# Human Brain Activity as a Function of Memory Age from One Hour to One Month


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## Background

- Findings from animals and humans with hippocampal damage reveal that retrograde amnesia is temporally graded across hours to months.[1,2] Remote memory is relatively spared in comparison to information learned recently.
- In humans, recent and remote memory have been studied almost entirely with retrospective designs that investigate memory on a relatively long timescale (years to decades).
- These studies showed that some structures (e.g., the hippocampus), become less critical, while neocortical structures take on increasing importance.[3,4]
- Prospective designs[5] hold promise for controlling important variables that contribute to learning (e.g., the time of learning and the strength of learning and memory), and for assessing memory age on a timescale (hours to months) that can connect the human and animal literatures.

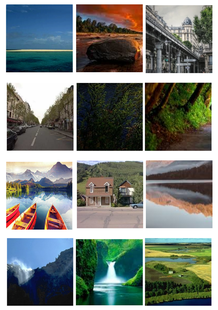
## Aims

1. Determine how retrieval-related brain activity changes as a function of Memory Age from 1 hour to 1 month (consolidation).
   - Analysis of Targets as a function of Memory Age: ANOVA vs. Power Function
2. Identify if retrieval-related brain activity associated with Memory Age reflects changes in behavioral measures that change as a function of memory age.
3. Identify if retrieval-related brain activity associated with Memory Age reflects re-encoding of targets.

## Methods

*Encoding Questions*

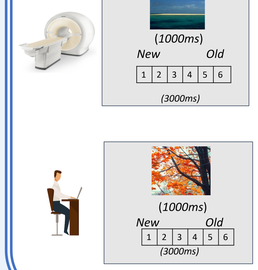
*"Does the photo remind you of a place you have been?"*
*"Is it easy to picture yourself in the photo?"*
*"Is this an everyday scene?"*




**Study Phases**

- 80 target scenes
- 80 target scenes
- 80 target scenes
- 80 target scenes

**Recognition Trial**




**Digit Baseline**

5
Even Odd
(2000ms)

**Test Phase**

**Recognition test**

- 240 target scenes (60 per condition)
- + 240 foil scenes

1 = definitely new
6 = definitely old

**Post-Scan Recognition test**

- 240 old foil scenes
- + 240 new foil scenes

## Results

**Participants**
N=21 (12 F)

Mean age:
28.6 ± 1.3 yrs

Mean education:
16.5 ± 0.4 yrs

### Behavioral Findings

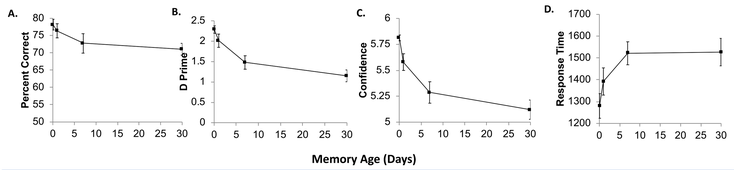



Fig. 1. Behavioral measures changed as a function of memory age. A. Percent Correct, B. Discrimination (D Prime), C. Confidence Level, and D. Response time.

