Flexible updating of hippocampal representations guides multi-step prediction

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Introduction

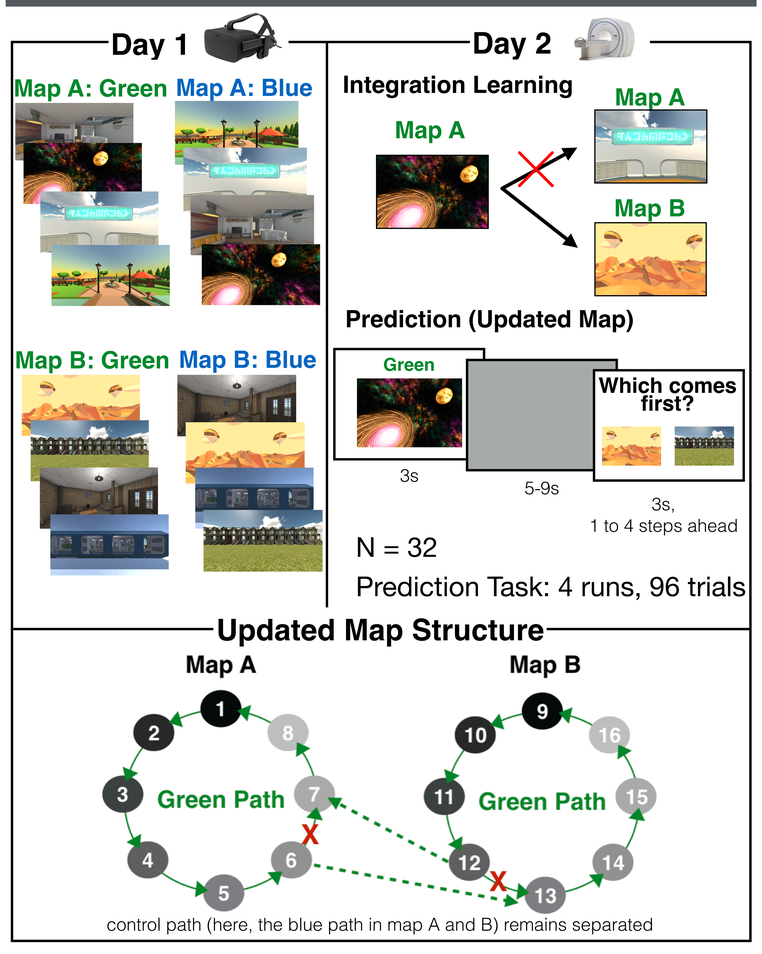
Internal models are useful for making predictions about future events[1]. Updating memories when we learn new information enables flexible behaviour[1,2].

The hippocampus flexibly integrates representations of discrete episodes[3,4], but our daily experiences tend to be temporally extended.

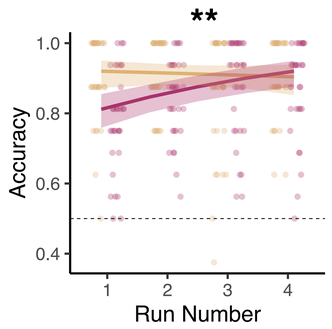
How does new learning update neural representations of temporally extended sequences?

How does this support flexible updating of predictions over multiple timescales?

