Parametrically scalable memory cueing using multiple object tracking

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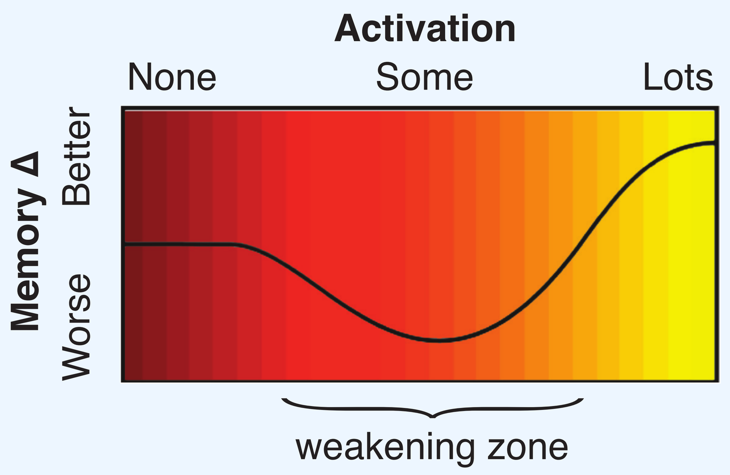
Introduction

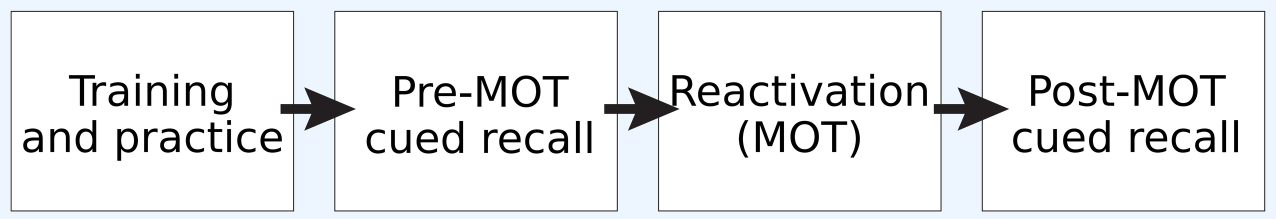


- According to the non-monotonic plasticity hypothesis (Newman & Norman, 2010), memories are strengthened and weakened by full and partial activations, respectively.
- Our recent work has supported this idea; for example, we observed that brief cuing of scene memories causes those memories to be partially activated and subsequently weakened (Poppenk & Norman, 2014).
- In that experiment, we were able to control the extent to which memories were reactivated, as measured by an fMRI pattern classifier, by altering the duration of cue exposures embedded in a stream of words monitored by participants.
- This control was imprecise, because there was no guarantee that participants would notice briefly presented cues (let alone recall the studied associate).

Experiment overview

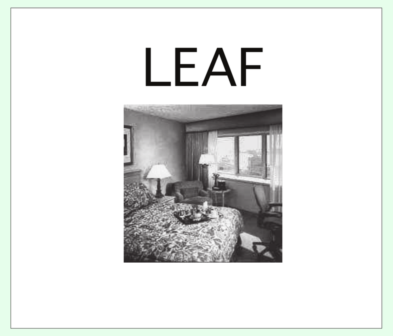
We attempted to create an experimental design with both reliable and parametrically scalable memory recall by incorporating a multiple object tracking (MOT) task: *P*s tracked target dots while – at the same time – deliberately attempting to visualize a cued associate and reporting on their success (see middle column for task details). By modulating the difficulty of the MOT task, we attempted to disrupt this cued visualization to differing degrees, predicting that doing so would weaken memory to differing degrees.

