Interactions between Working Memory and Long-term Memory

Memory Disorders Research Society
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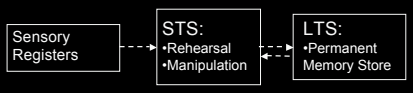
Interactions between WM and LTM

- Paul J. Reber, Northwestern Univ.
  - Intro, fMRI
- Charan Ranganath, UC Davis
  - fMRI
- Wendy Suzuki, New York Univ.
  - Electrophysiology
- Randy O'Reilly, Univ. of Colorado
  - Computational modeling
- Art Shimamura, Berkeley
  - Discussant

Memory Systems

- WM: temporary maintenance
  - activation based, rapid updating, flexible
  - DLPFC networks
- LTM: long-term storage
  - synaptic-change, slow consolidation, episodic
  - MTL networks

An old idea about WM/LTM interactions



- Short term store to Long term store
  - Atkinson & Shiffrin (1968); Broadbent (1958)
- Cognitive Revolution
  - Postulating processes and representations in the mind/brain
- STS/LTS gave way to single LTM store and separate WM system

WM as the gateway to LTM

- WM rehearsal time does not predict LTM storage on recall tests
  - Elaborative rehearsal is more effective than maintenance rehearsal
    - e.g., Craik & Watkins, 1973
  - May predict better performance on recognition tests (Glenberg et al., 1977)
- Patients with WM deficits can show normal LTM acquisition (Warrington & Shallice, 1969)

LTM supports WM

- Knowledge from long-term memory structures extends WM span
  - "Long-term WM" (Ericsson & Kintsch, 1995)
  - Chunking:
    - Ericsson, Chase & Faloon (1980) 79-digit span
    - Chase & Simon (1973) chess expertise
- LTM may allow recovery from WM disruption
  - Intuitively: recovering from distraction
  - Amnesic patients exhibit WM deficits at long delays (Buffalo et al., 1998) or with supra-span lists (Drachman & Arbit, 1966).

Neuroimaging

- LTM and WM are frequently imaged independently
  - Cabeza & Nyberg (2000): >50 WM, >100 LTM
- Both types of memory are associated with widespread activity in a variety of PFC areas
  - In addition to "signature" areas: DLPFC, MTL
- Ranganath & D'Esposito (2001)
  - MTL activity during WM delay
  - What process is this?

Understanding MTL activity during WM maintenance

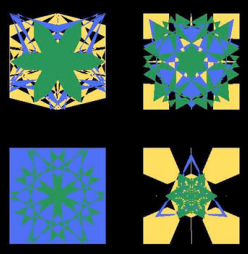
- WM as gateway to LTM or is LTM supporting WM performance?
- Examine MTL activity during WM and subsequent LTM
  - If this activity reflects encoding, then it should be associated with subsequent recognition (LTM success)
  - If this activity reflects retrieval, then effects should be observed on WM performance

