Modeling Hippocampal-Cortical Interaction During Event Processing

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Main point

Question: How does hippocampus help cortex with event understanding?

- Hippocampus' job is to "pre-fetch" features of the current situation. This will help cortex to make accurate predictions.

Model

Cortex actively represents features of the current situation and uses this to make predictions about what will happen next.

Hippocampus takes snapshots of actively maintained features; can pattern complete missing features using these stored snapshots.
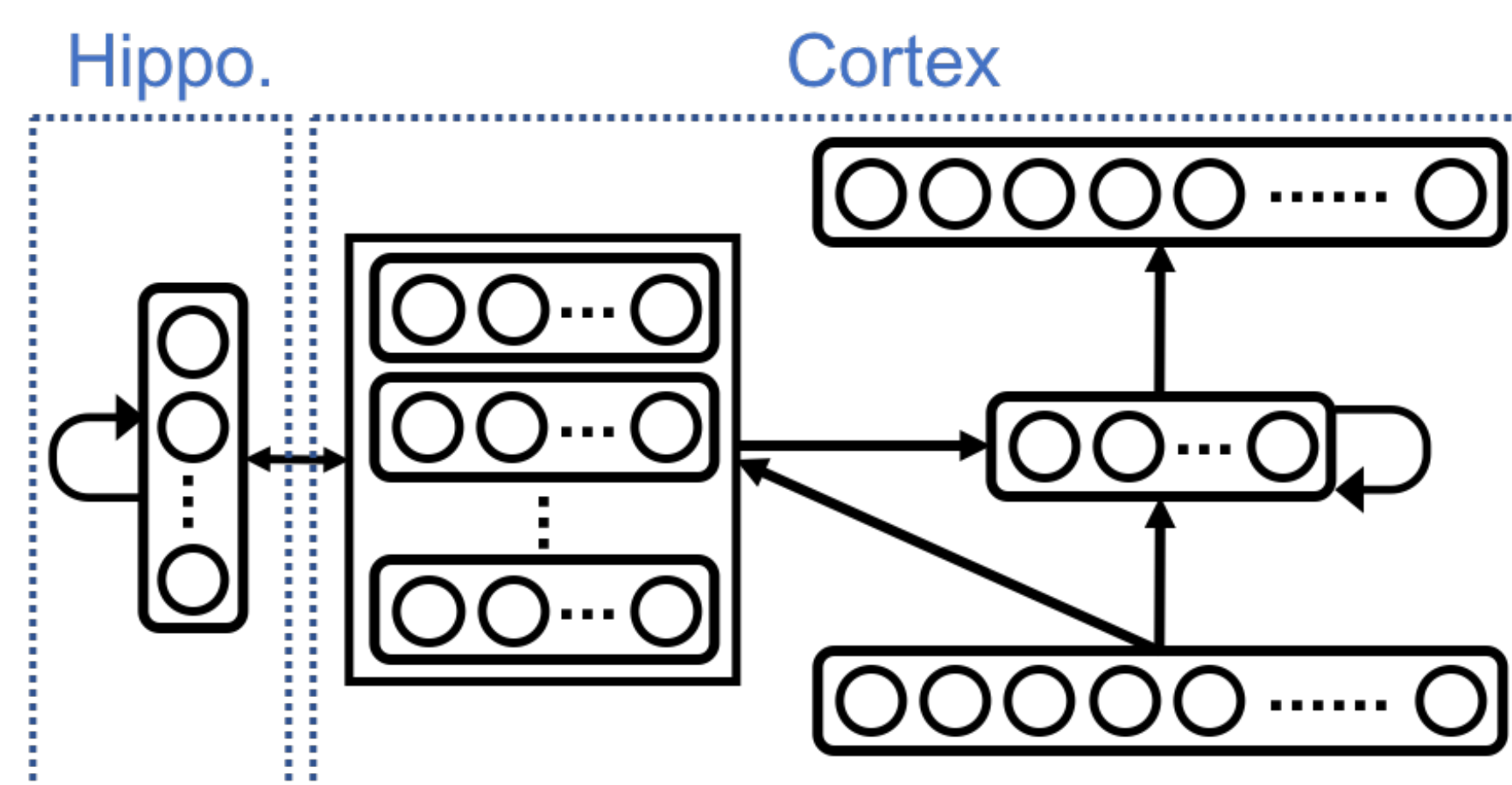

Figure 1: Cortex is an RNN that predicts the next state, and it has a buffer. Hippocampus is an RNN that stores snapshots of the buffer and recalls previously stored episodes to the buffer.

