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Neural correlates of a working memory process that influences long-term memory formation

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Working vs Long-Term Memory

Baddeley & Hitch: Working Memory (WM)

Craik & Lockhart: Levels of Processing

WM-LTM Interaction

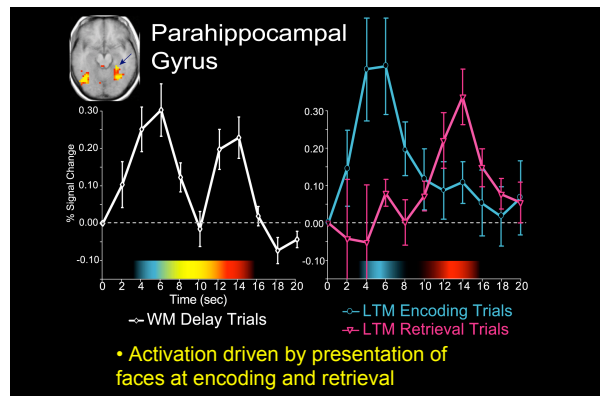
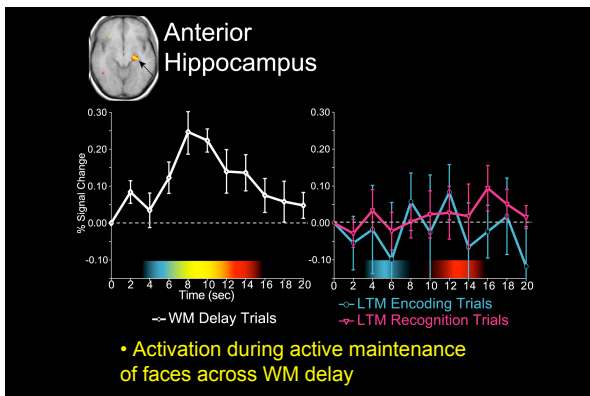
- Relationship between WM maintenance and LTM formation
 - Paul's talk
 - This talk (Ranganath, Cohen, & Brozinsky, in prep)
 - Davachi & Wagner (2001)
- Relationship between WM maintenance and LTM retrieval
 - Ranganath, Cohen, Dam, and D'Esposito (in prep)
 - Cabeza et al. (2001), Sakai & Passingham (2002)
- Relationship between LTM (knowledge/expertise) and WM maintenance (capacity/resolution)
 - Moore, Cohen, Trefethen, & Ranganath (preliminary data)
- All involve frontal-hippocampal interaction

Working Memory

LTM Encoding

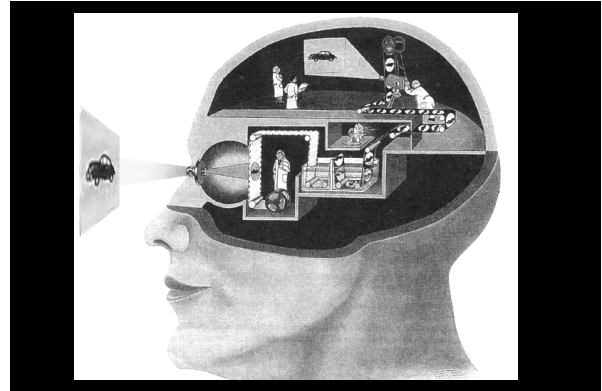
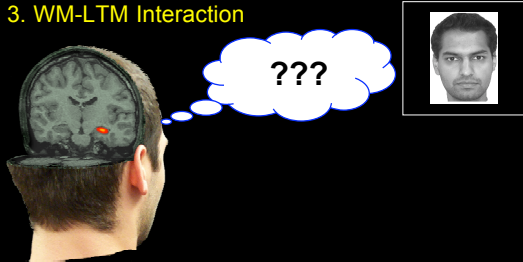
LTM Recognition

Ranganath & D'Esposito, 2001



Possible explanations for hippocampal activity

1. LTM Encoding
2. WM Maintenance
3. WM-LTM Interaction



Fractionating maintenance rehearsal

Short-Term Consolidation:

"the process of encoding information into durable storage"
 Jolicoeur & Dell'Acqua (1998) *Cognitive Psychology*

Refreshing:

"an operation that prolongs activation of just-activated representations"
 Johnson et al. (2002) *Psychological Science*
 Raye et al. (2002) *Neuroimage*

Item	Delay	Same Item (repeat)	New Item (read)							Blank
1450ms	550	• (refresh)		<	>	>	>			2000
		550	1400	600	1400	600	1400	600		



These WM processes are distinct from goal-directed processing of an item

Two-process model of rehearsal and LTM

Naveh-Benjamin and Jonides (1984):

- Two-stage Model of Maintenance Rehearsal
 - Early stage:
 - Processes required to retrieve/construct code for rehearsal
 - Relatively effortful
 - Contributes to LTM formation
 - Late stage:
 - More automatic/stereotyped
 - Minimal effect on LTM formation

Re-evaluating WM/LTM relationship

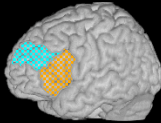


Re-evaluating WM/LTM relationship



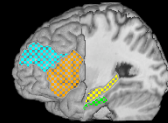
Two Experiments

1. Is there a distinction between early and late stages of rehearsal? Does early rehearsal stage disproportionately influence LTM formation?
2. What is relationship between brain activity associated with WM processes and LTM formation?
 - PFC: Dorsolateral (BA 9/46), Ventrolateral (BA 44,45,47)



Two Experiments

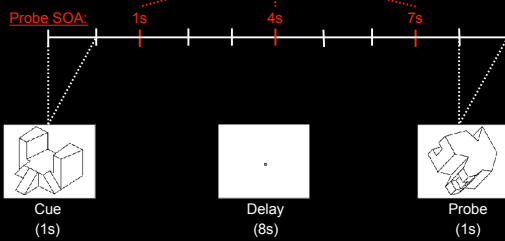
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2. What is relationship between brain activity associated with WM processes and LTM formation?
 - PFC: Dorsolateral (BA 9/46), Ventrolateral (BA 44,45,47)
 - MTL: Hippocampus, Perirhinal, Parahippocampal cortex



Behavioral Experiment

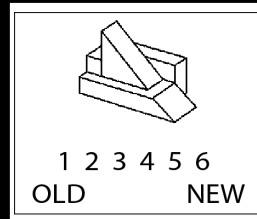
Distractor Task:

Count # of lines in this picture:



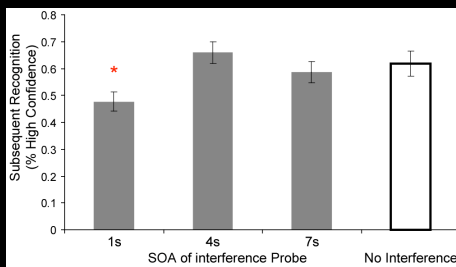
Behavioral Experiment

Surprise LTM Test



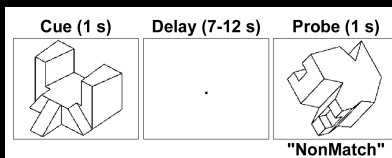
Hypothesis: Interference early in the delay period should impair subsequent LTM

