The dynamics of semantic and temporal cuing during episodic memory retrieval

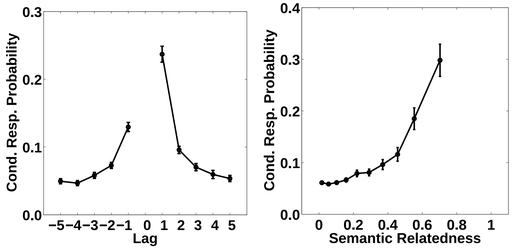
Per B. Sederberg & Kenneth A. Norman

Dept. of Psychology & Neuroscience Institute

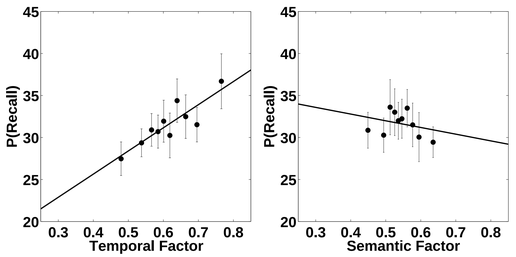
Princeton University

Introduction

- We are interested in the dynamics of memory encoding and retrieval.
- Free recall studies demonstrate that both temporal (Kahana, 1996) and semantic (Howard & Kahana, 2002b) cues drive memory retrieval.

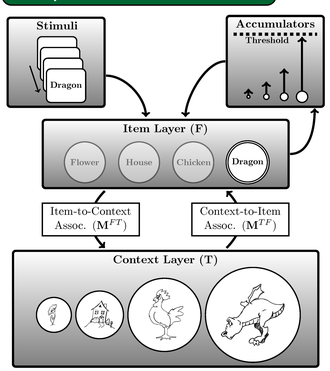


- Lag-Conditional Response Probability (above, left) and Semantic-Conditional Response Probability (above, right) calculated across 9 delayed free-recall studies.
- Participants who exhibit higher temporal contiguity recall more items (below, left).
- Individual differences in semantic contiguity do not significantly correlate with recall performance (below, right).



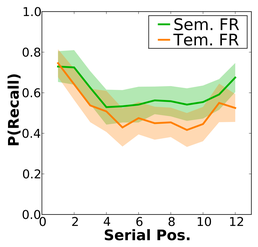
- Here we explore the dynamics of recall transitions when semantic information provides a more consistent cue for recall.

Temporal Context Model



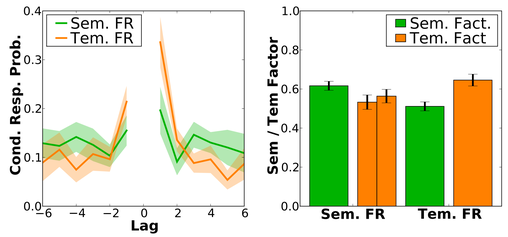
- Associative neural network that binds items and context during encoding.
- Item presentations and retrievals provide input to drive contextual drift.
- Contextual states serve as the cue for recall, weighted by the context-to-item connections.
- Recalling an item also reinstates the context that was present when that item was studied.
- Temporal contiguity effects arise because the retrieved contextual states overlap with the encoding context of nearby items (Howard & Kahana, 2002a; Sederberg et al., 2008).

Sem/Tem Free Recall



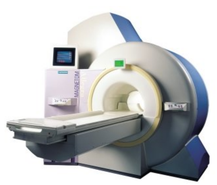
Pure Tem.	Mixed Sem./Tem.
COPPER	FOREHEAD[3]
ALLEY	GOLD[2]
SEAT	FOREST[0]
PEBBLE	FRUIT[1]
CAMERA	LAWYER[4]
BEVERAGE	BEARD[3]
BEDROOM	BERRY[1]
DOUGH	FLAG[6]
PLANET	BRONZE[2]
PIANO	DOORWAY[5]
SOCK	JUDGE[4]
BANDAGE	TIMBER[0]

- Delayed free recall of 12-item lists with 20 seconds of math distractor.
  1. Pure Temporal lists (i.e., no semantic relationships between items)
  2. Mixed Semantic / Temporal lists where list items have a single semantically related item at a distant list location.
- 30 Participants (6 with fMRI) performed 8 blocks, each with one of each list type.



- Less temporal contiguity in the semantic condition.
- Even when you have already recalled the semantic associate.

fMRI Methods

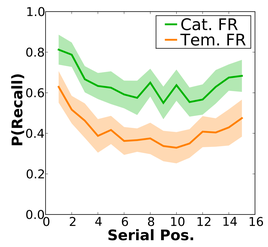


- Scanning was performed with a 3-Tesla Siemens Allegra fMRI scanner.
- Participants' anatomical data were acquired with an MPRAGE pulse sequence (176 sagittal slices) before functional scanning.
- Functional images were acquired using a T2-weighted echo-planar pulse sequence. TR was 2000 ms; TE was 30 ms.
- Functional data were slice-time corrected, despiked, and motion-corrected with AFNI (`http://afni.nimh.nih.gov/`) and then detrended (up to a 3rd order polynomial).
- All of the multi-variate analyses described were implemented using the Multivariate Pattern Analysis for Python (PyMVPA) toolbox, which is available online at `http://www.pymvpa.org` (M. et al., in press).