Task formulation

- We used a probabilistic graph to generate event sequences. Transitions are context-dependent: they depend on features of the current situation.
- We trained the model to learn these context-dependent transitions.
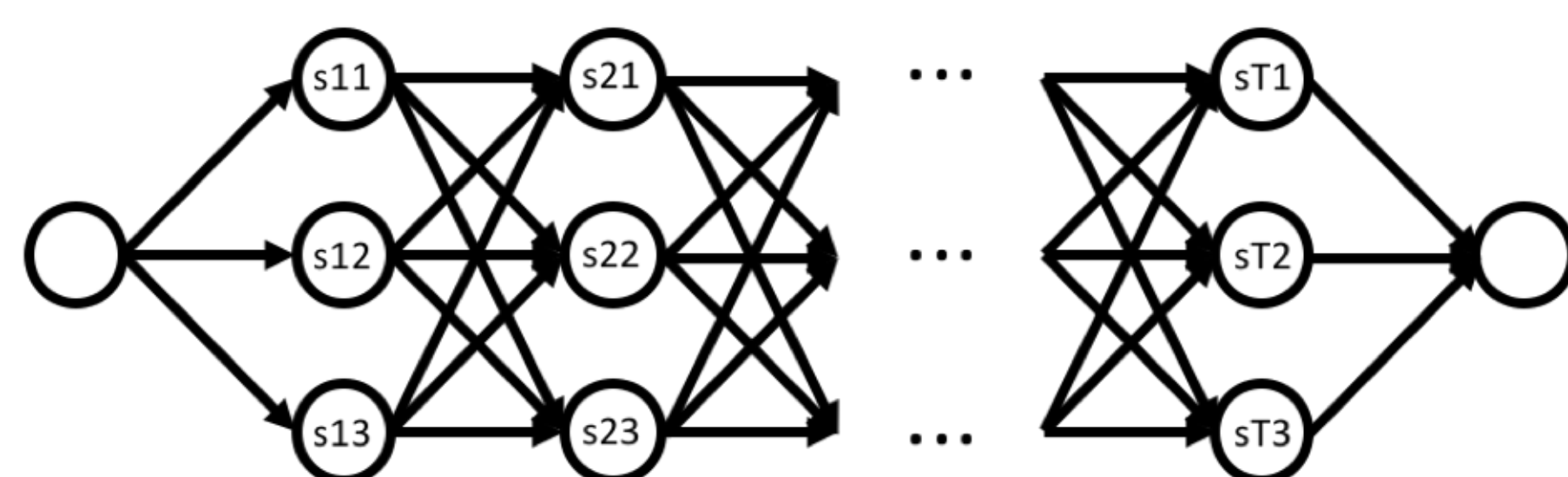

Figure 2: In this schema graph, each node represents an event and each edge has a default transitional probability.

