Observing mental time travel in action: neurophysiological support for context-based models of episodic memory

Jeremy R. Manning, Sean M. Polyn, & Michael J. Kahana

University of Pennsylvania, Vanderbilt University

Background & Summary

- Context-based episodic memory models use contextual reinstatement at the time of recall to explain why participants often successively recall temporally proximal experiences (the *contiguity effect*).
- Here we test whether ECoG recordings taken as 69 neurosurgical patients studied and recalled lists of words showed patterns consistent with the context reinstatement hypothesis.
- We found that the pattern of activity recorded from the temporal and frontal lobes during recall was consistent with context reinstatement.

Methods

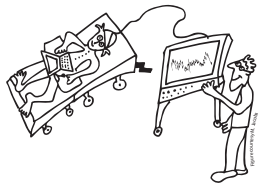

Figure 1. *Our setup.* Patients are implanted with subdural and depth electrodes by clinical teams. Experiments are administered on a bedside laptop computer.

Results

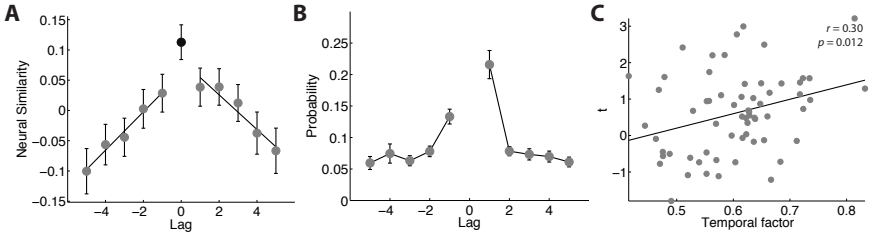

Figure 4. *A neural signature of mental time travel.* **A.** Neural similarity between the feature vector corresponding to recall of a word from serial position i and study of a word from serial position *i*+lag (black dot denotes study and recall of the same word, i.e., lag = 0). **B.** Participants tend to successively recall neighboring study items (the contiguity effect). Here, we plot the probability of recalling an item from serial position *i*+lag immediately following an item from serial position *i*, conditional on the availability of an item in that list position for recall. **C.** The magnitude of neural context reinstatement (A) is correlated with the tendancy of subjects to cluster their recalls in time (B).

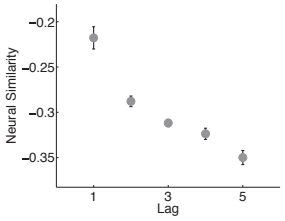

Figure 3. *Evolution of neural activity during study.* Neural activity drifts gradually during the study interval.

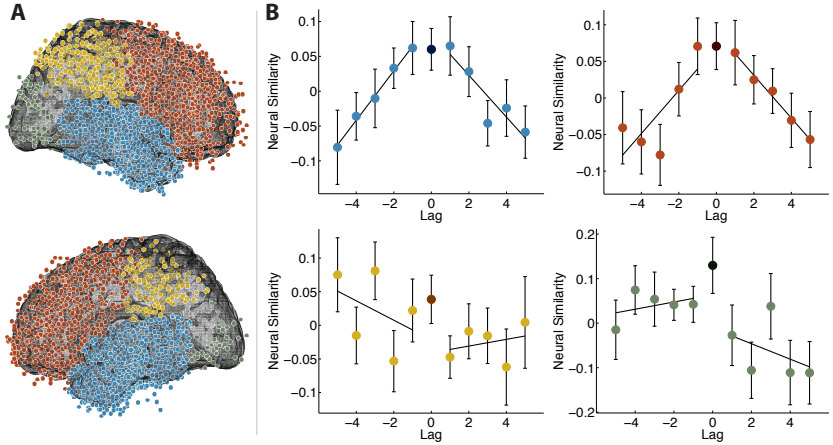

Figure 5. *Regional specificity of the context representation* **A.** Each dot marks the location of a single electrode in Talairach space. We divided our dataset into four regions of interest: temporal lobe (blue; 1,815 electrodes), frontal lobe (red; 1,737 electrodes), parietal lobe (yellow; 512 electrodes), and occipital lobe (green; 138 electrodes). **B.** Each plot is in the same format as Fig. 4A, but corresponds to a single region of interest, as indicated by the coloring of the dots.

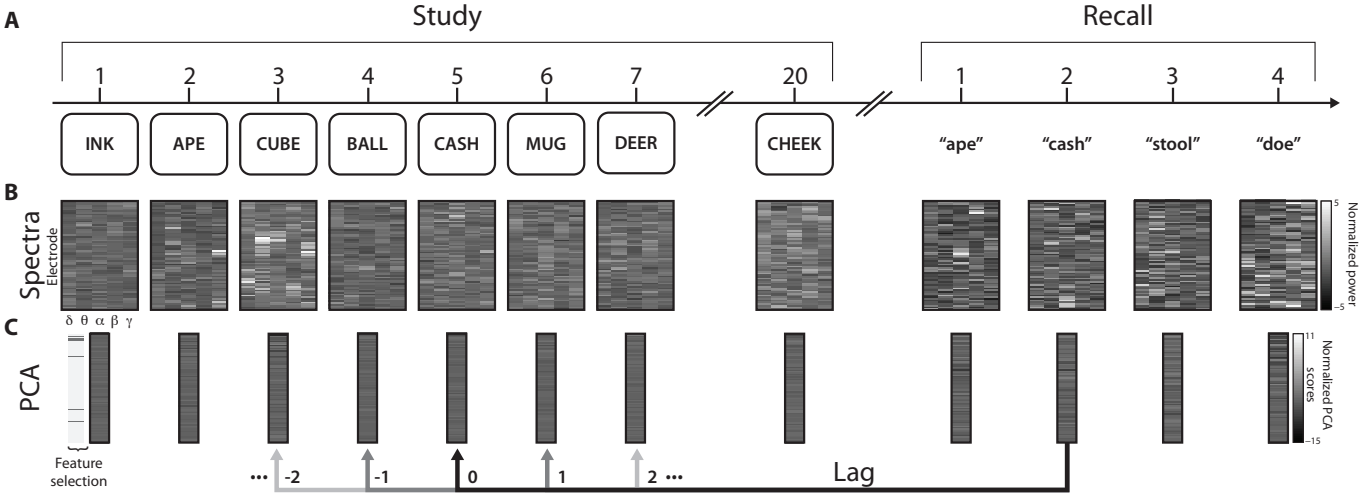

Figure 2. *Experiment and analysis.* **A.** The participant studies and freely recalls lists of 15 or 20 common nouns. **B.** For each electrode we compute mean power in 5 frequency bands during each study and recall event. **C.** We reduce the dimensionality using principal components analysis (PCA). We identify principal components which exhibit gradual change during study. Study and recall events are compared using Euclidean distance.

Conclusions

- We identified patterns of slowly changing neural oscillatory activity as participants studied and recalled lists of words.
- When a word is recalled, the neural pattern observed during study of that word is reinstated.
- The retrieved neural activity also shows graded similarity to activity recorded during the presentation of neighboring words on the studied list.
- The strength of this neural context reinstatement effect is correlated with the contiguity effect across participants.
- This phenomenon is localized to the temporal and frontal lobes.

For reprints contact **manning3@mail.med.upenn.edu**