Processing during early in delay period influences subsequent LTM

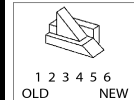


FMRI Experiment

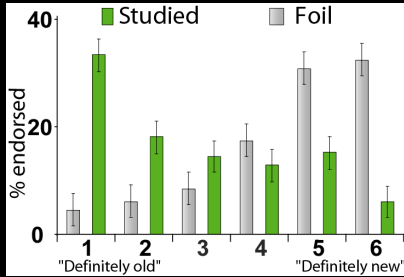
Scan Phase:
WM Task



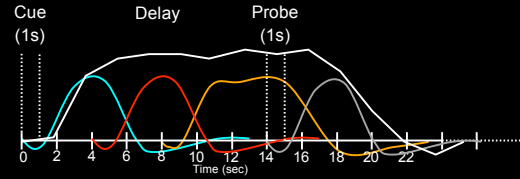
Post-Scan:
Surprise LTM Test



Post-Scan Recognition Performance



fMRI Analysis Method



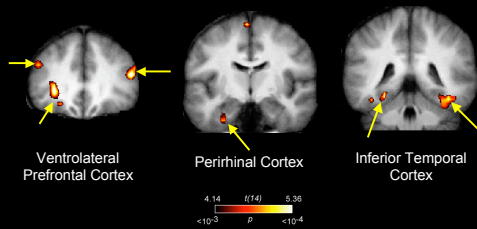
3 trial periods: Cue, Early Delay, Late Delay, Probe

- Multiple regression used to separately estimate BOLD responses associated with each trial period

Critical Comparisons:

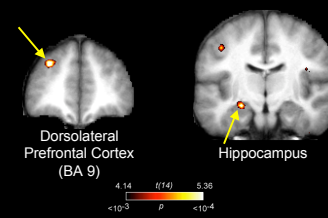
Remembered vs. Forgotten during cue, early, and late delay

fMRI Subsequent Memory Effects: Cue Period



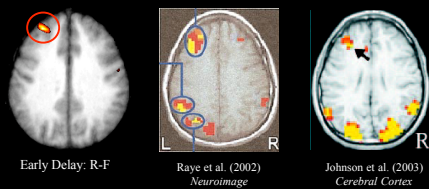
Other areas: Posterior Thalamus, Occipital Cortex (BA 17, 18, 19)

fMRI Subsequent Memory Effects: Early Delay Period

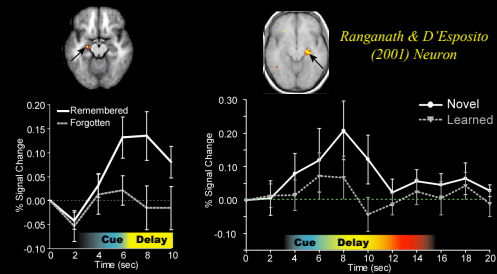


Other areas: Precuneus (BA 5), Occipital (BA 17, 18) Cortex, SMA, Central Sulcus

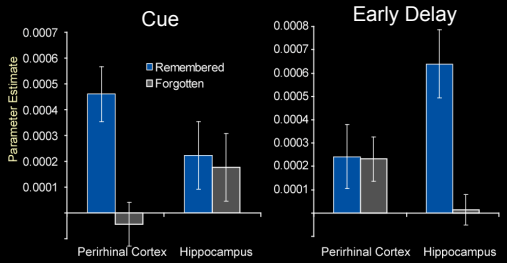
BA 9: Comparison with "Refresh" Activations



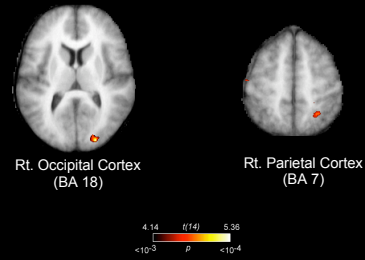
Anterior Hippocampus: Comparison with earlier WM findings



Differential time course of effects in perirhinal cortex and hippocampus



FMRI Subsequent Memory Effects: Late Delay Period



WM and LTM Encoding: Summary

Behavioral study:

- WM processing early in rehearsal period disproportionately impacts subsequent LTM formation

FMRI study:

- Activity during early rehearsal period in dorsolateral PFC (BA 9) and hippocampus predicts subsequent LTM formation

Conclusions

- Maintenance Rehearsal can be subdivided into two stages:
 - Early stage
 - Can be distinguished from goal-directed processing of an item
 - Directly contributes to LTM formation
 - Is associated with sustained activation in dorsolateral PFC and hippocampus
- Fronto-hippocampal interaction supports formation of representations that support memory in the short term and long term.
- Relationship between WM and LTM is more than "oddly interesting"

Acknowledgements

- Mike Cohen, Craig Brozinsky
- RA's: Chris Moore, Sarah Trefethen, Jennifer Young

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Questions ?

