores was used to identify significant group effects.

## Modeling of recall behavior and context dynamics
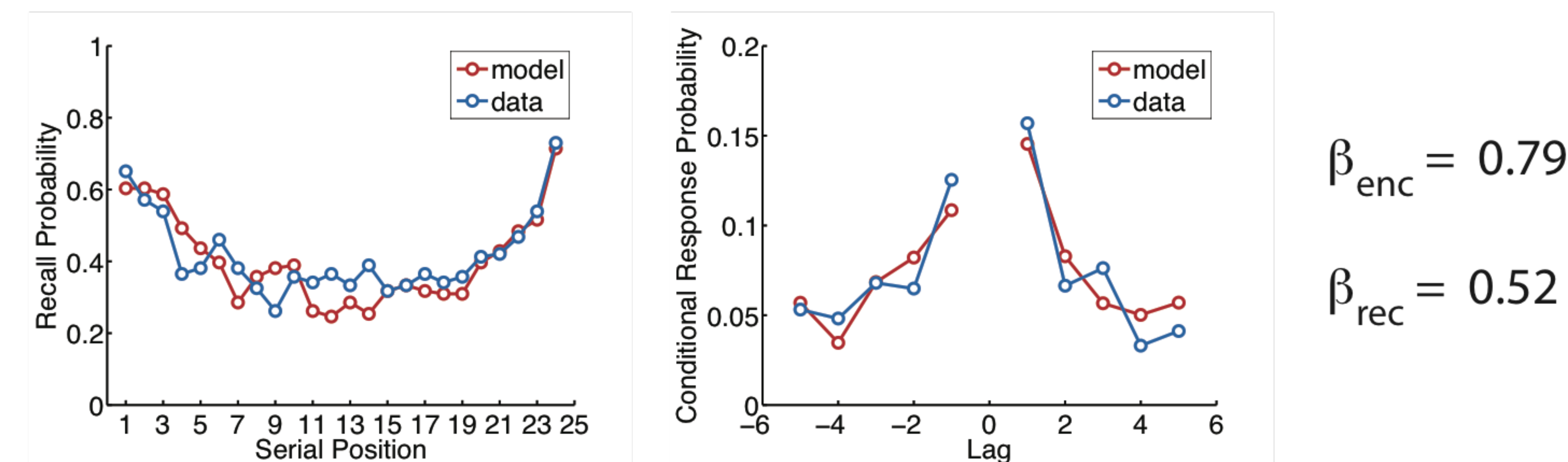
$$\beta_{enc} = 0.79$$
$$\beta_{rec} = 0.52$$

