Deactivation of Items in Working Memory Can Weaken Long-Term Memory

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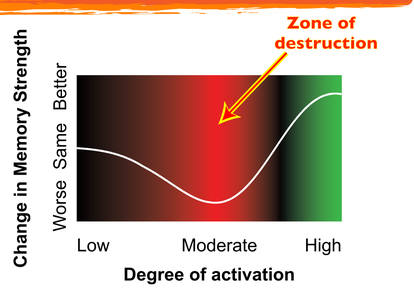
1 Introduction: Nonmonotonic Plasticity

Hypothesis: the relationship between memory activation and learning is **nonmonotonic**



If a memory is strongly activated, it gets **strengthened**

If a memory has very low activation (or none at all), nothing happens

If a memory activates to a moderate degree, it gets **weakened**

This nonmonotonic relationship is predicted by computational models of learning (e.g., Bienenstock, Cooper, & Munro, 1982; Norman, Newman, Detre, & Polyn, 2006)

The nonmonotonic pattern has been found at the synaptic level (post-synaptic potential: Artola et al., 1990; post-synaptic Ca2+ concentration: Hansel et al., 1996)

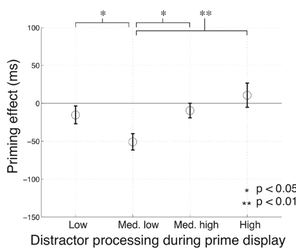
We want to see if this pattern occurs at the level of **memory representations**

2 Prior Work: Newman & Norman (2010)

Newman & Norman set out to test the nonmonotonic plasticity hypothesis using a negative priming paradigm

Negative priming effect: Ignoring a distracting stimulus makes you slower to respond to it later (Tipper, 1985)

According to the nonmonotonic plasticity hypothesis, moderate activation of the distractor should weaken the distractor, leading to negative priming



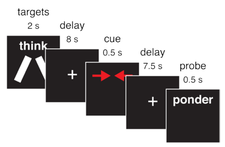
Approach: Use pattern classifiers to track activity of the distractor. Relate this neural measure of distractor activity to priming effects.

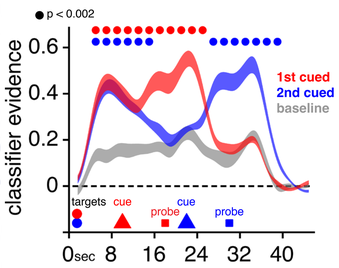
Results (shown at right) fit with the nonmonotonic plasticity hypothesis.

3 Background: Modified Sternberg Task

Oberauer (2001) demonstrated the working memory unloading effect: You are faster to respond to a memory probe if given enough time (~ 1 sec per item) to remove your attention from a subset of items in working memory

Lewis-Peacock, Drysdale, Oberauer & Postle (2011) adapted this task for fMRI to test the hypothesis that unattended items in working memory become neurally **deactivated**





Approach: Use pattern classifiers to track sustained activity of two items being held in working memory. Assess neural fate of the uncued item

Results (shown at left) demonstrate that uncued items in working memory are deactivated, but can be reactivated, and are not forgotten after a brief delay

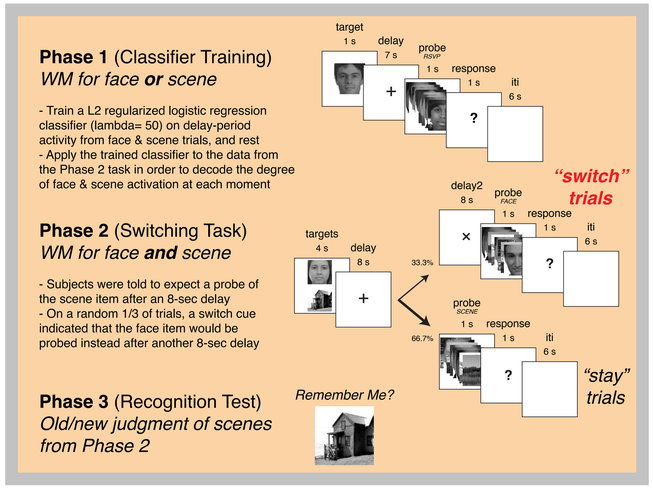
Question: Can deactivation of an item in working memory weaken long-term memory for that item?

4 Hypothesis and Experimental Approach

Key prediction: Forgetting will happen when an item gets "stuck" in the **moderate activity** range while it is being deactivated from working memory

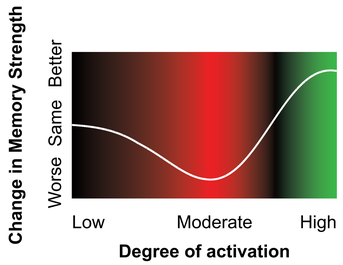
Strategy for testing this prediction: Use fMRI pattern classifiers to read out the deactivation of an item following the cue in a modified Sternberg task

Use this neural measure to predict recall of the item on a final memory test



Note: Stimuli were selected based on moderate memorability ratings, as assessed by a stimulus evaluation experiment conducted through Amazon.com's Mechanical Turk

Predictions from nonmonotonic plasticity hypothesis:



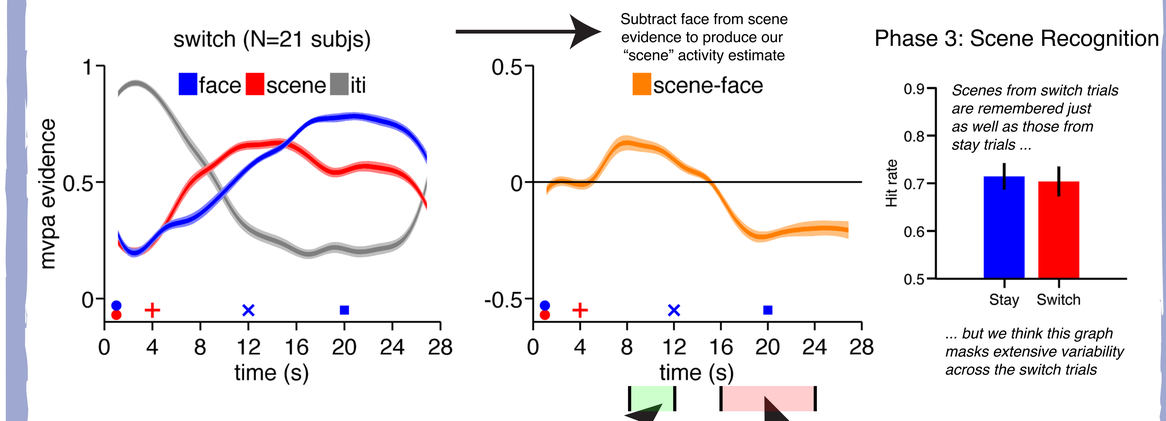
If the scene memory is deactivated efficiently, resulting in **low scene activity**, the memory will be mostly unharmed

If the scene memory gets "stuck" in the **moderate activity** range while it is being deactivated, this will lead to weakening of the memory, and (consequently) poor recognition memory for that item on the final test

Analysis Strategy:

1. Use a pattern classifier (applied to fMRI) to track scene and face activity throughout the switch trials
2. Measure how efficiently participants deactivate the scene on switch trials -- how much scene activity is there after the switch cue?
3. Relate this **residual scene activity** to subsequent memory for that scene (in the Phase 3 recognition test)

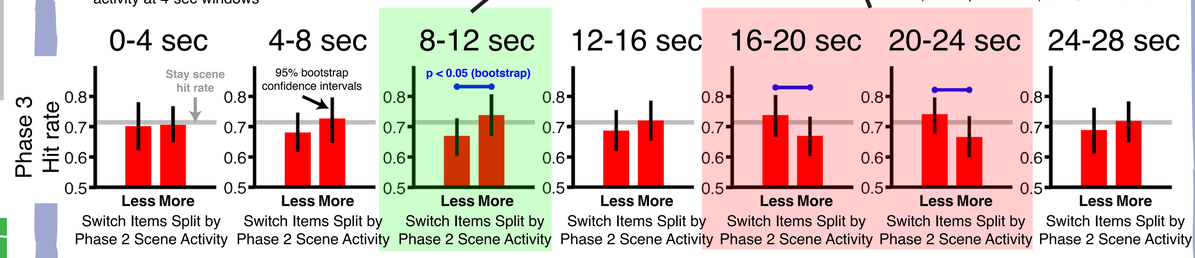
5 Measures of *Scene* Deactivation (in Phase2) and *Scene* Memory (in Phase 3)



6 Deactivation Predicts Memory: Post-Switch *Scene* Activity Leads to Forgetting

Analysis: Grab all switch trials from all subjects, and do a median split of Phase 3 hit rates based on Phase 2 scene activity at 4-sec windows

Bootstrapped the analysis to convert it from a fixed effect into a random effect. Sampled N=21 (with replacement) on 1,000 iterations



More scene activity before the switch predicts **better** memory

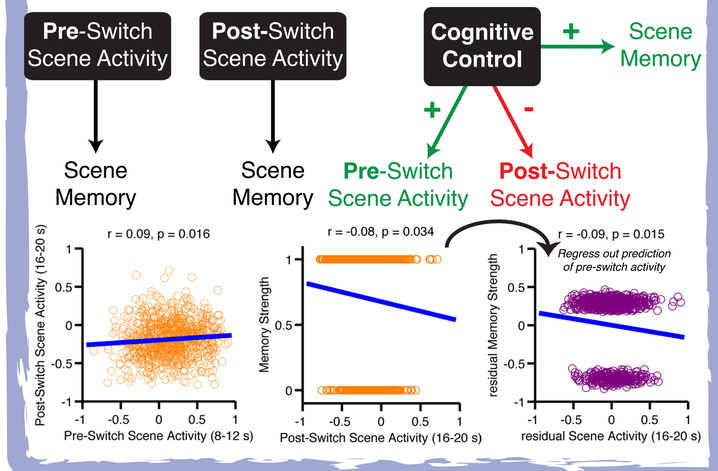
More scene activity after the switch predicts **worse** memory!

Counterintuitive result, but makes sense under the nonmonotonic plasticity hypothesis

7 Ruling Out an Alternative (Latent Variable)

Account #1?: Post-switch deactivation predicts memory independently of pre-switch activity

Account #2?: Cognitive control is a latent variable mediating effects on memory



8 Conclusions

1. More activation of the scene **after** the switch cue was associated with subsequent forgetting of that scene
2. Post-switch scene activity predicted forgetting independently of the pre-switch activity
3. This finding converges with others from our lab (Think-no think, Negative priming) to suggest that nonmonotonic plasticity is a **general principle** that applies across multiple domains

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