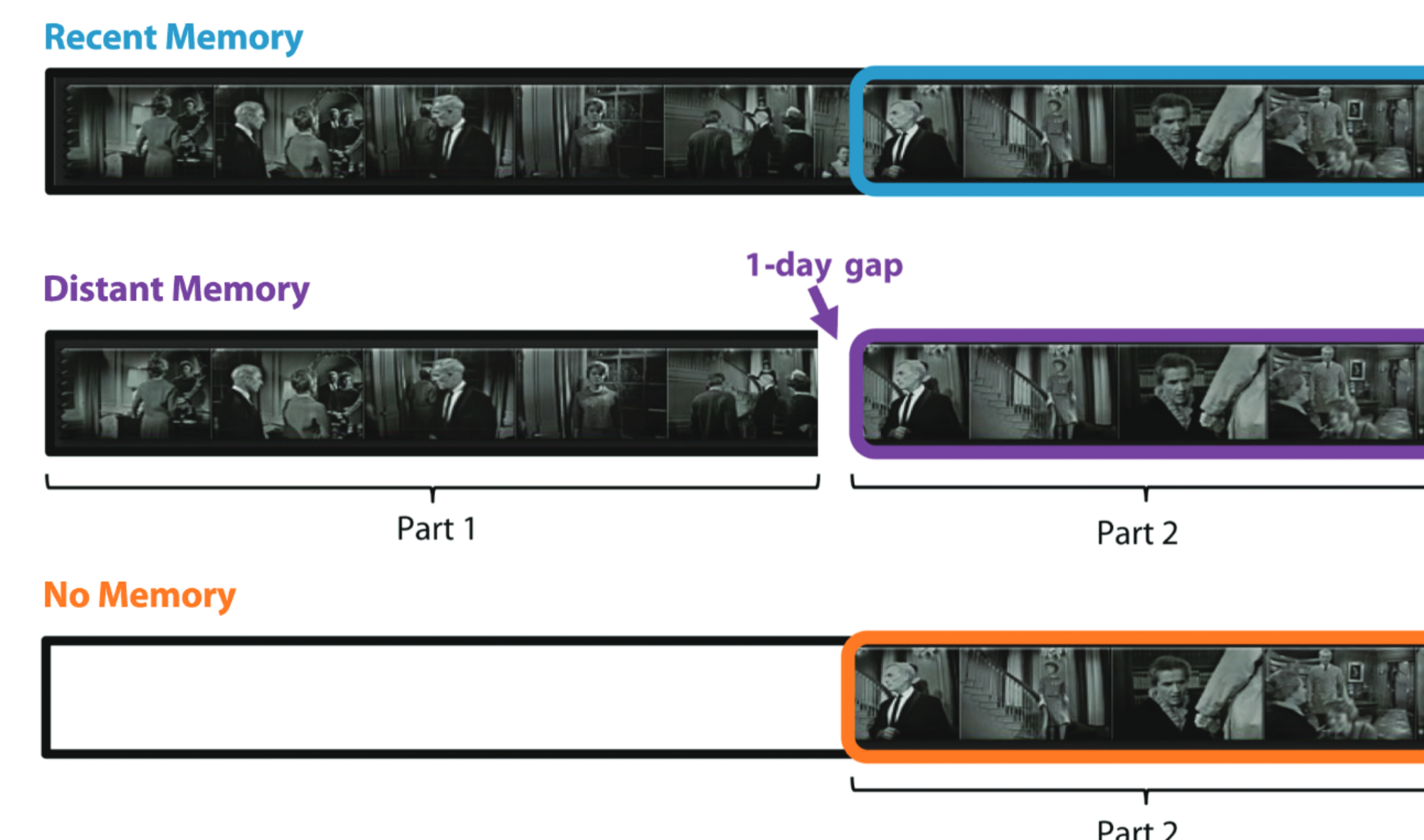## Shared situation model enhances inter-subject correlation (ISC)[4]