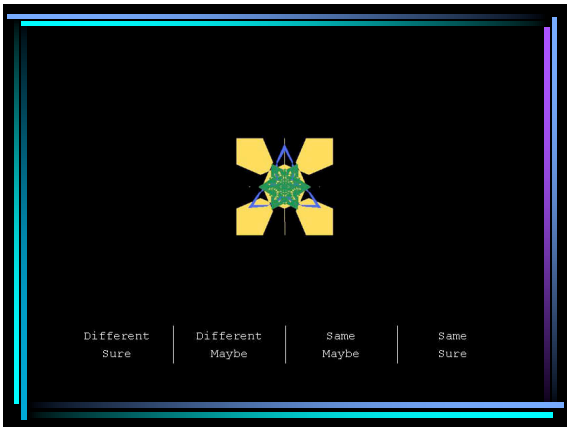
LTM processes during WM

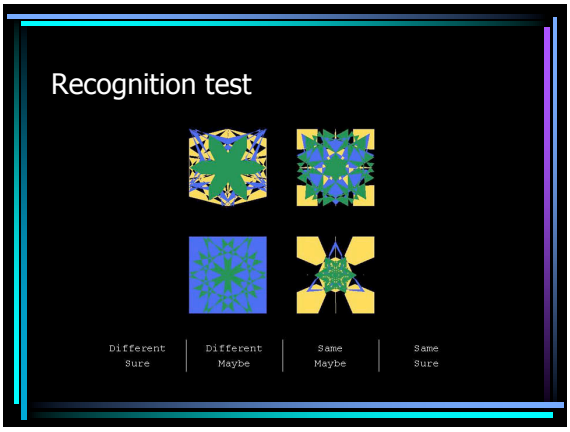
- Participants perform WM task in scanner
- Check for recognition of stimulus arrays after WM testing is complete
  - Is there spontaneous LTM encoding during WM?
- Successful WM should predict successful LTM
  - If WM acts as a gateway to LTM
- fMRI during WM
  - Find dM effects
    - Activity predicting later recognition
  - Find dWM effects
    - Activity predicting successful WM response

Experimental Design

- WM paradigm with 4-element arrays
  - 3 sec to encode array
  - Complex, nonverbal polygon stimuli
  - Difficult to encode
- 5 second maintenance period
- Probe & Response
  - Was this probe in the original array?
  - Yes/no with confidence
- Post-scan Recognition of stimuli
  - Did you see this array during scanning?
  - Yes/no with high/low confidence







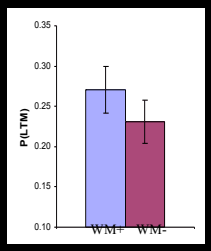
Design Details

- Subjects:
  - n=23
    - 10/33 Ss eliminated due to poor quality imaging data
  - n=9 with inter-scan recognition tests
    - Recognition in scanner after each scan
  - n=14 with post-scanner recognition test
    - All recognition tests given after exiting scanner
- 3.0T Siemens Trio
- Event-related design
  - 12s blank periods interspersed

Memory performance

- Overall WM performance was 68.2% correct (± 1.4 SE)
  - 36.8% were high-confidence correct trials (WM+)
- Participants recognized the stimulus arrays on 25.8% (± 2.6% SE) trials
  - High-confidence "old" responses
  - False alarm rate: 14.0% (± 2.6% SE)
  - Performance better on inter-scan tests: 30.7% vs 20.5% (p<.06)
    - But similar # of SM trials: 23.1 vs. 22.7

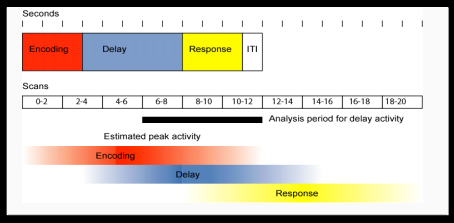
WM/LTM interaction



Stimulus arrays seen during a WM+ trial are more likely to be remembered subsequently.

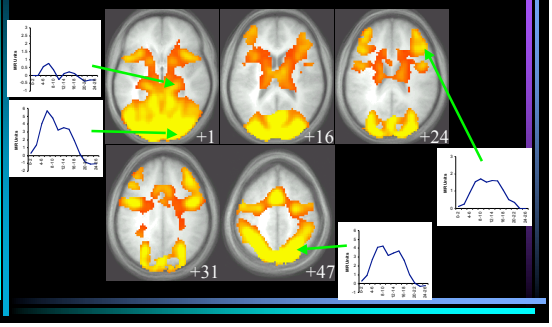
Successful WM performance is associated with a a higher rate of LTM encoding, t(22)=2.35, p<.03

fMRI Data Analysis

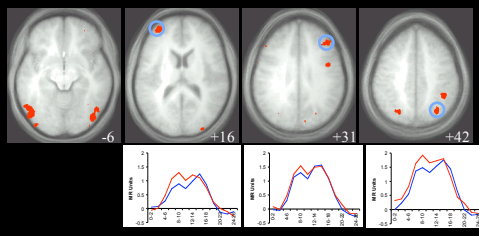


Activity predictive of successful WM and LTM was examined in the 6-12s post-onset period.

