Measuring a covert influence of episodic memory on working memory

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How do different memory systems interact?

Working memory (WM) maintains information across delays; during these delays, episodic memory (EM) replays recent experiences.
Does episodic memory replay intrude on WM maintenance?

Approach: We test the idea that reinstatements from EM occur even under the conditions of a traditional "pure WM" manipulation

- Reinstating an episode reinstates its temporal and associative context (Howard & Kahana, 2002)
- Recalling a given context can cause the subsequent, involuntary recall of other memories sharing that context (Hupbach, Gomez & Nadel, 2009)
- These involuntary recalls are indexed by neuroimaging measures of context reinstatement (Gershman, Schapiro, Hupbach & Norman, 2013)
- These recalls occur, as indexed by neuroimaging measures, even at short delays typically associated with WM not EM (Hannula, Tranel & Cohen, 2006)

Hypothesis: During WM task delay periods, episodic memory replay intrudes on WM maintenance. These intrusions carry context, which impacts performance.

Short term memory task with no distractions

Context Training: Subjects learned 4 different sets of words

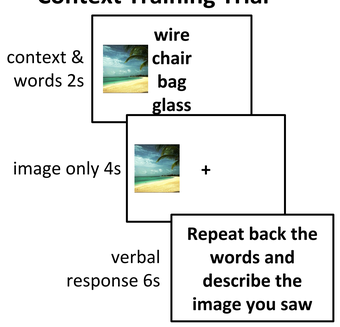
- 12 words per set
- Words presented four at a time, each word presented four times
- 1 "context picture" presented with each set; face/scene X left/right

Delayed Non-Match to Sample Task (DNMS)

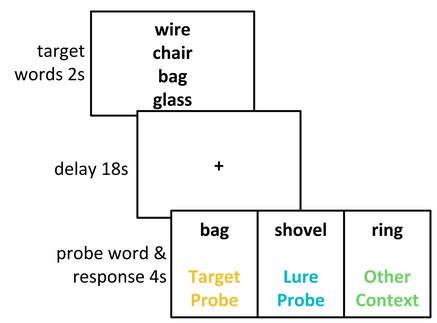
- Retention targets: 4 words, drawn from one of the context sets
- 18 second delay, no interference
- Probe: subjects asked to affirm probes were not one of the targets
- Three kinds of probe words: Target, Lure (same context set as targets), Other (different context set from targets)

Beach Context  **wire chair light salt folder shirt pen desk cup glass bag shovel**

Context Training Trial



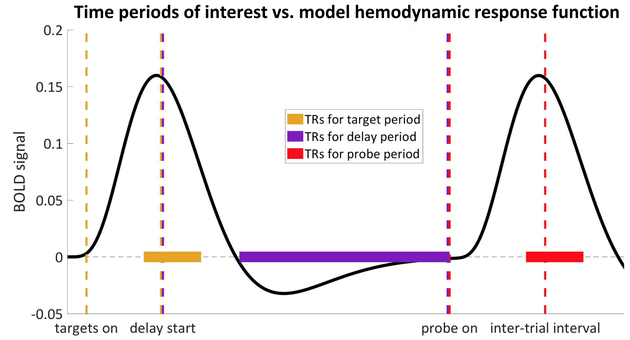
DNMS Trial



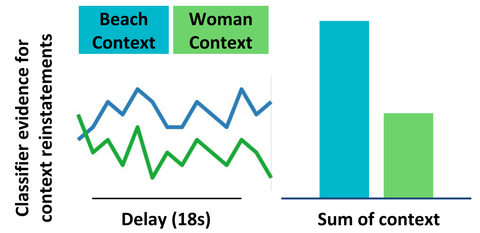
Methods: Measuring which memories are recalled during the delay on each trial

Use fMRI to measure which contexts participants (n = 36) recalled during DNMS delays. 4-way MVPA classifier trained to identify face/scene X left/right.
Does recalling the original word list during the delay introduces those words into WM, making it harder to reject any word associated with the original context as a probe?

