INVESTIGATING HOW MEMORY REPRESENTATIONS CHANGE AS A FUNCTION OF COMPETITION-DEPENDENT LEARNING AND SLEEP

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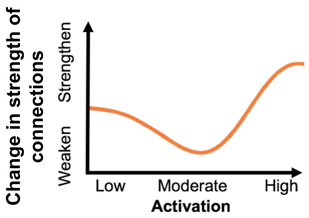
Background

When we retrieve a memory, competing memories can come to mind. **How does this competition drive plasticity and lead to representational change?**

The **nonmonotonic plasticity hypothesis (NMPH)** posits a U-shaped relationship between coactivation of competing memories and changes to their synaptic connections (Ritvo et al., *TiCS* 2019):



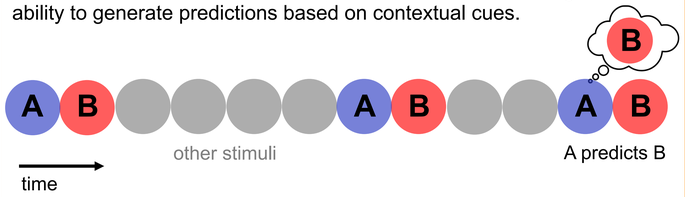
For example, if a competing memory (B) activates moderately when another memory (A) is retrieved, this will trigger weakening of the connections between A and B, leading to **neural differentiation** (i.e., a decrease in neural overlap).

Sleep is another opportunity to revisit competing memories. **REM sleep**, in particular, may be a focused period of revisiting competing memories in an interleaved manner (Norman et al., *Neural Networks* 2005). **Can we "mark" memories for representational change during learning, and implement those changes during sleep?**

Approach:

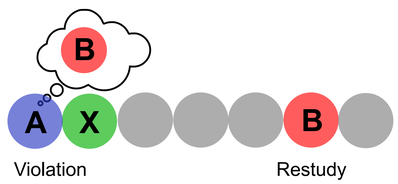
- Manipulate competition during awake learning
- Manipulate post-learning sleep
- Measure representational change post-sleep

We used a **statistical learning** paradigm to manipulate pre-sleep competition. One important consequence of statistical learning is the ability to generate predictions based on contextual cues.



According to the NMPH, if item B is moderately activated due to prediction, but fails to appear, the neural connections between A and B are weakened.

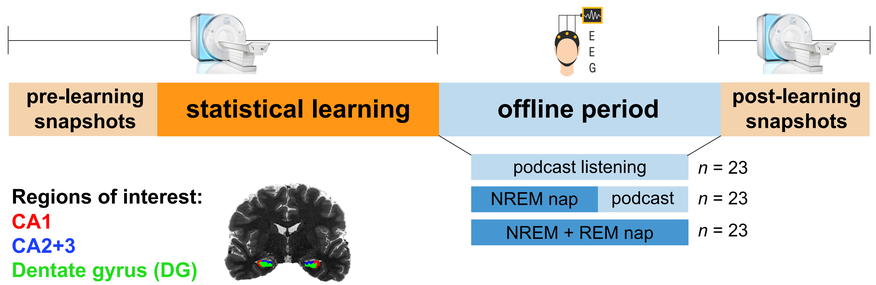
If B is later restudied in a different context, this activates new features not previously shared with A.



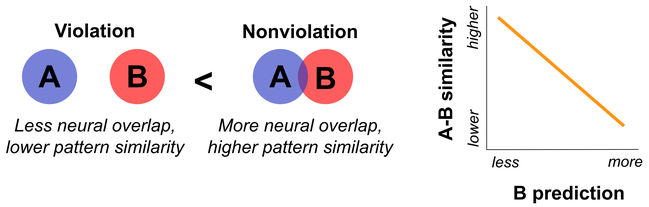
The result is violation-related neural differentiation: A and B representations are less similar than A-B pairs that did not undergo violation and restudy (Kim et al., *J Neuro* 2017).

