Activity within the default mode network predicts the organization of human memory.

James E. Kragel[1,2] and Sean M. Polyn[2]

[1]Neuroscience Graduate Program, [2]Department of Psychology, Vanderbilt University

Introduction

• The default mode network can be fractionated into sub-networks that support specific cognitive functions including memory retrieval.[1]

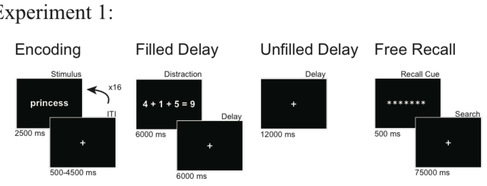
• A posterior medial subsystem has been proposed to support context-based representations fundamental to episodic memory.[2]

• Despite evidence linking these cortical networks to mnemonic functions, it is unclear how they influence memory search.

• We developed a family of neurally informed computational models to test the relationship between functional network activity and cognitive mechanisms that predict the organization of memory search.

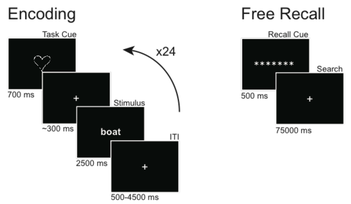
Experimental Methods

Experiment 1:



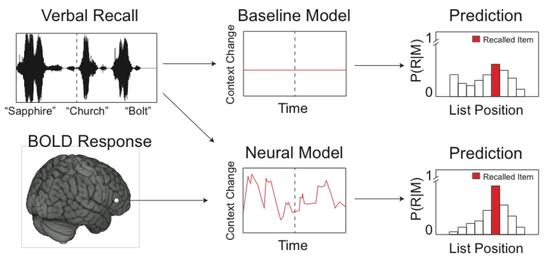
• 18 participants (12 female) performed 18 recall trials each during fMRI scanning
• Preprocessing via SPM8 (realignment, unified segmentation, smoothing)
• Independent component analysis (ICA) was used to identify functional networks of interest

Experiment 2:



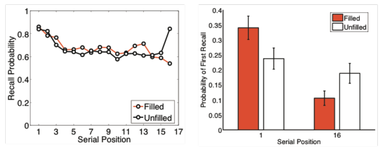
• 20 participants (12 female) performed 6 recall trials each during fMRI scanning
• Preprocessing and analysis of functional data match Experiment 1

Computational Framework



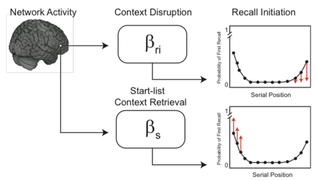
Default mode network activity informs context maintenance

Behavioral Results:



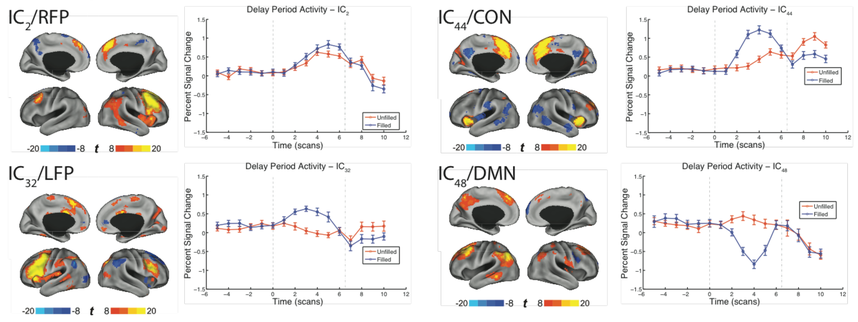
• Distraction during the delay conditions caused a decrease in recall of recency items ($t = 4.44$, $P < 0.0001$), and a shift in recall initiation ($F_{1,17} = 5.13$, $P = 0.036$).

Linking Hypotheses:



• Delay period activity in networks of interest reflects the disruption of a current contextual state.
• Delay period activity reflects the integration of start-of-list information following distraction, allowing access to the list.

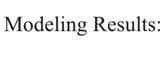
Neural Signals of Interest:

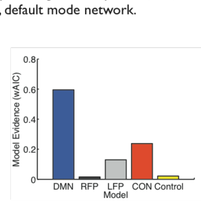


• Using ICA, we identified multiple functional networks that exhibit delay-period sensitive activity. RFP, right frontoparietal; LFP, left frontoparietal; CON, cingulo-opercular network; DMN, default mode network.