Figure 3: Experimental design[4]. Participants watched an episode of Twilight Zone movie while being scanned.
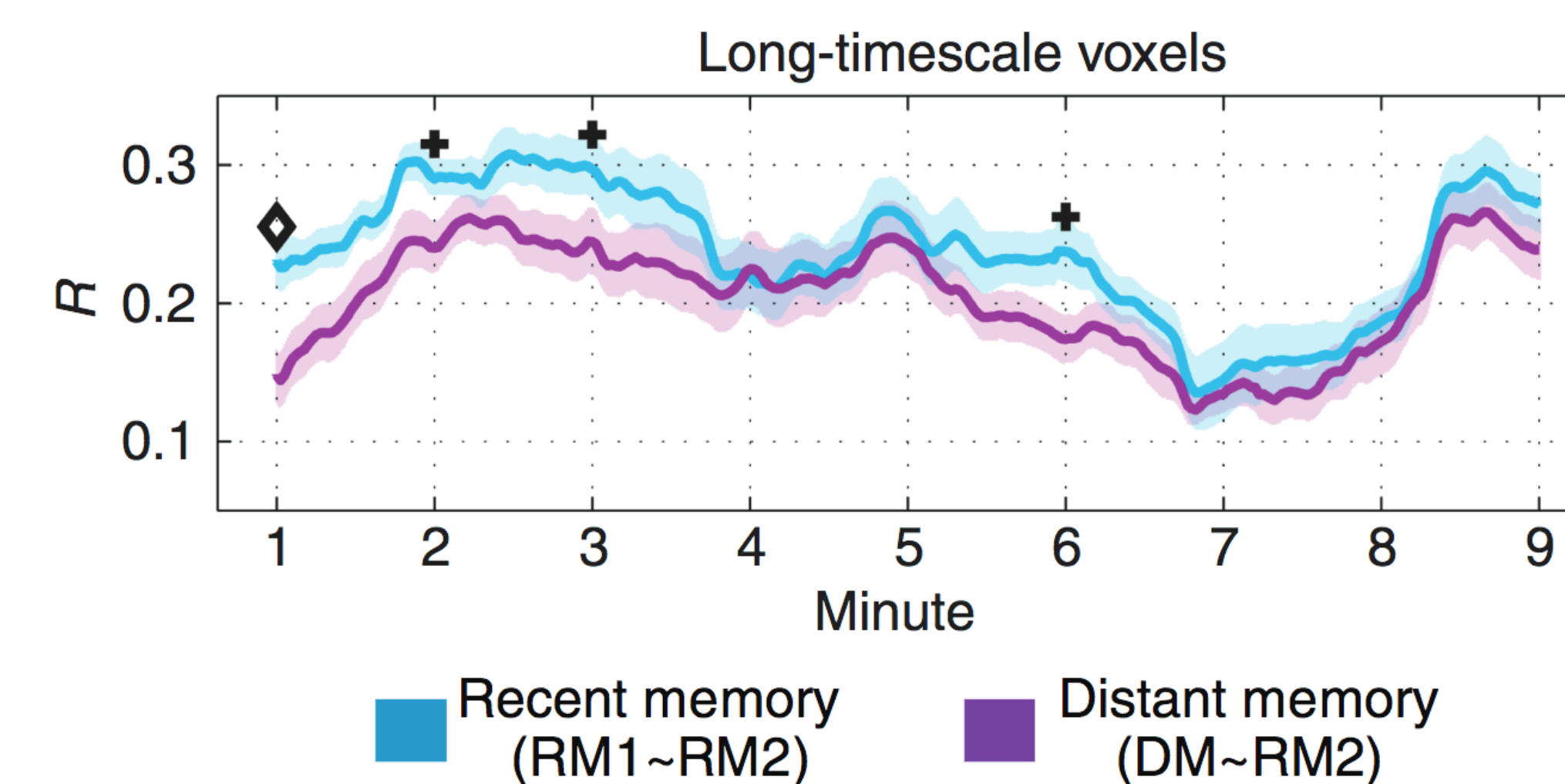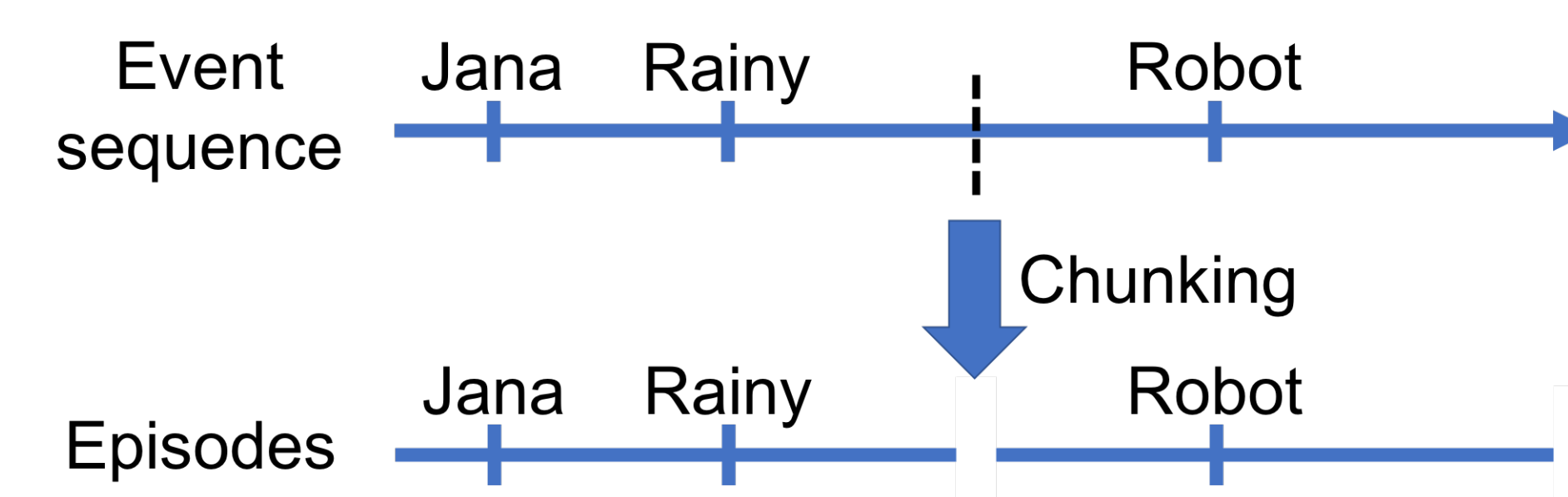

