Learning when to encode/recall episodic memories

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Main point

Q: How should hippocampus parameterize its encoding and retrieval processes to support event sequence processing?
Through simulations with an episodic neural network, we found that certain amount of waiting, for both encoding and retrieval, reduces the probability of false recall, which boosts the extent to which episodic memory benefits event understanding.

An episodic neural network

Cortex i) actively maintains features of the current situation; ii) make predictions about the next event. **Hippocampus** i) takes "snapshots" of cortical patterns; ii) pattern completes the situation model using these stored "snapshots".

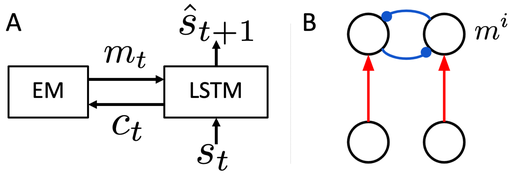

Figure 1: A) A neural network model with episodic memory (EM); B) A leaky competing accumulator (**LCA**) governs the dynamics of episodic recall.

A recall/no-recall task

- Encoding phase: Sample k event sequences from k different schema.
- Test phase: Flush the cortical activity or LSTM hidden state. With $p = .5$, present a event sequence from one of the k schema (a **recall trial**, e.g. see Fig 2 A); otherwise, present a sequence from a new schema (**no-recall**).

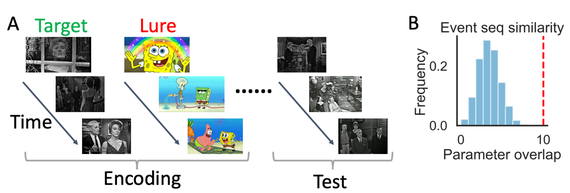

Figure 2: A) An example of a recall trial; B) Pairwise similarity/ambiguity across event sequences.

Task performance

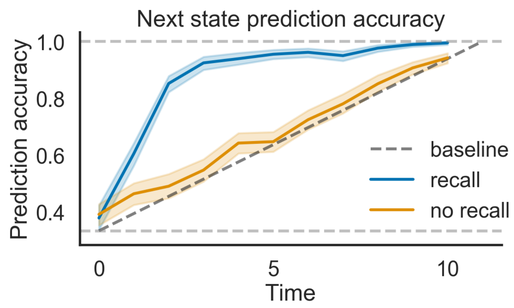

Figure 3: The event prediction performance for recall trials is much higher (when there is a target) than no-recall trials.

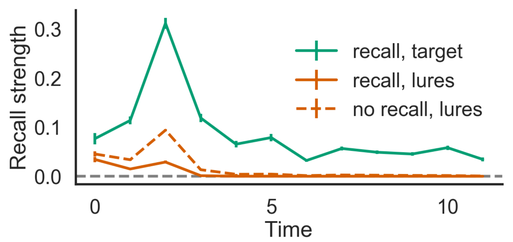

Figure 4: Target memories are more activated than lures.

Memory benefit decay over time

The **memory benefit**, or the predictive gain of recall decreases rapidly as the event sequence unfolds (Fig 5 A, B). Delaying prediction demand also lower the overall "need" for episodic memory (Fig 5 B).

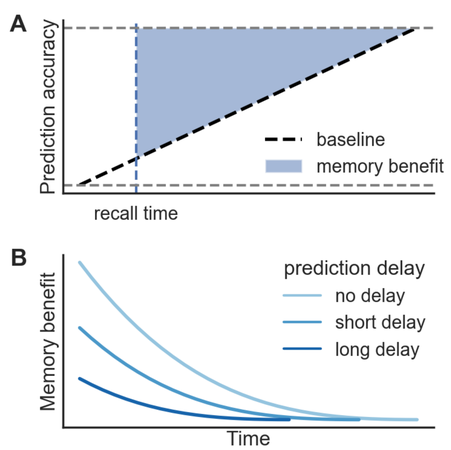

Figure 5: A) Define the memory benefit at time t; B) Memory benefit diminishes over time/ with prediction delay;

Temporal dynamics of recall

Delaying prediction demand reduces recall demand (Fig 6 A); Recall is time-locked with prediction demand (Fig 6 B); The system learned to raise the level of competition over time (Fig 6 C).