The Context Maintenance and Retrieval model[5] provides an accurate description of subject behavior during recall. Best-fitting model parameters were used to generate predictions of item and context based activity. Context updating (β) was predicted to be greater during encoding than recall.
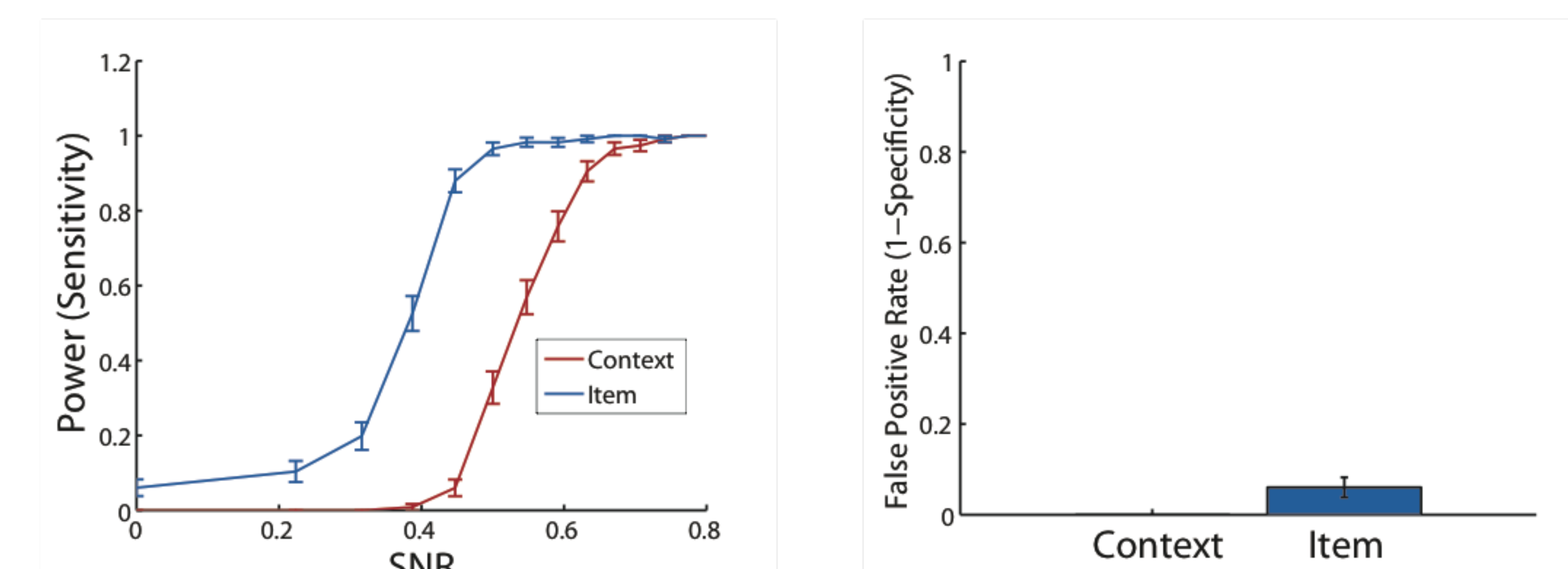
Synthetic fMRI analysis
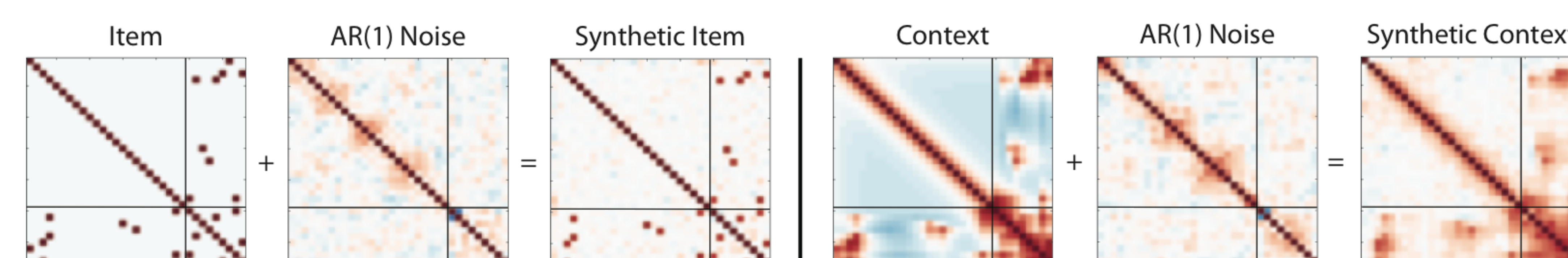
To test the ability to separate context-like signals from autocorrelated noise, synthetic fMRI data was generated based on observed recall sequences and timing, as well as model-based estimates of temporal context.
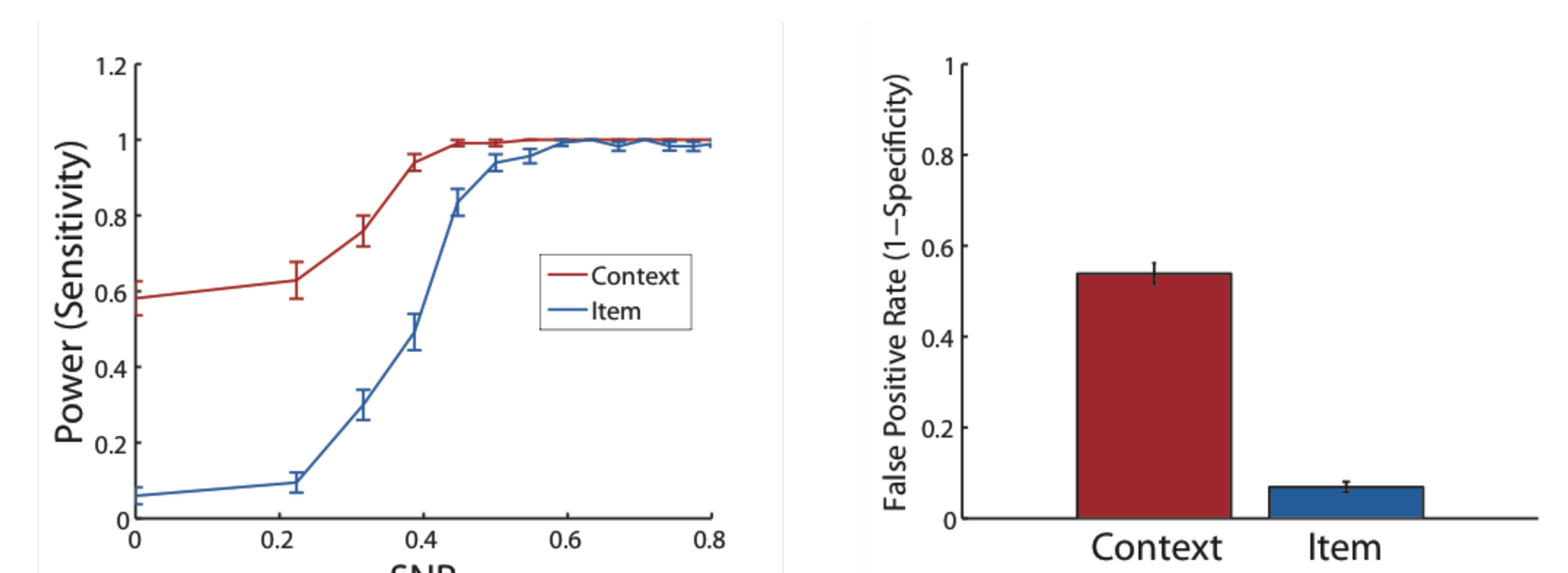

Context regions exhibited 80% power with an SNR of 0.32, while item regions exhibited 80% power with an SNR of 0.45.