Figure 4: Empirical fMRI ISC[4] during the second half of the movie. DM-RM ISC gradually converged to RM-RM ISC.

Demo: Encoding and retrieval

Encoding: Chunk the event sequence into pieces.

Retrieval:
- Load the episode with maximal **match**
- Reject episodes with **mismatch**
- Inhibit previously recalled episodes

e.g.: At time t,
Buffer = {subject = Jana, weather = rainy}

ISC simulation

Model simplifications: Save the 1st part of the movie as 1 chunk and retrieve it during the 2nd part.
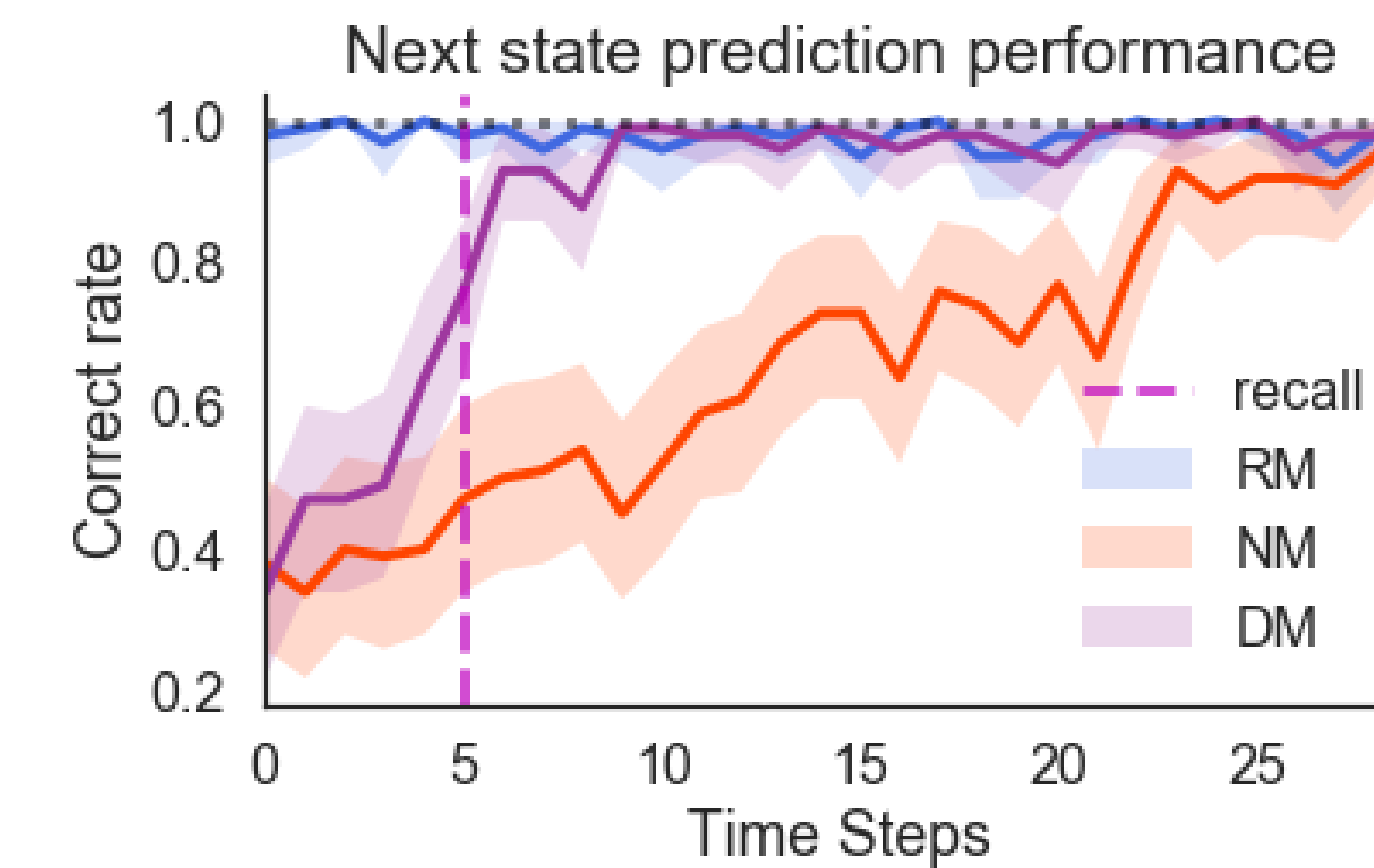

