Graded Clustered Reactivation during Declarative Memory Retrieval: Evidence from MEG Recordings

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Overview

- How do humans retrieve interconnected information?
- Is retrieval supported by sequential replay or simultaneous reactivation?

Retrieval is enabled by reinstatement of activity patterns that initially encoded the information. Two mechanisms have been observed: sequential replay or simultaneous reactivation of relevant items [1].
We investigated these mechanisms using a graph learning paradigm. First, we let participants learn triples taken from a hidden graph structure. Using a previously recorded localizer task, we extracted patterns of the individual items and looked for similar patterns during cued retrieval using brain decoders.
We found that participants simultaneously reactivate related items, with item reactivation strength corresponding to distance on the graph. Participants with worse memory performance showed a stronger tendency to replay sequentially. In line with previous studies [1] we postulate that better memory performance shifts retrieval from sequential replay to clustered, simultaneous reactivation.

Experiment

- 30 participants, 10 visual items, MEG recordings
- Task: Learn sequential triplets with hidden graph structure
- Short consolidation (8 minutes)
- Cued retrieval of triples

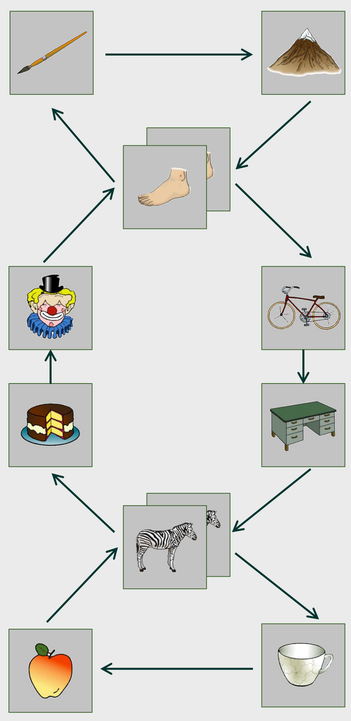
Tasks (in MEG)