Wavelet coefficient resampling was used to control false positive rates by preserving autocorrelated noise and destroying any mapping between cognitive processes and the simulated BOLD response. This baseline was used in the following fMRI analyses, ensuring context-like regions are not identified due to autocorrelated noise.

Candidate contextual regions
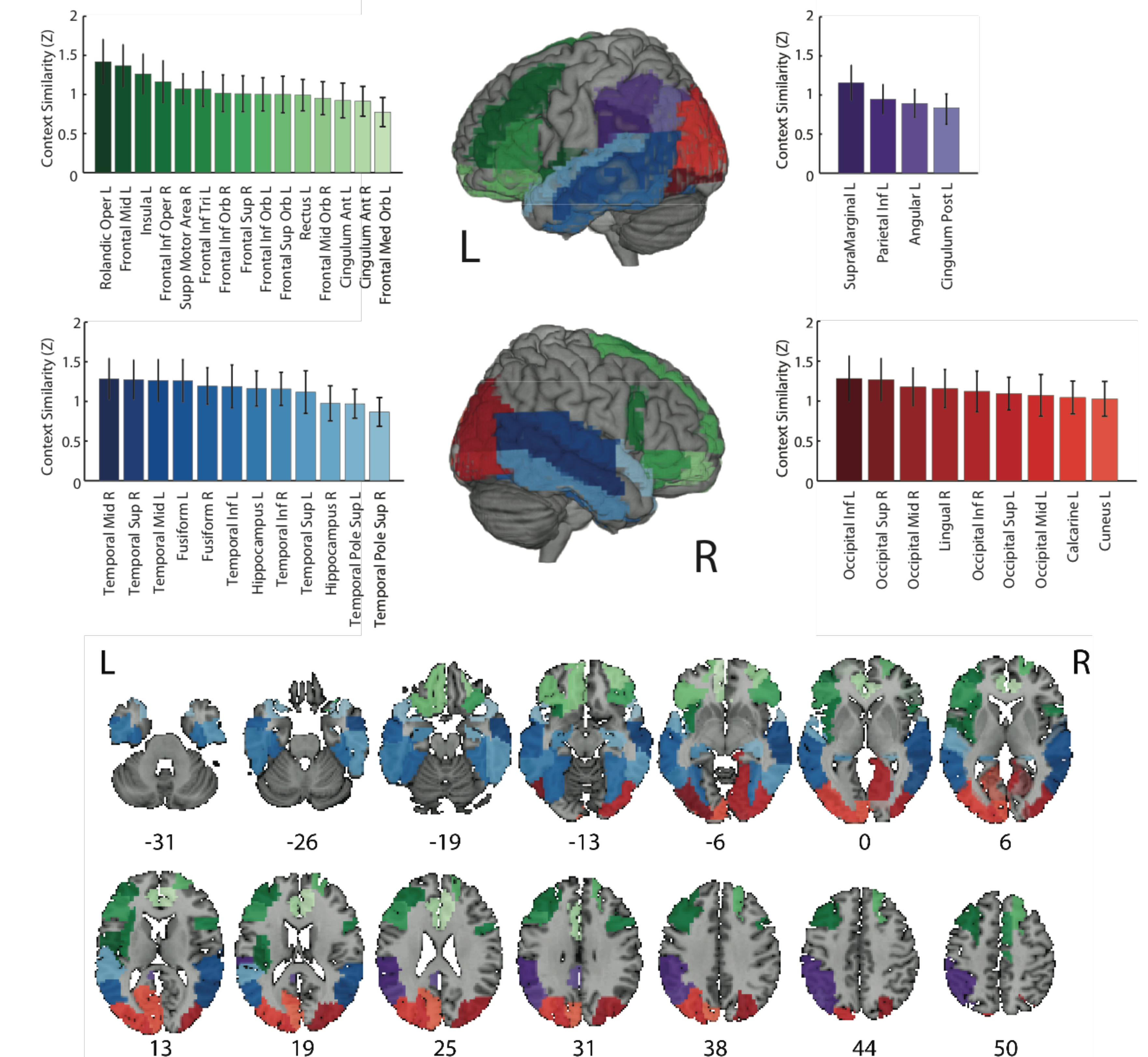
Conclusions

We demonstrate the capacity to discriminate between autocorrelated noise and context-like signals in both synthetic and neural data. We observed context-like behavior in widespread cortical regions, with the left prefrontal cortex demonstrating the highest degree of similarity to temporal context. Future work will test the extent to which pattern information in these regions is predictive of subject behavior during recall.

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