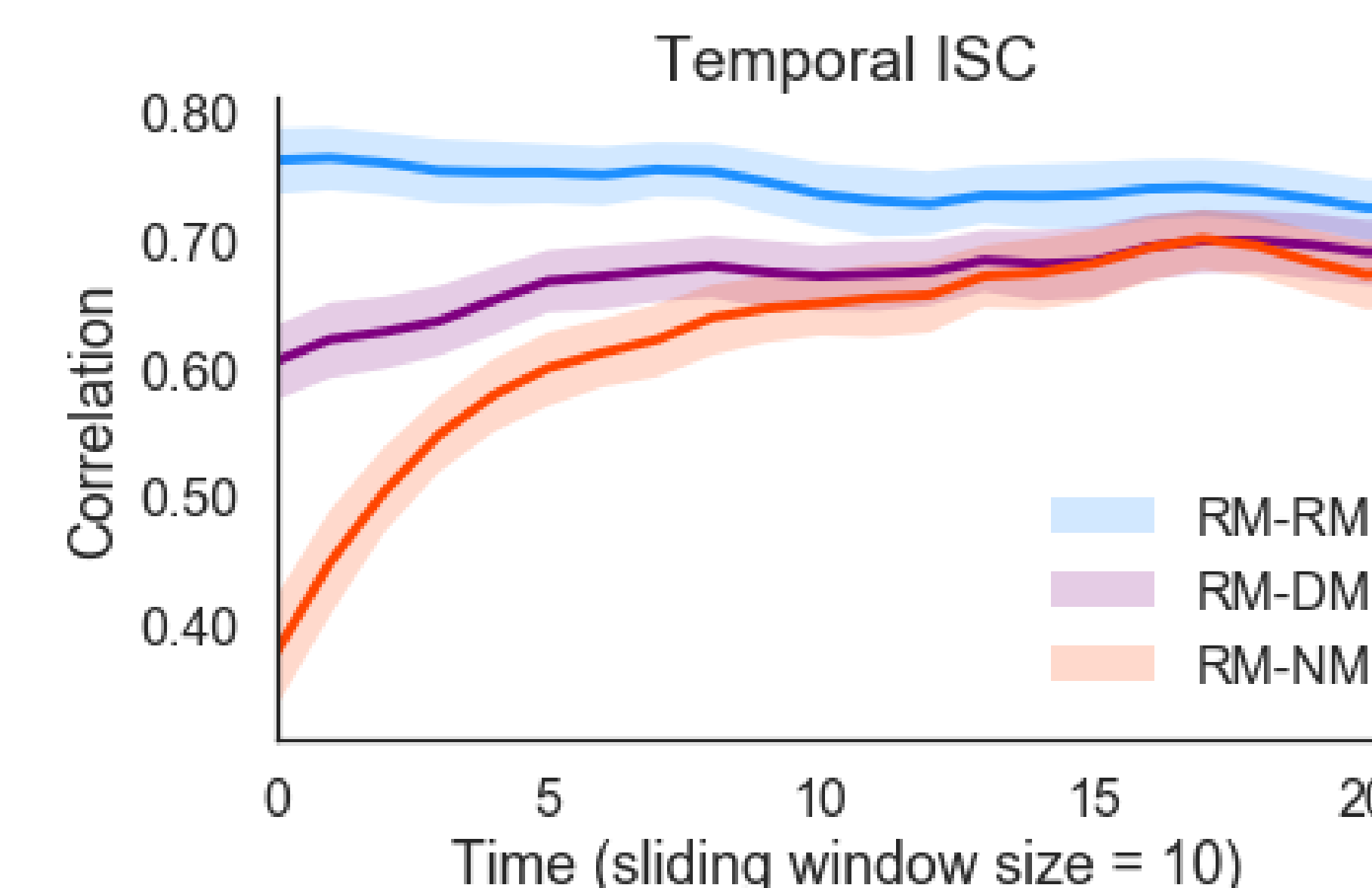Figure 5: Model next state prediction accuracy. We forced all models to retrieve memory at t = 5.