1. Localizer task

Extract MEG patterns of stimuli using decoders

2. Graph Learning

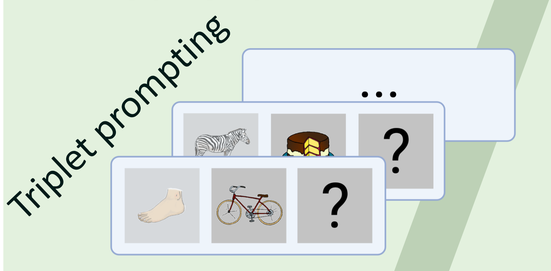
Hidden graph structure



3. Consolidation

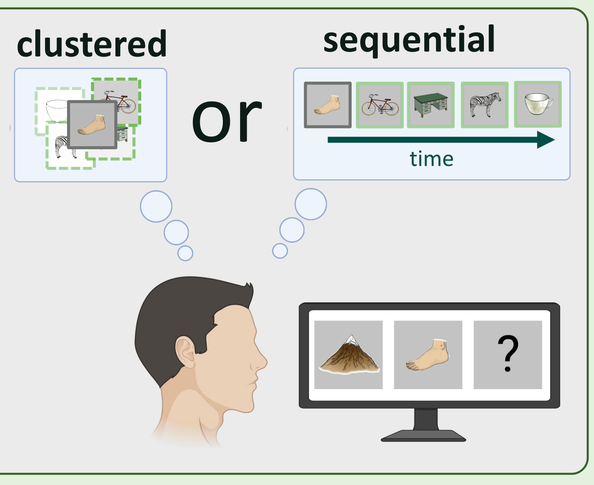
8 minutes
Resting State

4. Retrieval



Find patterns of stimuli during cued retrieval using decoders

clustered or **sequential**

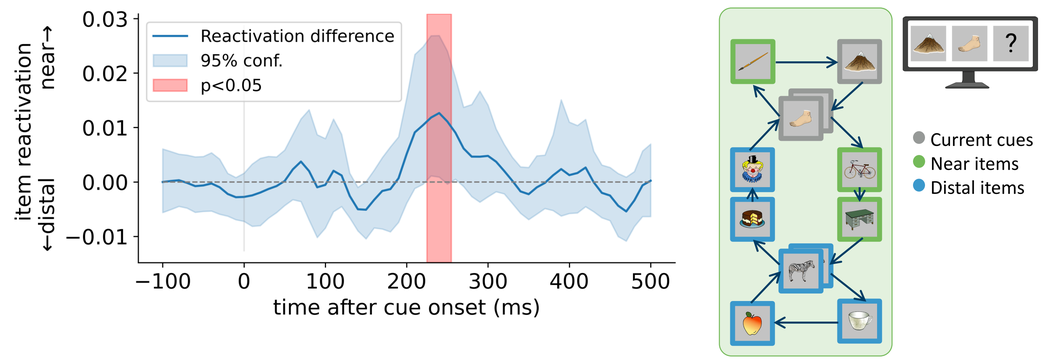


Analysis

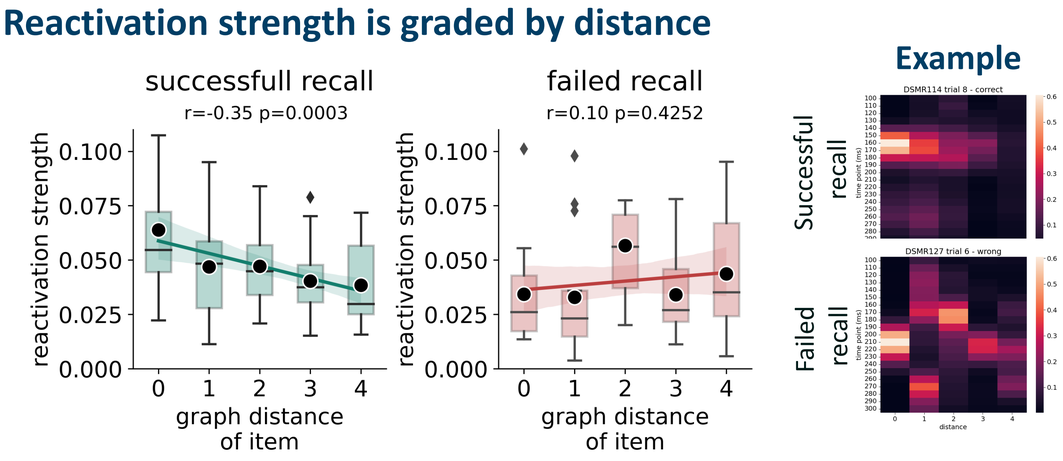
- Extract patterns of items from MEG sensor space
- Train brain decoders with these patterns (Logistic Regressors)
- Search for patterns during retrieval
- Are items reactivated in sequence or simultaneously?
- Use Temporally Delayed Linear Modelling [2] to look for sequential replay of stimuli given the graph transitions at different time lags
- Use raw classifier probabilities to assess simultaneous replay

Results

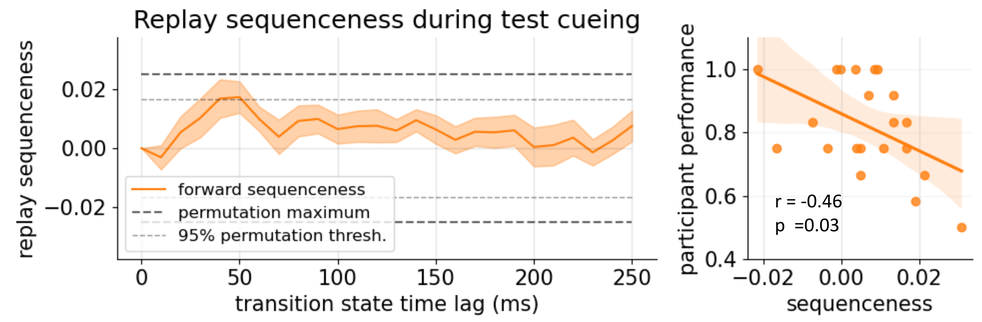
Near items are stronger clustered reactivated than distal items



Reactivation strength is graded by distance



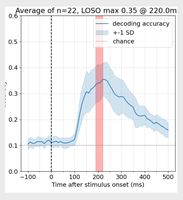
Tendency to replay when memory performance is low



What we found out

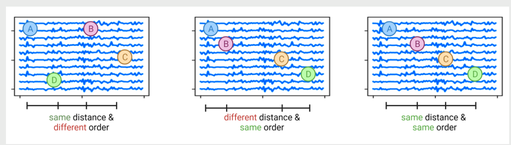
- Successful retrieval is supported by clustered reactivation of items near on graph
- Reactivation strength of individual items is graded by graph distance
- Additionally, sequential replay is found at around 40-50ms in forward direction, but is mainly related to worse memory performance
- Interpretation: With increasing performance, retrieval shifts from sequential replay to clustered, simultaneous reactivation

Method details



Decoder Training
- Logistic Regression with LASSO
- Input: Raw Sensor data of 10 ms
- Peak decoding performance: ~35%
- Range: 30-60% per participant
- Left: cross validated accuracies

TDLM measures if decoded reactivation is in same order and equidistant to each other using a general linear model for a specific time lag



Literature

[1] Wimmer et al. (2020) Episodic memory retrieval success is associated with rapid replay of episode content. Nature Neuroscience.
[2] Liu et al. (2021) Temporally delayed linear modelling (TDLM) measures replay in both animals and humans. eLife.

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