Incorporating neural signals into computational models of memory search

572.01

S. M. Polyn[1], J. E. Kragel[1,2], N. W Morton[1]

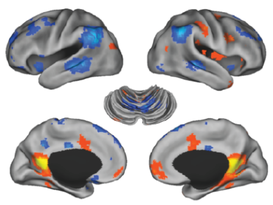
1. Vanderbilt Computational Memory Lab, Dept. of Psychology, Vanderbilt University; 2. Neuroscience Graduate Program, Vanderbilt University

VANDERBILT

Introduction

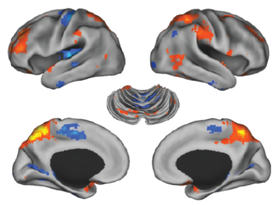
Kragel & Polyn, in press, Cerebral Cortex:
Using Independent Component Analysis (ICA) we identified brain networks engaged during self-initiated memory search (the free-recall paradigm)

Posteromedial (PM)



- Part of the default mode network.
- Sustained increase during memory search.
- Memory-related regions.

Dorsal frontoparietal (DFP)



- Topography matches dorsal attentional network.
- Transient increase for individual recall responses.
- Executive control regions.

The PM network shows functional coupling with the DFP network throughout the recall period.

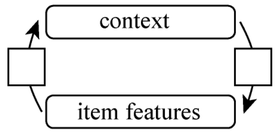
Hypothesis: Activity in PM reflects the memory system interacting with executive control systems.

Strategy: Incorporate PM signal into a computational model of memory to determine whether the signal allows us to better predict recall sequences.

Other large-scale brain networks examined:
Right frontoparietal **(RFP)**
Posterior cingulate **(PC)**
Medial prefrontal **(MP)**

A likelihood-based modeling approach

The Temporal Context Model (TCM)

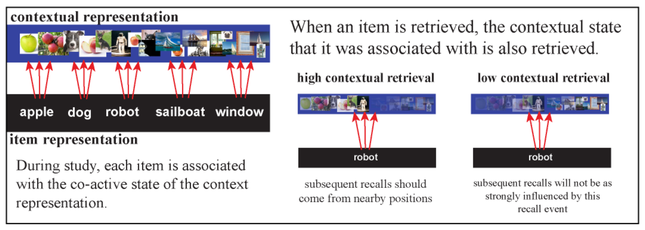


The data: recall sequences

Trial 1
24, 23, 20, 19, 11, 14, 21, 22 …
Trial 2
24, 19, 20, 21, 22, 5, 9, 1, 2 …
Trial 3
20, 21, 22, 23, 24, 13, 14, 18 …

We use TCM to calculate the likelihood of observing a given recall sequence, as if it was the generating model.

The mechanism: Contextual retrieval

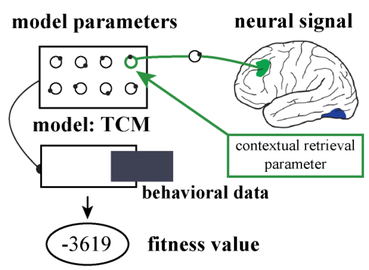


Strategy: Use neural signal to control the level of contextual retrieval, on a recall-by-recall basis. Will this improve how well the model predicts behavior?

An integrated neural-behavioral model

Each ICA component provides a time-varying signal that can be used to control the contextual retrieval parameter.

CMR allows us to test the hypothesis that the PM signal corresponds to retrieved context.



Comparing the model variants

wAIC scores represent the probability that each model generated the observed data (assuming that one of them did).

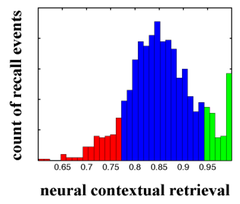
control	PM	DFP	RFP	PC	MP
no neural signal					
0.011	0.939	0.006	0.005	0.018	0.021

Of all the models considered, the posteromedial (PM)-contextual retrieval model is the one most likely to have generated the observed behavioral data.

A closer look at the neural variability

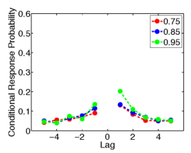
We partition the recall events according to the intensity of the neural component.

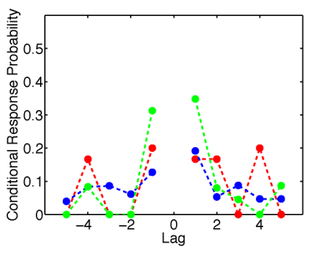
high contextual retrieval
med. contextual retrieval
low contextual retrieval



events sorted by neural intensity

model predictions

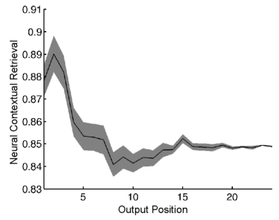




When a recall event has high neural contextual retrieval, the next recalled item tends to come from a nearby list position.

Context retrieval across recalls

The neural component is higher earlier in the recall sequence, suggesting that the first few recalled items retrieve more context than later recalled items.



In a follow up analysis, we examined a version of the model where the average PM activity for that output position controlled the strength of the contextual retrieval parameter. The PM model with full event-by-event variability did a better job predicting participant behavior.

Conclusions

- We identified large-scale brain networks involved in memory search, using ICA.
- We used a computational model as a statistical framework, to assess the viability of a neural-cognitive linking hypothesis.
- Fluctuations in posteromedial network activity can be used to improve the model's predictions of the participant's free-recall behavior.
- **Proposal:** PM activity is related to the contextual retrieval process described by the Temporal Context Model.

Acknowledgements

Many thanks to Andrew Tomarken, Tom Palmeri, Michael Pratte, Gordon Logan, Per Sederberg, and the members of the Vanderbilt Computational Memory Lab for helpful discussions and advice. This work was supported by NSF grant 1157432 and a Vanderbilt Discovery Grant. Visit **memory.psy.vanderbilt.edu** for more information!