Alternating study and retrieval practice leads to neural and behavioral differentiation of competing memory representations

Justin C. Hulbert[1], Kenneth A. Norman[1,2]

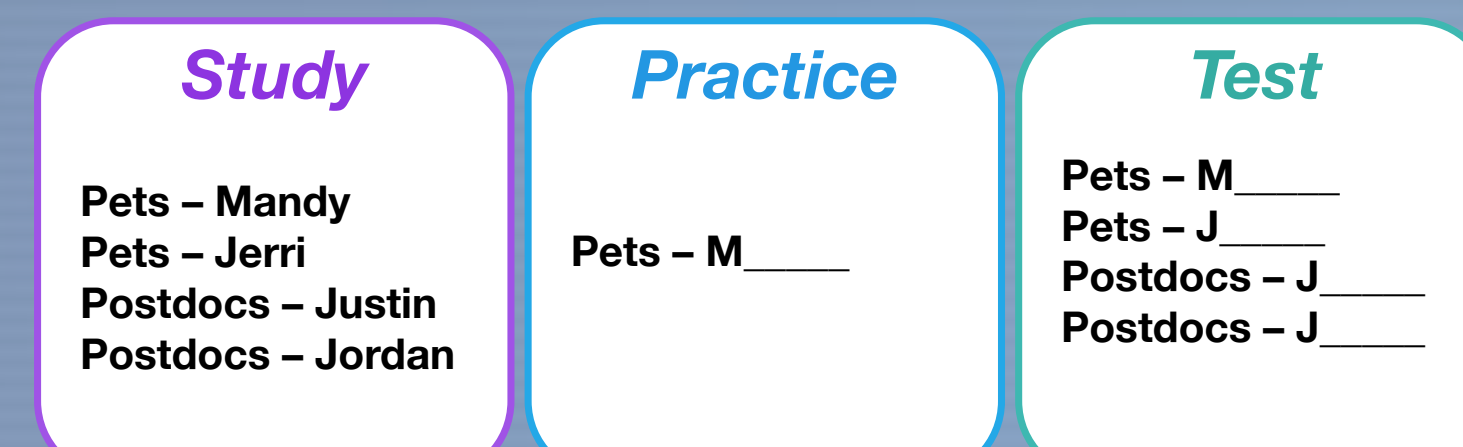[1]Princeton Neuroscience Institute; [2]Department of Psychology, Princeton University

Background

Retrieval-Induced Forgetting (RIF)[1]

- Selectively retrieving target memories inhibits subsequent memory for related competitors

Previously inhibited competitors benefit disproportionately from additional restudy opportunities[2]

RIF → Reverse RIF (revRIF)

We propose that[3,4]:

a) Overlapping representations set the stage for competition

b) Activation from selective retrieval practice spreads to linked competitor features

c) Weights linking target and competitor are weakened to reduce future competition
  - If tested now: RIF

d) Competitor restudy activates surviving representational features, activation spreads to other distinguishing features
  - Inhibitory interneurons enforce "set point" of neural activity in the network