Activity > baseline during WM delay

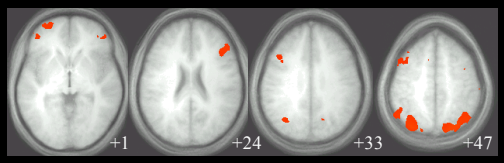


dWM: Activity that predicts successful working memory



Greater activity for high-confidence correct WM responses

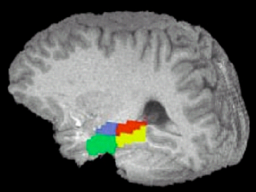
dM: Activity predicting LTM



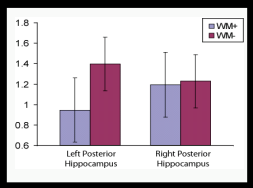
Areas in which increased activity was greater for stimulus arrays that were subsequently recognized with high confidence

Activity in the MTL

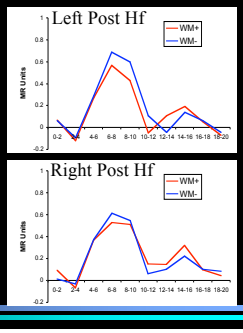
- Evoked activity assessed for each trial type across ROIs within the MTL
- ROIs defined by anatomical boundaries
  - (Reber et al. 2002)



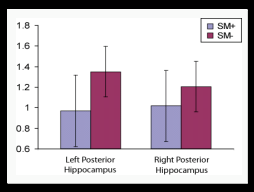
Posterior MTL activity predicted by WM performance



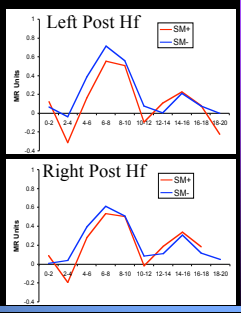
t(22)=3.51, p<.002



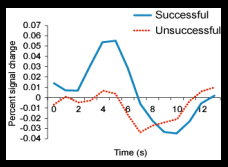
Posterior MTL activity and subsequent recognition



t(22)<1.00, n.s.



Normal Successful Memory



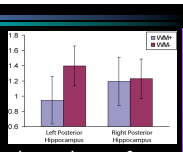
Left Posterior Hippocampus & PHC

From Reber et al. (2002)

Summary

- MTL activity during WM found to be related to incorrect WM responses
  - MTL activity does not appear to be associated with LTM encoding in this study
- dWM activity is consistent with previous WM studies
  - DLPFC/Parietal activity
- dM activity is fairly consistent with previous encoding studies
  - LPFC, posterior parietal
  - But no MTL differences

WM/LTM interactions



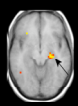
- WM as gateway to LTM
  - Behavioral evidence, but no neural correlates of subsequent memory
- LTM role in WM performance
  - LTM in WM failure
    - Retrieval of irrelevant information
    - Attempted recovery strategy after distraction
  - Four complex stimuli is a high WM load
    - Under high-load conditions, retrieval of LTM information during the delay may play an important role

Project Collaborators

- Antonio Gisbert (graduate student, NU)
- Mike Levitt (research assistant, NU)
- NU Cognitive Brain Mapping Group
  - Marsel Mesulam, M.D.
  - Darren Gitelman, M.D.
  - Todd Parrish, Ph.D.

MTL WM activity

- Delay period activity in the MTL during a WM maintenance task
  - Ranganath & D'Esposito (2001)
  - Face stimuli, match to sample with 12s delay
- What process does this activity reflect?



Anterior Hippocampus