### Aims 1 & 2: Brain activity as a function of Memory Age: Controlling for Behavior

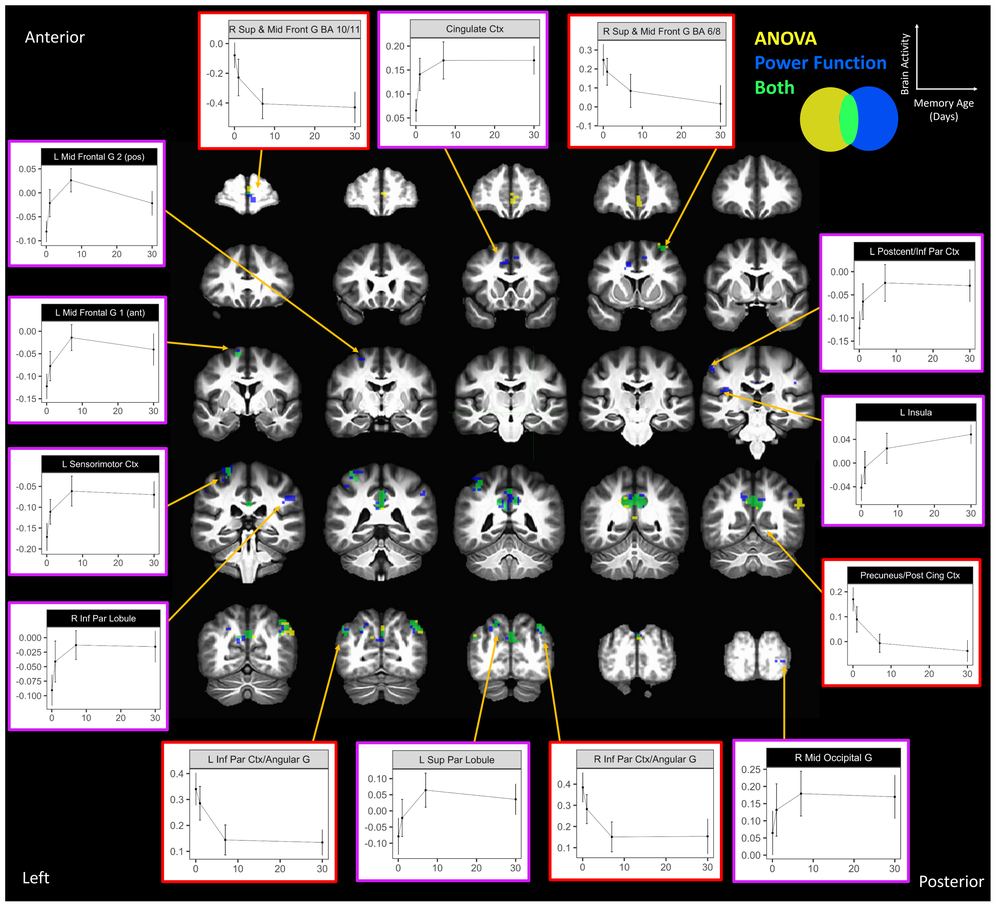



Fig. 2. Brain activity associated with targets as a function of memory age as identified by an ANOVA (yellow), by a power function (blue), or both (green). Black labels indicate region where activity did not reflect memory age after the effects of behavioral changes were minimized. Clusters corrected p < 0.05. Red graph: increasing monotonic relationship. Purple graphs: decreasing monotonic relationship.

### The Hippocampus and Memory Age

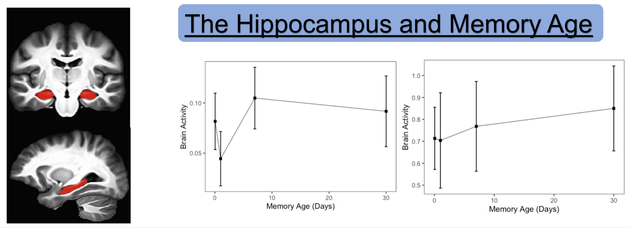



Fig. 3. Brain activity as a function of memory age for anatomical ROIs in the hippocampus (bilaterally). Left. Coronal and sagittal sections showing hippocampal ROIs. Center. Mean hippocampal activity associated with targets as a function of Memory Age. Right: Mean hippocampal activation as a function of Memory Age when the effects of behavioral changes have been minimized. Brain activity did not change as a function of memory age for either analysis (p values > 0.50).

### Aim 3: Encoding-Related Activity during Retrieval Test

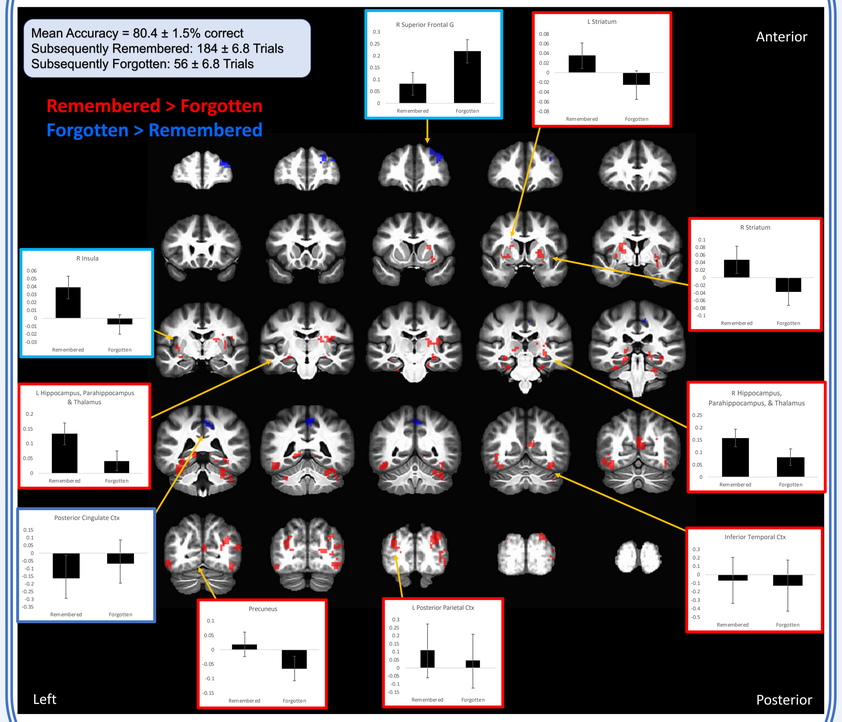



Fig. 4. Brain regions where activity was different for Subsequently Remembered vs Forgotten items (T-test). The 10 largest clusters from this contrast are shown (ETAC permutation p<0.05,0.005,0.001). Red clusters and graphs: Remembered > Forgotten. Blue clusters and graphs: Forgotten > Remembered.

## Summary

- Behavioral measures changed as a function of memory age from 1 hour to 1 month.
- Brain activity in the neocortex changed as a function of memory age and appears to follow a power function.
- When the effects of behavioral changes were minimized, activity in a subset of these brain regions no longer reflected memory age (left sensorimotor, prefrontal cortex, and posterior parietal cortex).
- Brain regions where retrieval-related activity reflected memory age did not overlap with regions where activity reflected successful encoding during the retrieval test.
- Activity in the medial temporal lobe reflected successful encoding during the retrieval test, but did not reflect memory age during retrieval.

## Conclusions

- The findings underscore the importance for controlling for behavioral changes when investigating memory consolidation, particularly across short study-test intervals.
- The findings in the cortex that increase with memory age are consistent with the concept that long-term memory reorganizes in the cortex through consolidation.

## Future Directions

- Conduct a functional connectivity analysis (generalized psychophysiological interaction analysis) to identify brain regions where connectivity with the MTL changes with memory age


### References

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### Acknowledgments

This work was supported by the Medical Research Service of the Department of Veterans Affairs (Award 5I01CX001375 to C.N.S.) and NIHM (R01 MH024600 to Larry Squire). We thank Du Xiang for assistance.