e) Weights between these features are strengthened, stabilizing the representation
  - Differentiation reduces competition at retrieval, leading to better recall
  - If tested now: revRIF
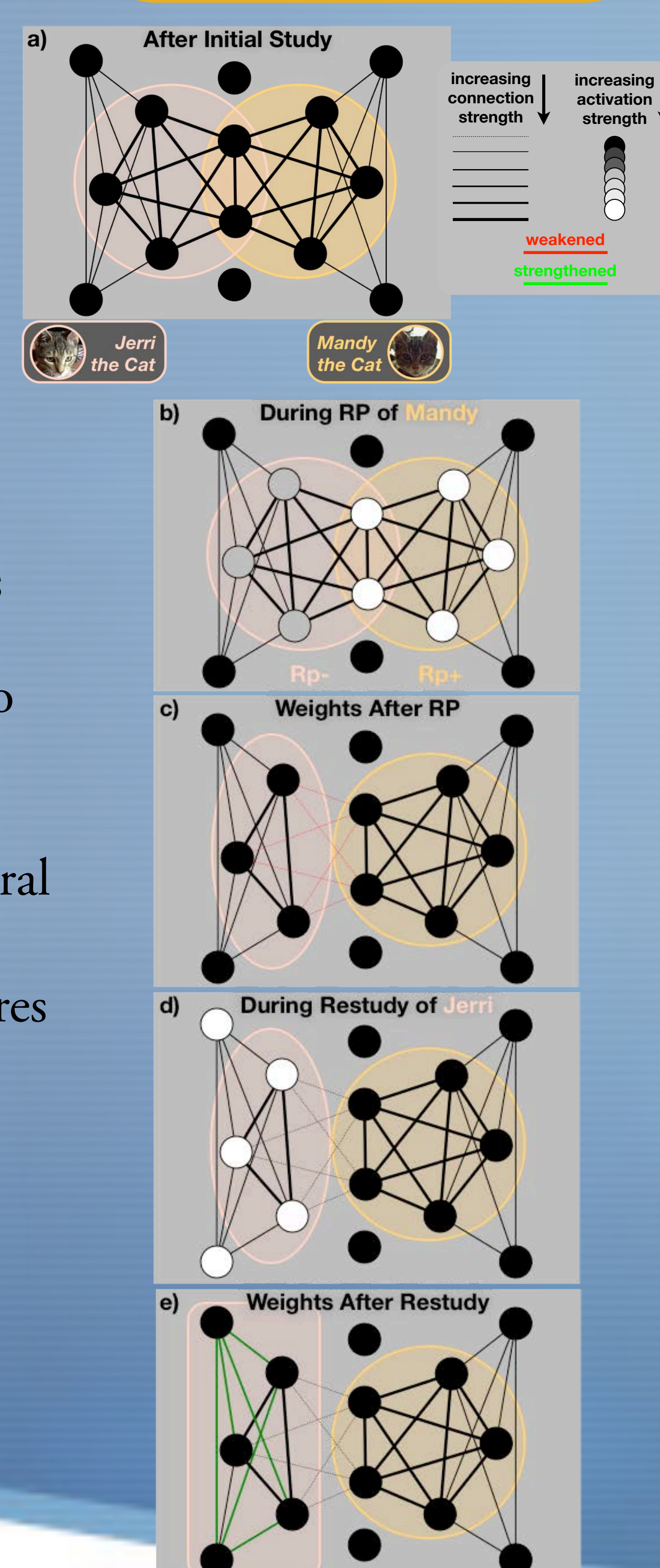