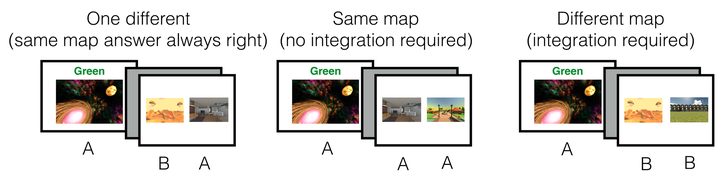
Experimental Design

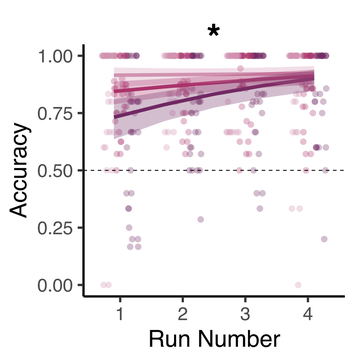


Behavioural Updating of Multi-Step Predictions



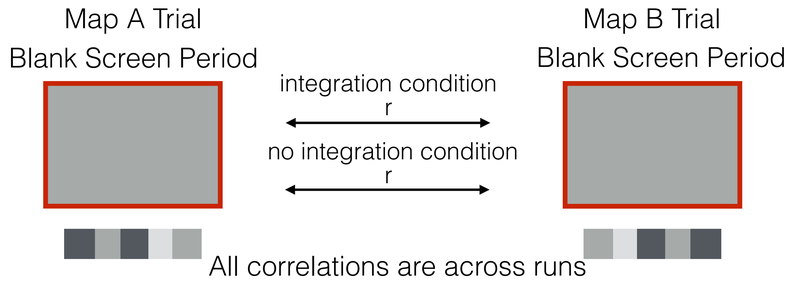
Participants immediately updated predictions to reflect the integrated map structure, but also improved over time, suggesting both rapid and gradual updating.



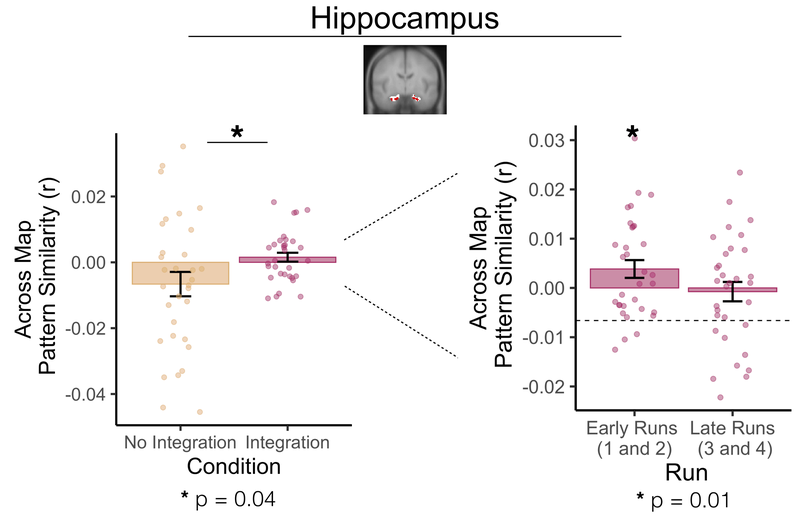


Improvement was greatest for trials that required successful integration.

Neuroimaging Analyses

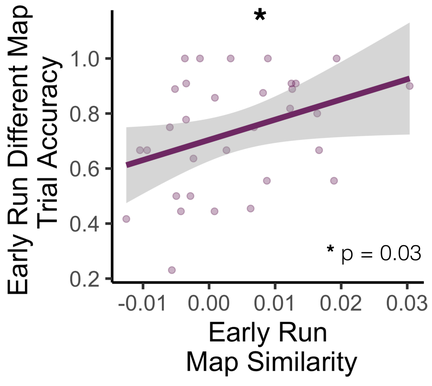


Rapid Hippocampal Updating of Map Structure



In hippocampus, pattern similarity across maps was greater for the integration vs no integration condition. This difference was driven by an increase in across map pattern similarity for early runs, suggesting rapid updating of the entire map structure.

Hippocampal Representations Predict Behavior



In the hippocampus, rapid updating of across-map activity patterns was related to more accurate predictions—especially predictions that require integration.

Summary

After learning new information, memory for temporally extended sequences are rapidly updated, and then continue to improve with time and experience. Such rapid updating is reflected in hippocampal representations of the entire sequence structure. Rapidly integrating sequence representations supports behavioural updating when making anticipatory judgements.

References

[1]Momennejad (2020). Learning Structures: Predictive Representations, Replay, and Generalization, *Current Opinion in Behavioral Sciences, 32*, 155-166
[2]Epstein et al. (2017). The cognitive map in humans: spatial navigation and beyond. *Nature Neuroscience, 20, 1504–1513*
[3]Schlichting et al. (2015). Learning-related representational changes reveal dissociable integration and separation signatures in the hippocampus and prefrontal cortex, *Nature Communications*, 6
[4]Cohn-Sheehy et al. (2022). The hippocampus constructs narrative memories across distant events, *Current Biology, 31, 4935-4945*