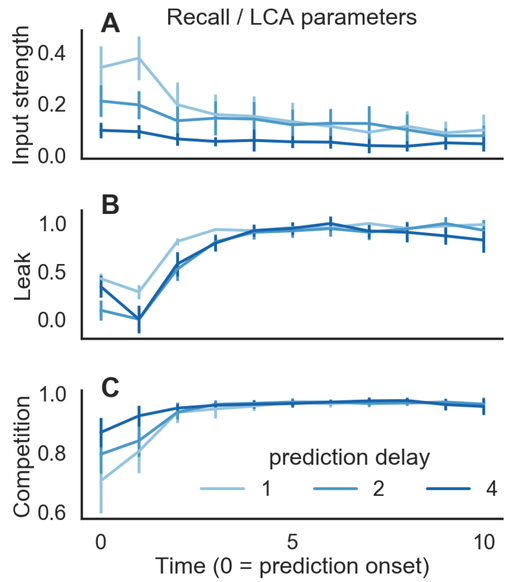

Figure 6: LCA parameter time courses, aligned to event prediction onset. A) The "need" for episodic memory; B) The "decay" term on memories activation; C) Lateral inhibition across memories.

LCA as an approximation to hippocampus-like recall

The signal detection performance of our LCA-based recall system is inferior than a standard CLS (e.g. Norman O'Reilly, 2003) due to insufficient competition during no-recall trials. We are exploring additional mechanism to overcome this issue.

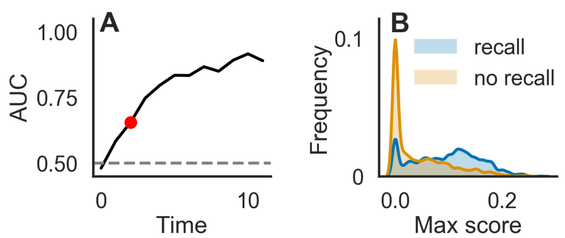

Figure 7: A) Sensitivity and specificity of recall. B) The maximal activation of memory, or "max score", for recall vs. no-recall trials.

Optimal encoding timing

Bigger "chunk size" leads to better event prediction (Fig 8 A), and lower false recall rate (Fig 8 B).

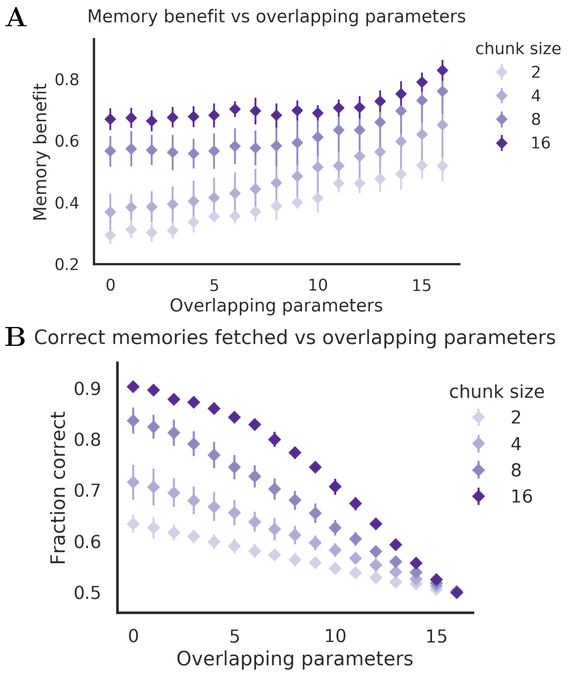

Figure 8: Event prediction performance (A) / recall accuracy (B) as a function of the target - lure similarity.

Summary

To help with event prediction, episodic system should recall right before prediction demand, and encode at event boundaries. These results provide a normative account of the observation that the neural signature of retrieval and encoding is temporally sparse and time-locked with event boundaries [1][2][3].

References & Acknowledgement

[1] Baldassano, et al. (2017) Neuron.
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