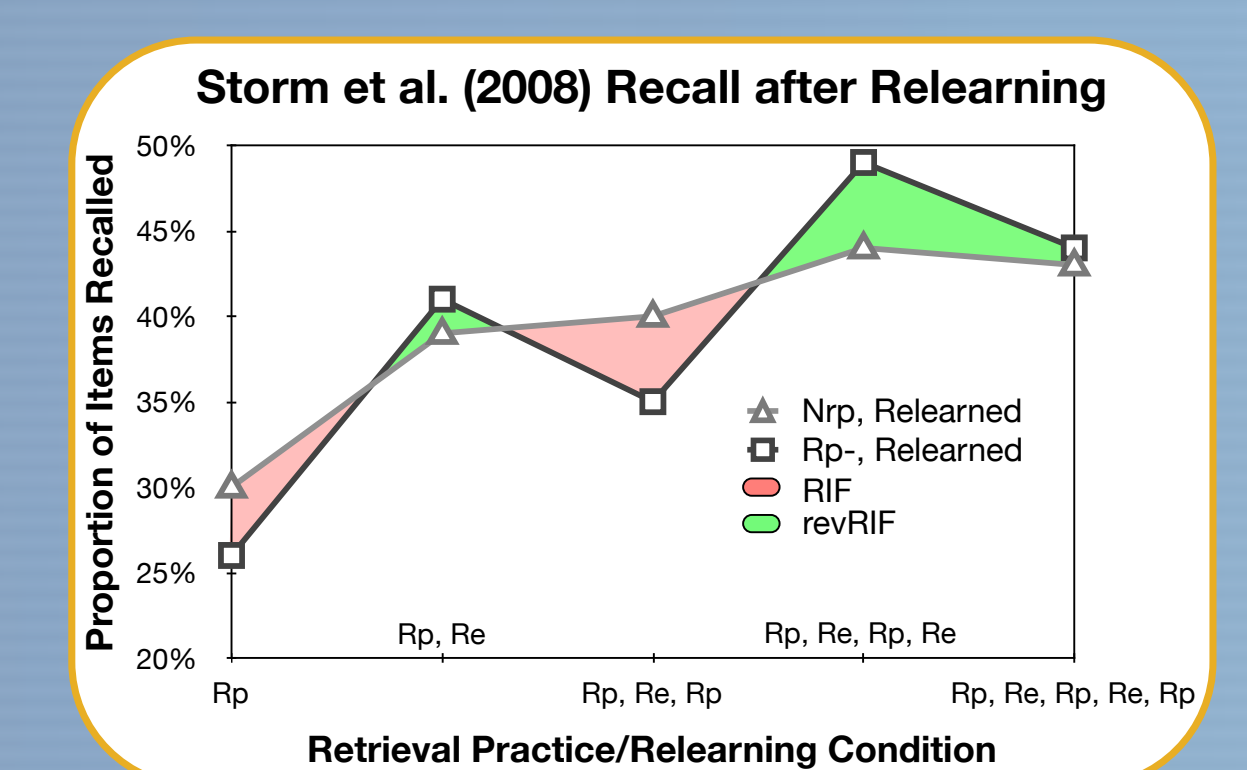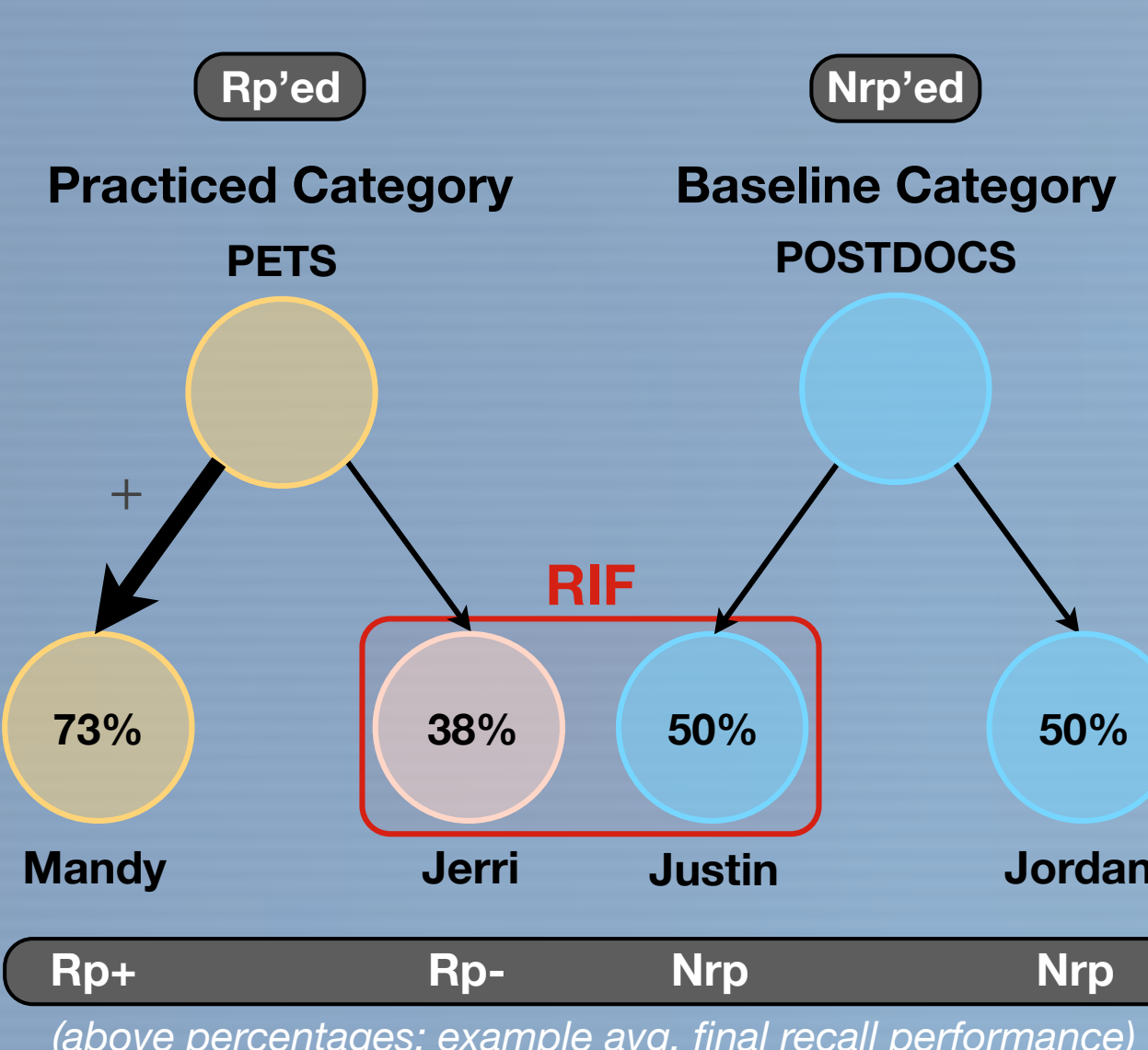
Predictions:

- Interleaved competitive retrieval practice and restudy should lead to:
  - revRIF for recall of picture-name pairs
  - Differentiation of hippocampal representations of targets and competitors, as measured by pattern similarity analysis[5,6]
- Across participants, the amount of hippocampal differentiation should predict the amount of revRIF

Methods

Stimuli

- 6 animal categories
  - Retrieval status counterbalanced
- 8 exemplars/category
  - Randomly assigned to condition
  - Randomly paired w/ low-frequency proper name beginning w/ category's 1st letter

Subjects

- N=24

Design

1. Pattern similarity benchmarking
   - Initial study
2. Retrieval practice with interleaved restudy
3. Pattern similarity re-acquisition
   - Passive restudy
4. Final cued-recall test

fMRI acquisition

- MTL-optimized scan sequence
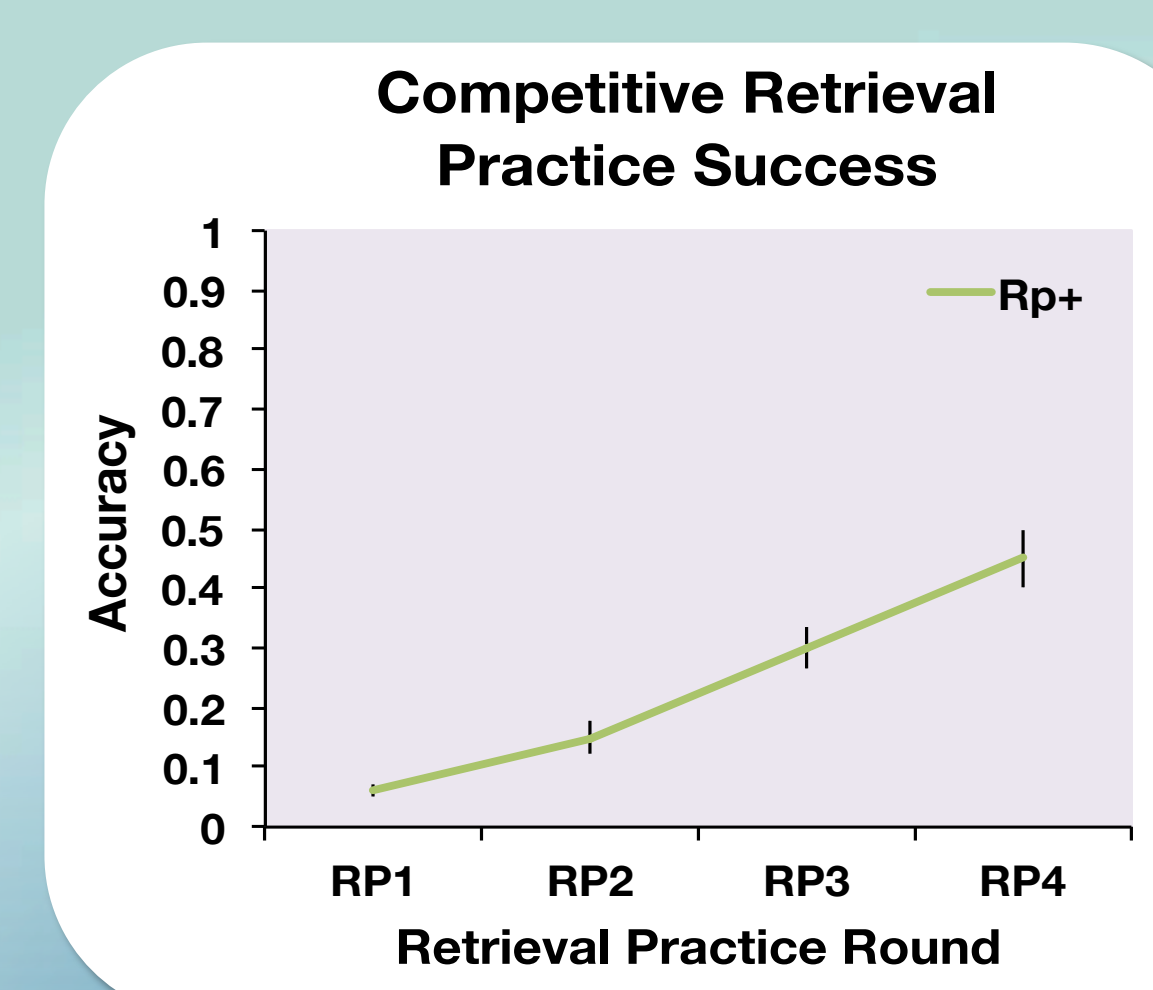 - Axial slices, oriented parallel to hippocampus
 - 2x2x3mm voxels

Results

Behavioral Results

Retrieval Practice Success

- Feedback retrieval trials (for Rp+ items) proved more challenging than the other trial types, as per design
- Retrieval practice success for Rp+ items increased across rounds