Methods

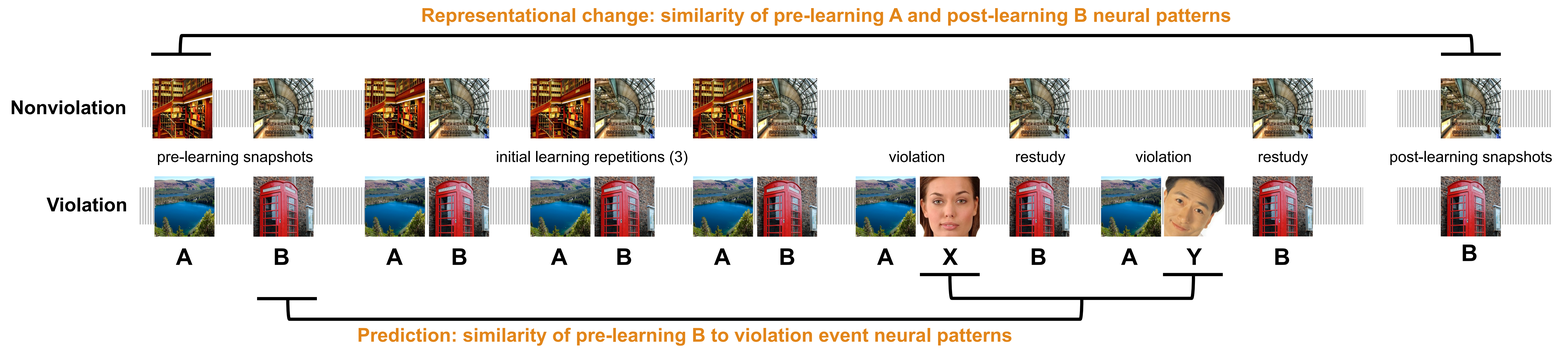
Study Overview



Representational change predictions:

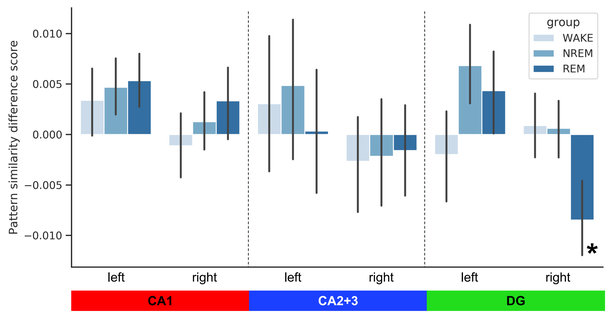


Task Design & Analysis



Results

Representational change: Do violation pairs become less similar than nonviolation pairs?

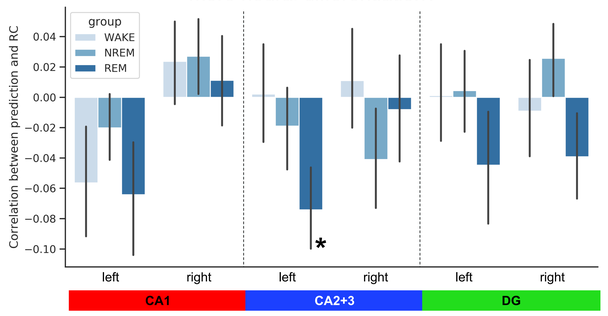


Plot shows the difference in average representational change between task conditions (violation – nonviolation). Negative values indicate more violation-related neural differentiation.

- Right DG: The REM group shows significant violation-related differentiation. Differences between groups are trending (*p*s < .07).
- Randomization analysis confirmed this effect is item-specific (*p* = .02).

Error bars are +/- 1 SEM

Relationship between prediction and representational change: Is stronger activation of B during violation events associated with more neural differentiation?



Correlations are computed within-subject in a pairwise fashion.

- Left CA2+3: The REM group shows the predicted relationship – more B prediction is associated with less representational similarity between A and B (i.e., more differentiation).
- Randomization analysis confirmed this effect is item-specific (*p* = .02).

Conclusions

All of the "movement" happens in the REM group:

- Item-specific, violation-related neural differentiation
- Some evidence that B prediction during violation events is related to differentiation
- This suggests a period of REM sleep can promote the plasticity instantiated by competition-dependent learning.

Next steps:

- Can we improve our neural patterns (e.g., using GLMsingle to derive single-trial estimates)?
- Test for a U-shaped relationship, rather than linear, between prediction strength and representational change (Wammes et al., *eLife* 2022)

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