Modeling Results:

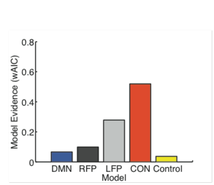
Neural signal reflects end-of-list context disruption





• Decreased activity in the DMN reflects an increase in context disruption, leading to improved prediction of recall sequences ($D = 10.64$, $P = 0.005$).

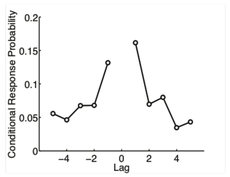
Neural signal reflects retrieval of start-list context



• Increased CON activity during the delay reflects start-list context retrieval, allowing for improved prediction of behavior ($D = 9.28$, $P = 0.009$).

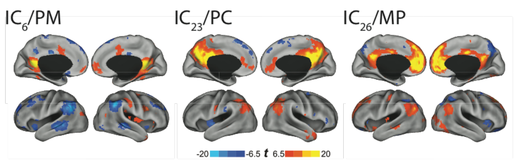
Posteromedial network activity informs contextual retrieval

Behavioral Results:

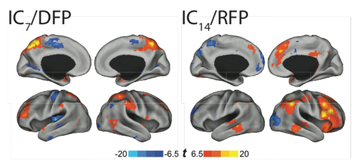


• Subjects demonstrated temporal organization during free recall, with a mean temporal factor score[3] of 0.59 ($t = 6.50$, $P < 0.0001$).

Neural Signals of Interest:

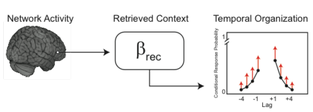


• Three independent components from Kragel and Polyn[4] that demonstrate spatial correspondence to the default mode network. PM, posteromedial; PC, posterior cingulate; MP, medial prefrontal.



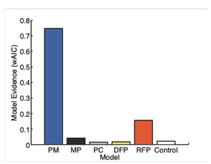
• Two independent components from Kragel and Polyn[4] that demonstrate spatial correspondence to the dorsal attention, and frontoparietal control networks. DFP, dorsal frontoparietal; RFP, right frontoparietal.

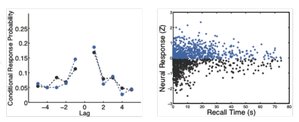
Linking Hypotheses:



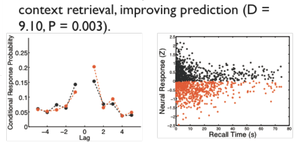
• Activity in components of interest during recall reflects the integration of contextual information into a recall cue that is influences memory search.

Modeling Results:

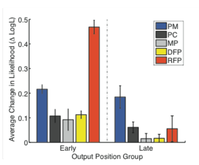


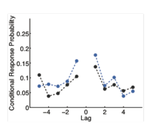


• Increased PM activity reflects increased context retrieval, improving prediction ($D = 9.10$, $P = 0.003$).

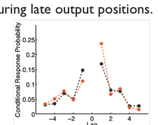


• Decreased RFP signal reflects increased context retrieval, also improved the fitness of the neural model ($D = 5.97$, $P = 0.01$).





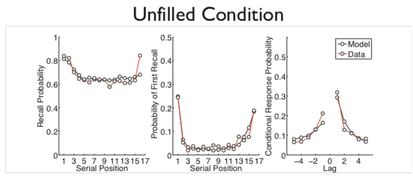
• PM signal was most informative during late output positions.



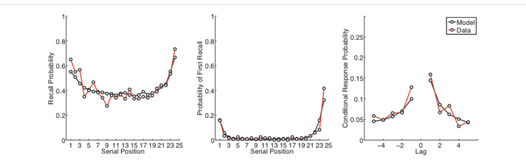
• RFP signal improved prediction during early recalls.

Model Performance

Experiment 1: DMN Informed Model



Experiment 2: PM Informed Model



Conclusions

• Deactivation in the default mode network predicts the disruption of recency effects during recall initiation. These findings link activity in this network to the maintenance of internal contextual states.

• Increased activity within a posteromedial network increases the likelihood that episodic associations are utilized during memory search. This links activity in this network to contextual retrieval processes that guide free recall behavior.

• Neurally informed computational models provide a means to identify explicit cognitive mechanisms supported by neural systems, and constrain formal models of human memory.

References

1. Andrews-Hanna, et al. Neuron 65, 550–562 (2010).
2. Ranganath, C. & Ritchey, M. Nature Reviews Neuroscience 13, 713–726 (2012).
3. Polyn, S. M., Norman, K. A. & Kahana, M. J. Psychological Review 116, 129–156 (2009).
4. Kragel, J. E. & Polyn, S. M. Cereb. Cortex (2013).

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