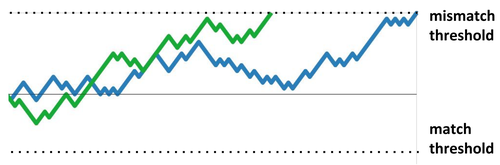
Time periods of interest vs. model hemodynamic response function



MVPA of fMRI Data: Measuring context reinstatements on each trial



Predicted drift rates when the probe was NOT a target

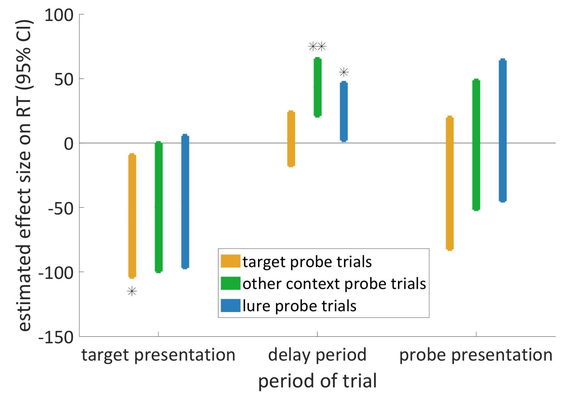


Beach probe: more context evidence incorrectly indicates probe was a target → low drift rate, slow RT
Woman probe: less context evidence correctly indicates probe not a target → high drift rate, fast RT

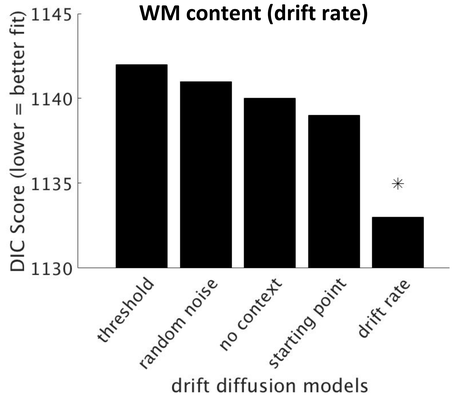
Results: Episodic memory intrudes on working memory, even in the absence of distraction

The more participants reinstate the original word list during the delay, the slower they are to discard lure probes after the delay ($p < .05$).
The more participants mistakenly reinstate the word list associated with the probe word on other probe trials, the more they slow down ($p < .01$).
Linear mixed effects model. Fixed effects: reinstatement during targets, delay, and probe. Random effect: subjects
We hypothesize that reinstating the original word list during the delay strengthens representations of those words in WM.
Prediction: context reinstatements affect the fidelity of WM, as measured by drift rate.
Alternative hypotheses: context reinstatements affect response selection via starting point, or response strategy via threshold.
HDDM (Wiecki, Sofer & Frank, 2013) used to fit DDM to between subject and within subject (trial type) data.
Models where context evidence predicted the fidelity of WM representations on each trial were better fits than models that did not include context evidence, models where context evidence affected response selection or response strategy, or models with random noise in the WM representations ($p < .05$).

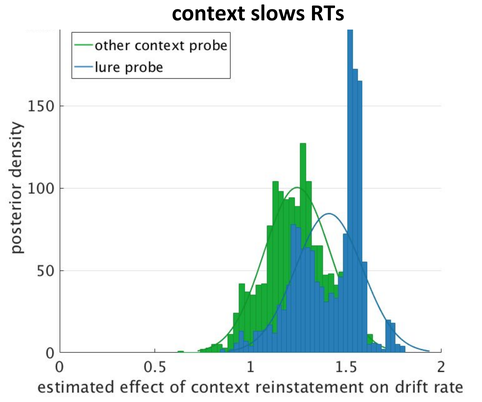
Probe context reinstatements slow RTs on non-target trials



DDM comparison: Context affects WM content (drift rate)



If probe word was not a target, reinstating its context slows RTs



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Conclusions

1. **Performance on an interference-free working memory task was impacted by context information from episodic memory.**
2. **Episodic memory intrusions during working memory maintenance significantly predicted trial-by-trial changes in RT.**
3. **Context evidence affected the fidelity of working memory representations, as measured using Drift Diffusion Models (DDM).**