Final Recall Test

- Rp+ recall showed a standard facilitation effect above baseline
- Rp- recall was also significantly above baseline, replicating Storm et al.'s (2008) revRIF
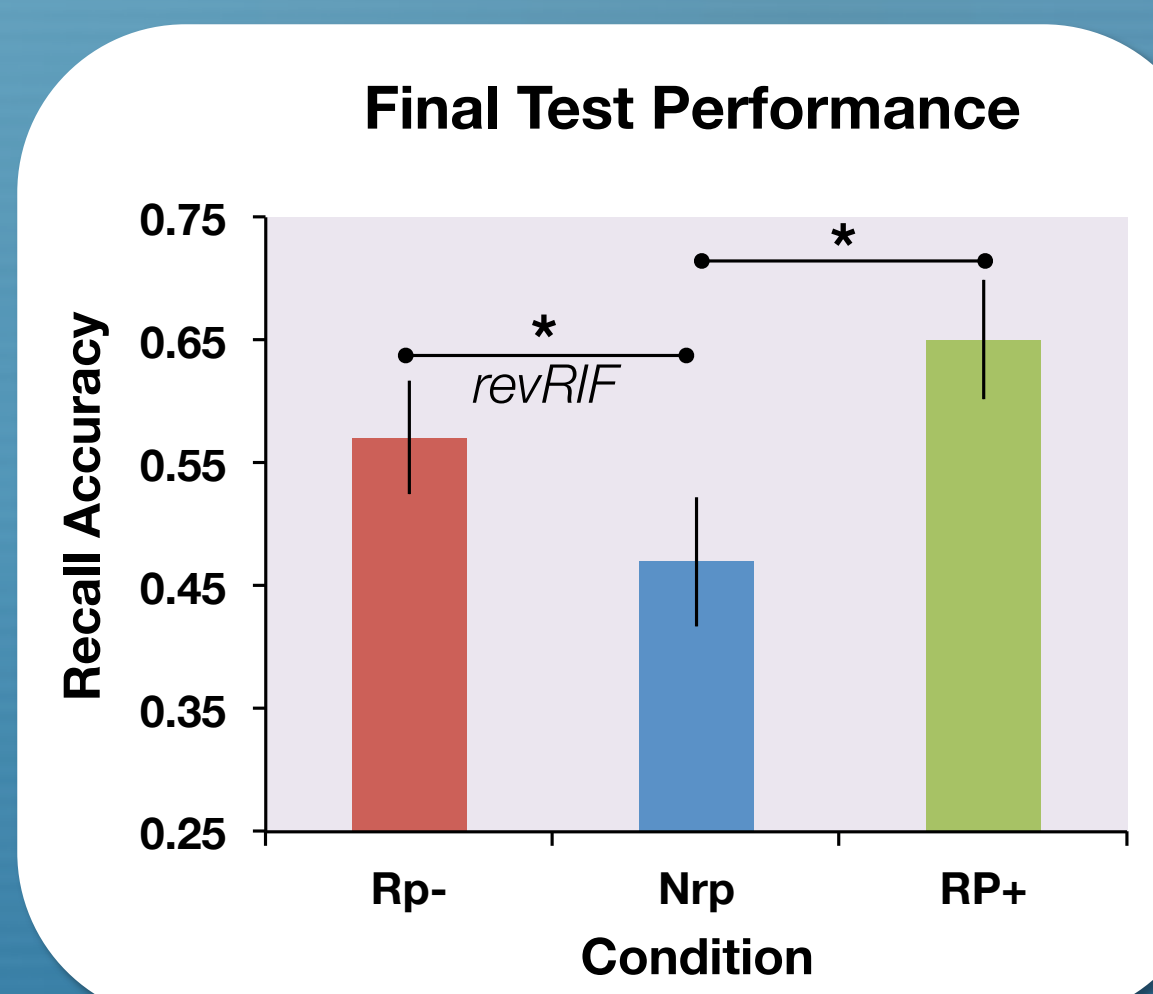
Neuroimaging Results

Pattern Similarity Analysis of Learning

- Assessed the correlation (similarity) of BOLD activity patterns across conditions and time points
- Determined whether the neural differentiation advantage for Rp'ed items predicted the size of the behavioral revRIF effect within a priori hippocampal ROIs