Organization of tasks



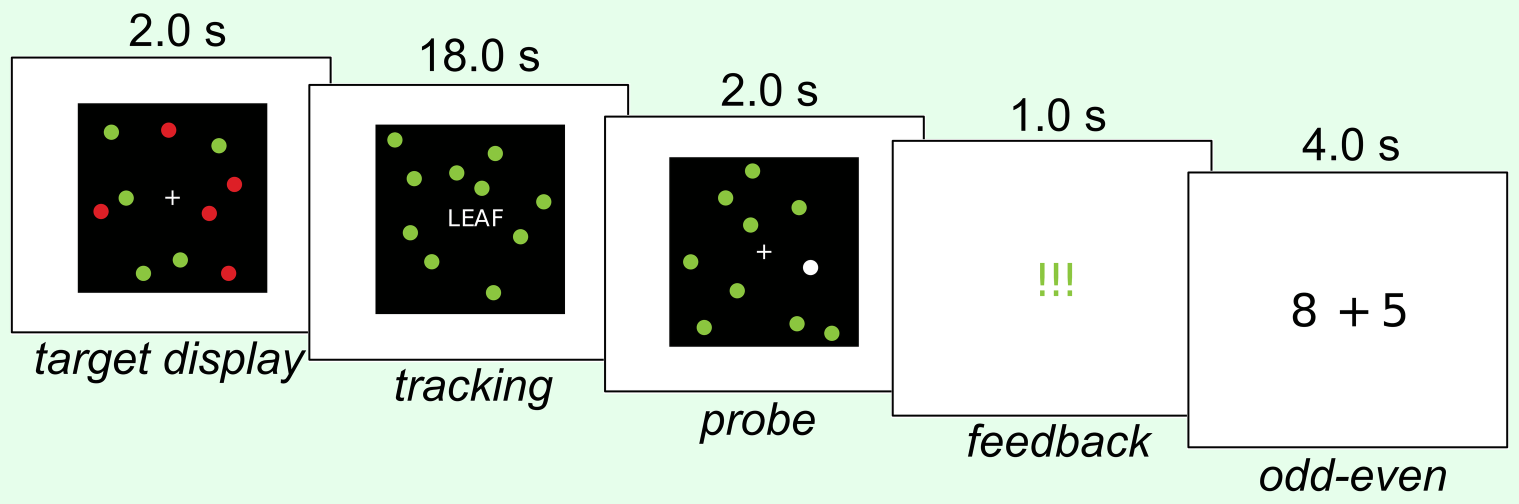
- Present word-scene pairs for study.
- Cue memories by different amounts by varying difficulty of a multiple-object tracking (MOT) task.
- Examine impact of cuing on memory by measuring:
  - change in memory strength before and after
  - change in fMRI classifier readout before and after.

Training and practice



- *P*s: 22 healthy adults (16 F, mean age 20.5 years).
- *P*s learned 46 arbitrary word-scene associations.
- *P*s were familiarized with other words.
- We identified the MOT speed that yielded 85% dot-tracking accuracy in each participant.

MOT memory reactivation (fMRI)



- *P*s tracked 1 or 5 targets for 18s of motion, then decided whether a probe dot was one of the targets.
- To calibrate difficulty for *P*s, speed of dot motion was set to the speed yielding 85% accuracy in a pre-experiment session.
- *P*s simultaneously visualized the associate of a central cue throughout the trial (instructions: this is secondary to dot-tracking).
- But, on half of trials, the cue was familiar but not a scene associate (instructions: no visualization required).
- *P*s reported on visualization with key-presses throughout each trial.

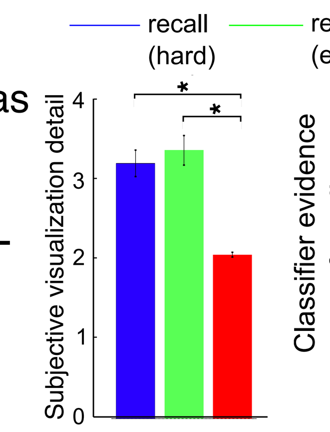


Fig. 1. Greater subjective detail was reported behaviourally for recall trials than no-recall trials during MOT, P<0.05.

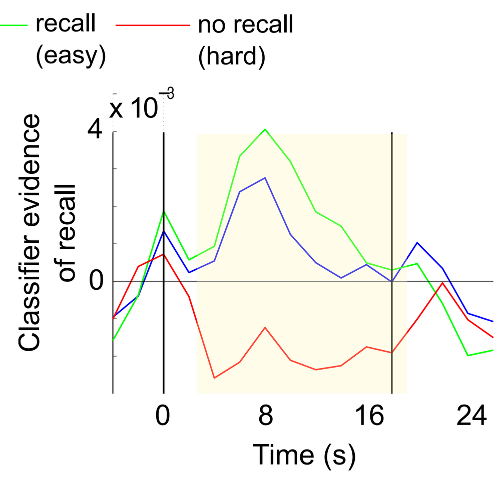
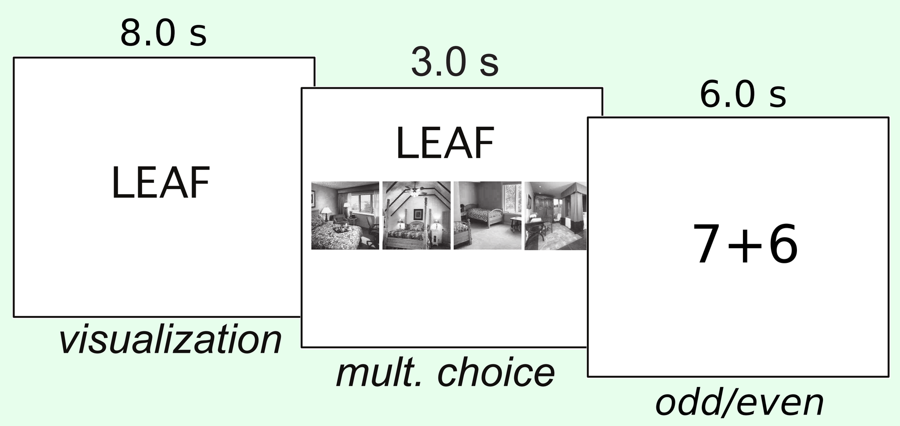


Fig. 2. This pattern was also found in classifier output, which also showed more evidence of recall in easy than hard trials during MOT, P<0.05, average signal from HDR-adjusted visualization window (yellow).