Acknowledgments

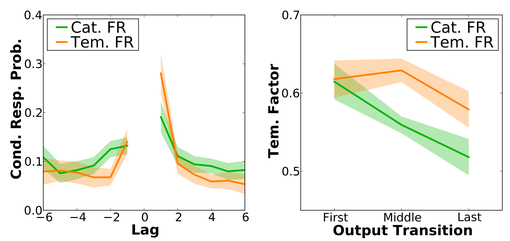
- This poster was created in LaTeX 2ε with the posterboxen style and TikZ.
- This work was supported by NIH grants MH069456, MH062196, and MH080526.

Category Free Recall



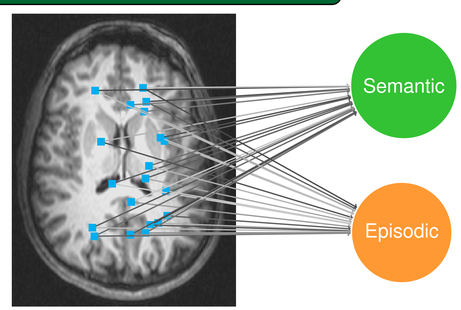
Pure Tem.	Sem. Category
NEST	TROMBONE
WALRUS	CLARINET
DOLL	FIDDLE
MONUMENT	FLUTE
MEADOW	ORGAN
ORANGE	CYMBAL
TOWN	TRIANGLE
TOOTH	TIMPANI
BRAKE	VIOLIN
BAND	HARP
BISCUIT	KEYBOARD
POOL	BELL
COIN	RECORDER
PRINCESS	TUBA
STATION	HORN

- Better recall performance for lists from a single category.
- Delayed free recall of 15-item lists with 20 seconds of math distractor.
  1. Pure Temporal lists (i.e., no semantic relationships between items)
  2. Semantic Category lists where list items are all members of a single category.
- 30 Participants (10 with fMRI) performed 8 blocks, each with one of each list type.



- Less temporal contiguity in the category condition ($p < .001$ for first–last paired t-test).

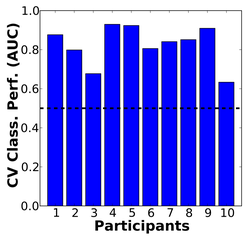
Multi-Variate Pattern Classification

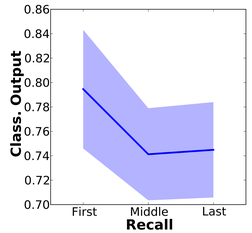


- Convolved time-periods of interest with HRF and picked boxes around TRs with peak activation.
- Data were Z-scored by run to the math as a baseline with the PyMVPA.
- Sparse Multinomial Logistic Regression (SMLR) classifier performs multivariate feature selection during training.

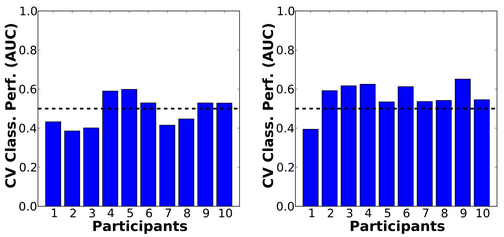
Predicting Free Recall Contiguity

- Train classifier to distinguish Category Free Association and Temporal Free Recall responses.
- Classifier can easily predict when each participant is making a semantic free association or retrieving a studied list item.





- Test classifier on Category Free Recall responses.
- Mean classifier value decreases with output position across subjects.
- Significant across-subject positive correlation between the drops in temporal factor and classifier output ($R = 0.62$, $p < .02$).



- Unable to predict the contiguity of the current response from the brain activity during the recall (left).
- Can predict the contiguity of next response above chance ($p < .02$, right)

Conclusions

- When semantic associations provide a good cue for recall, participants exhibit less temporal contiguity, yet they recall more items.
- Temporal contiguity decreases as a function of output position in each list, especially for lists of highly related items.
- A pattern classifier trained to disambiguate semantic free association and pure temporal free recall predicts this drop in temporal contiguity during category free recall.
- Neural activity around a response predicts the temporal contiguity of the next response, possibly measuring the degree of contextual reinstatement (Schwartz et al., 2005).

References

Howard, M. W., & Kahana, M. J. (2002a). A distributed representation of temporal context. *Journal of Mathematical Psychology, 46*, 269-299.

Howard, M. W., & Kahana, M. J. (2002b). When does semantic similarity help episodic retrieval? *Journal of Memory and Language, 46*, 85–98.

Kahana, M. J. (1996). Associative retrieval processes in free recall. *Memory & Cognition, 24*, 103–109.

M., H., Y.O., H., P.B., S., S.J., H., J.V., H., & S., P. (in press). Pymvpa: A python toolbox for multivariate pattern analysis of fmri data. *Neuroinformatics*.

Schwartz, G., Howard, M. W., Jing, B., & Kahana, M. J. (2005). Shadows of the past: Temporal retrieval effects in recognition memory. *Psychological Science, 16*, 898-904.

Sederberg, P. B., Howard, M. W., & Kahana, M. J. (2008). A context-based theory of recency and contiguity in free recall. *Psychological Review, 115*(4), 893–912.