Neural Learning Score: $(N_2 - N_1) - (R_2 - R_1)$
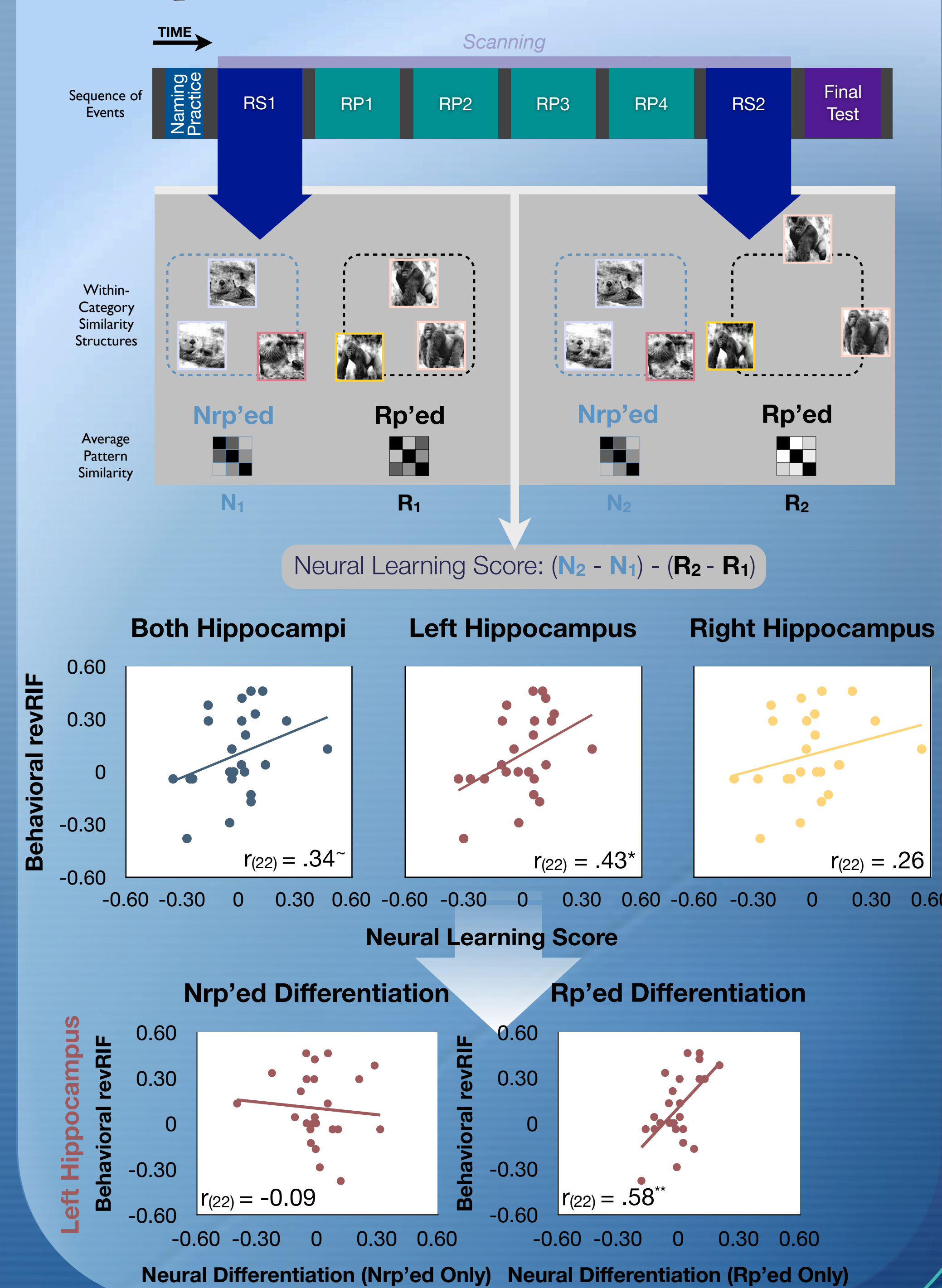
Conclusions

- As predicted by a neural network model of memory[3,4]:
- Interleaved competitive retrieval practice and restudy led to improved recall of competitors
- Differentiation in the left hippocampus predicted the magnitude of revRIF
- Without differentiation, learning would be a zero-sum process whereby strengthening one memory necessarily hurts competitors
- Differentiation contributes to a truly adaptive memory system[7] by allowing once-confusable memories to co-exist in an accessible state

References & Acknowledgements

1. Levy & Anderson (2002, TiCS)
2. Storm, Bjork & Bjork (2008, JEP:LMC)
3. Norman et al. (2006, Neural Computation)
4. Norman, Newman & Detre (2007, Psych Review)
5. Kriegeskorte (2009, Front. Neurosci.)
6. LaRocque et al. (2013, JoN)
7. MacLeod & Hulbert (2011, Chapter)

Corresponding author: hulbert@princeton.edu

284.06
III32