Figure 6: After functional alignment, the model ISC pattern qualitatively captures the empirical result[4] in Figure 4.

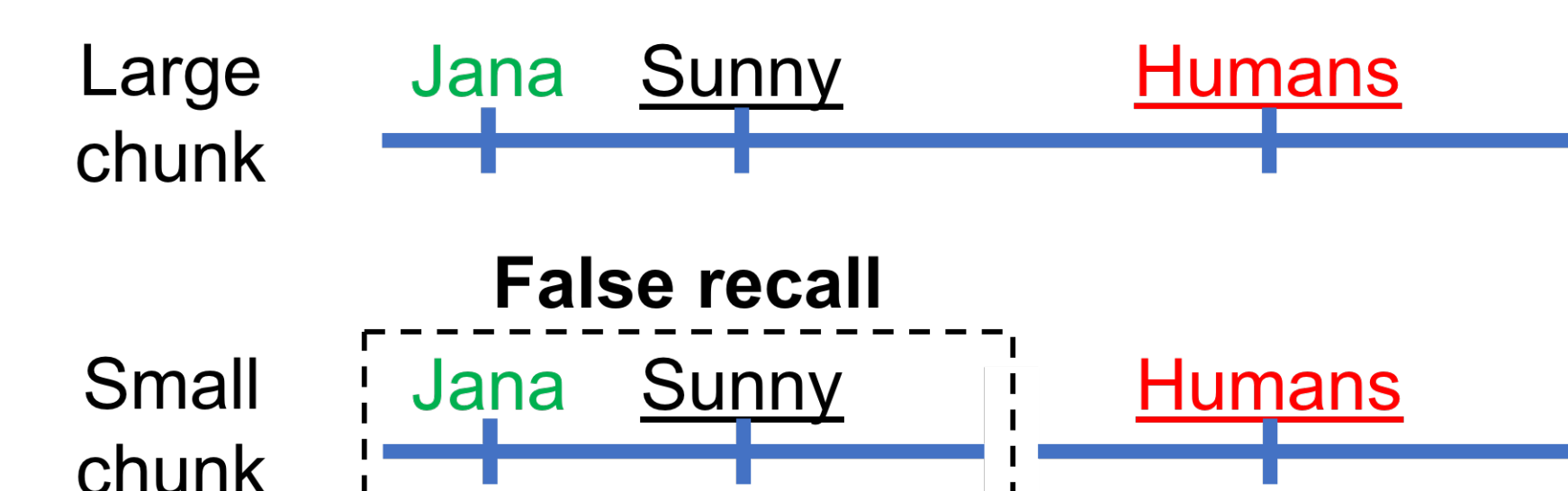## Demo: Large chunk sizes can prevent retrieving lure episodes

Assumption:
Lure episodes contain **mutated features**.

e.g., At time t,
Buffer = {subject = Jana, servants = robots}
Lure episodes:

Recall performance

Metric:
- How often has the model pre-loaded the required situation model features.
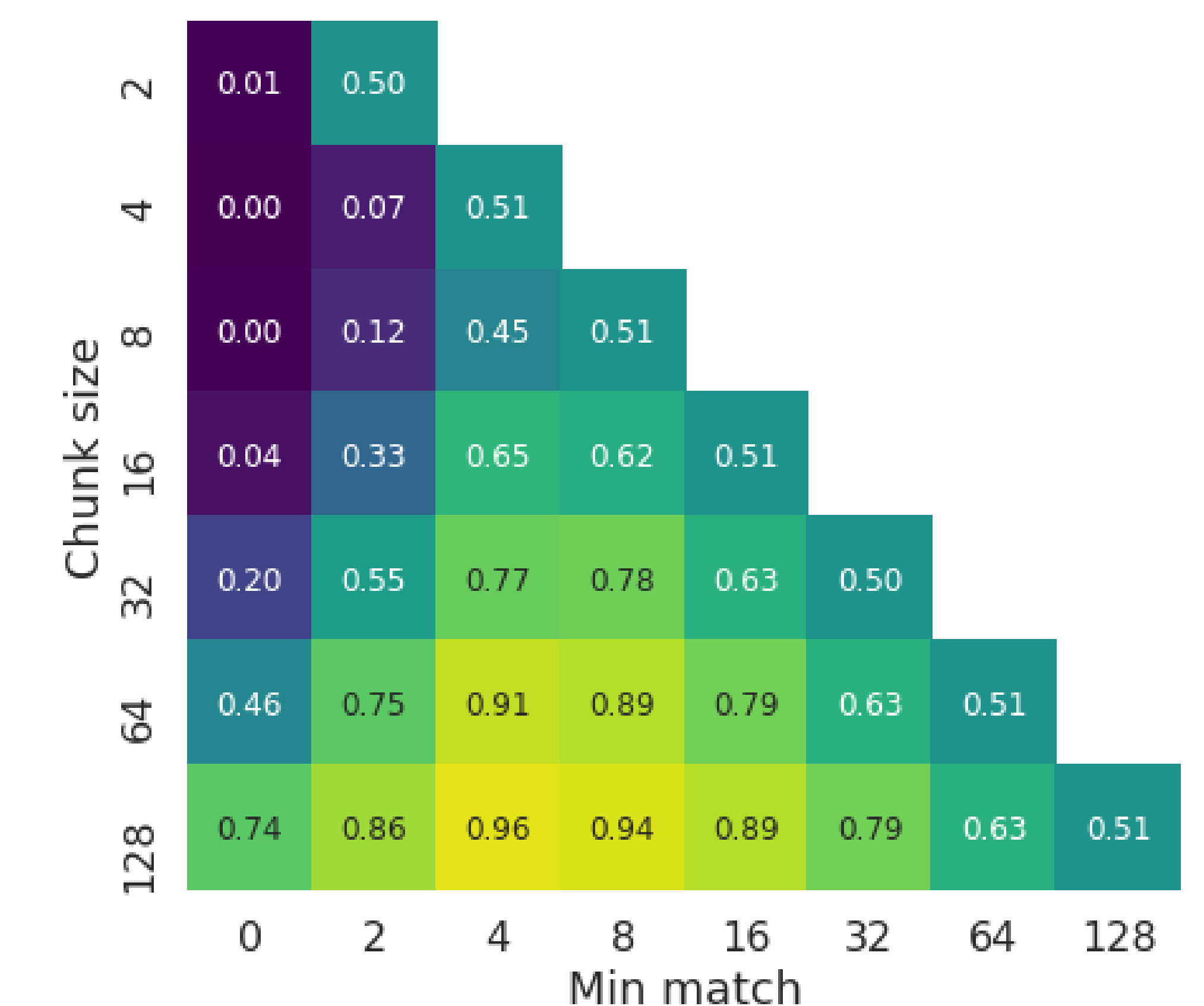- Strongly penalizes false recall.

Figure 7: Recall performance for different models.

Summary

- Shared situation model enhances ISC[4].
- Large chunks are good, which is consistent with evidence showing hippocampus saves episodic memories at event boundaries[1, 2, 3].
- Speed-accuracy trade-off on min match.

Future directions:

- How does the optimal rule change w.r.t. the penalty on false recalls?
- Explore benefits of "retrieval-on-demand".
- Implement biologically realistic hippocampus.

References & Acknowledgement

[1] Ben-Yakov A., & Dudai, Y. (2011). J Neurosci
[2] Ben-Yakov A., Eshel, N., & Dudai, Y. (2013). J Exp Psychol Gen
[3] Ben-Yakov A., & Henson, N. (2018). biorxiv.
[4] Chen, J., et al. (2016). Cereb Cortex

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