Classifier training (fMRI)

- Face-scene classifiers were sensitive to dot motion, confounding our typical neural measure of recall.
- We developed an alternative classifier trained on 16 MOT trials in which *P*s visualized scenes vs. 16 others in which they did not.
- We wanted the classifier to track scene recall, not dot-task difficulty, so we orthogonally varied MOT difficulty (1 MOT target = *easy*; 5 MOT targets = *hard*). We hoped to train the classifier to "attend" to scene recall and ignore dot-task difficulty.
- We applied a feature-selection mask consisting of ROIs identified in meta-analysis of episodic memory retrieval (Spaniol et al., 2009).
- Ridge regression classifier; λ=1; 8 xval folds (mean accuracy = 0.58).

Pre- and Post-MOT cued recall (fMRI)



- *P*s deliberately visualized scenes cued by their word associates, then selected the associate among lures (multiple choice).
- Comparisons across the tests measured impact of MOT reactivation on later memory.
- We investigated classifier estimates of memory retrieval to investigate possible implicit effects of reactivation during MOT.

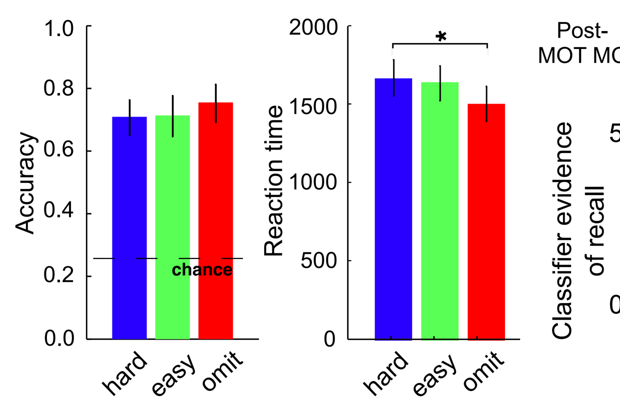


Fig. 3. Items omitted from MOT were numerically more accurate (left) and faster (right) than those visualized in MOT.

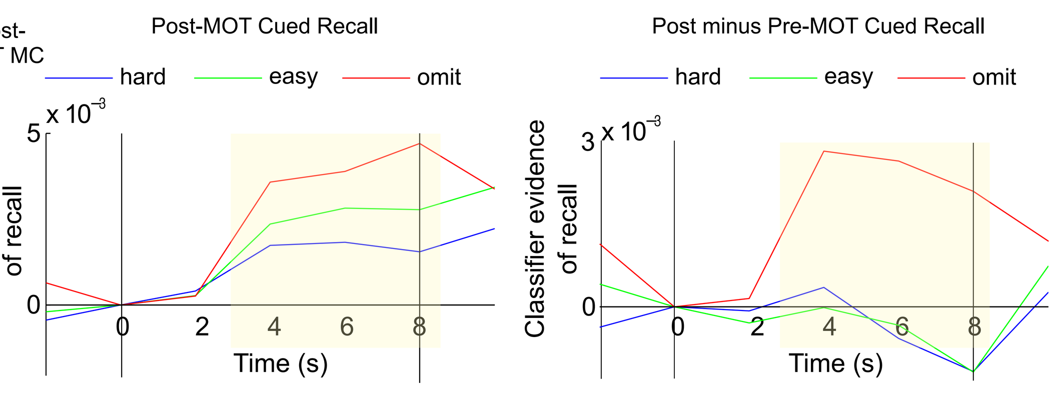


Fig. 4. Items omitted from MOT showed significantly more evidence of classifier reactivation than those visualized during MOT, P<0.05, average signal from HDR-adjusted visualization window (yellow).

Discussion

- Retrieval can be successfully detected during an MOT task.
- Adjusting difficulty parameters of MOT influences cued recall.
- Cued visualization during MOT reduced later memory recall, consistent with the competition-dependent learning hypothesis.
- As speed and number of targets are thought to reflect the same difficulty parameter in MOT (dot collisions), this suggests speed can be used parametrically to exert better control over memory reactivation, and hence, better test effects of the non-monotonic plasticity hypothesis.

Specific future directions

- Relate MOT memory activation to behavioural memory data
- Adjust distraction levels based on real-time fMRI decoding of recall
- Explore links to eye movement desensitization and reprocessing (EMDR).

References & Acknowledgements

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