An Introduction to Learning and Memory

Lecture 14/13

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Summary of semester

• Basic concepts in neuroscience of learning and memory
• Perceptual/non-associative learning
• Classical conditioning
• Instrumental conditioning
• Generalization/Discrimination
• Cognitive forms of learning - episodic memory, recognition memory
• Category and concept learning, hypothesis testing, rule-based learning
• Consolidation, interaction of episodic memory and semantic memory
Open questions for discussion

• Interactions between semantic and episodic memory

• Interactions between memory systems
  • Bringing two major threads of learning & memory research back together

• Instrumental effects on memory (e.g., self-directed learning, self-regulated learning)

• Application to education (Ed tech, etc..)
Post-encoding fate of episodic memories?

• Episodic memories are basis for knowledge
• How does this happen?
• Systems level consolidation theory
Systems Memory Consolidation

• **Observation:** MTL damage leads to time-dependent loss of episodic memory

• **Two different forms of consolidation:**
  ➞ **Synaptic** - within minutes to hours; the initial pattern of activation present during the experience becomes stabilized locally

  ➞ **Systems** - much longer time scale but may also begin quickly; proposed to shift representation of the memory from a hippocampal-dependent to a hippocampal-independent representation. Proposed to involve hippocampal-cortical interactions.
Systems Memory Consolidation: Evidence?

• Ribot’s Law (1882): more recent memories more likely to be lost after trauma compared to older ones.
• Retrograde Amnesia
• Retroactive interference
• ECT treatment in humans (~ 30 min critical)
Systems Memory Consolidation: Evidence?

Hipp + cortical areas surrounding hipp

Selective hippocampal damage

Critically, damage to other brain regions leads to impairment but with no temporal gradient
Systems Memory Consolidation: Evidence?

• All examples of **post-encoding interference** with ongoing memory organization..

• But also evidence for post-encoding facilitation!

• McGaugh (1966) - post-encoding drug administration can enhance memory for prior conditioning
Models of hippocampal-cortical interactions
Models of hippocampal-cortical interactions

Alvarez and Squire, 1994
Models of hippocampal-cortical interactions

Importance of interleaved presentations to avoid catastrophic interference

McClelland, 1995
Evidence for interleaving past with present?

Neural ‘replay’ as a possible mechanism
Story so far..

• Episodic representations are encoded locally in hipp, LTP...yadda yadda yadda

• Post-encoding hippocampal-cortical communication alters cortical weights to support learning of the episodic associations

• Cortical representations are more generalized and represent extracted knowledge from repeated episodes

• Semantic memory results from episodic learning
Semantic memory influences on episodic encoding

How are episodic representations incorporated into semantic knowledge structures/schema?
If the balloons popped, the sound wouldn't be able to carry since everything would be too far away from the correct floor. A closed window would also prevent the sound from carrying, since most buildings tend to be well insulated. Since the whole operation depends on a steady flow of electricity, a break in the middle of the wire would also cause problems. Of course, the fellow could shout, but the human voice is not loud enough to carry that far. An additional problem is that a string could break on the instrument. Then there could be no accompaniment to the message. It is clear that the best situation would involve less distance. Then there would be fewer potential problems. With face to face contact, the least number of things could go wrong.
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Table 1  Study design and tasks

<table>
<thead>
<tr>
<th>Condition</th>
<th>Pre-scan picture</th>
<th>During scanning 1st hearing</th>
<th>Pre-scan picture</th>
<th>During scanning 2nd hearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>No picture</td>
<td>Unusual story (1)</td>
<td>Irrelevant picture</td>
<td>Unusual story (1)</td>
</tr>
<tr>
<td>C2</td>
<td>Irrelevant picture</td>
<td>Unusual story (2)</td>
<td>Same irrelevant picture</td>
<td>Unusual story (2)</td>
</tr>
<tr>
<td>C3</td>
<td>No picture</td>
<td>Unusual story (3)</td>
<td>Relevant picture</td>
<td>Unusual story (3)</td>
</tr>
<tr>
<td>C4</td>
<td>Relevant picture</td>
<td>Unusual story (4)</td>
<td>Same relevant picture</td>
<td>Unusual story (4)</td>
</tr>
<tr>
<td>C5</td>
<td>No picture</td>
<td>Standard story (1)</td>
<td>No picture</td>
<td>Standard story (1)</td>
</tr>
<tr>
<td>C6</td>
<td>Relevant picture</td>
<td>Standard story (2)</td>
<td>Same relevant picture</td>
<td>Standard story (2)</td>
</tr>
</tbody>
</table>

Fig. A1  The line diagram (adapted from Bransford, 1979) provides a mental framework for the unusual story in Appendix 1. The story is virtually incoherent in terms of overall theme unless one has been shown this picture.

Fig. 1  For every condition and after each scan, subjects made subjective ratings of comprehension; and free recall of the story content. (A) Comprehension ratings. (B) The percentage of idea units correctly recalled.
<table>
<thead>
<tr>
<th>Comparison</th>
<th>Region</th>
<th>Coordinates (x, y, z)</th>
<th>Z scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4 – C2</td>
<td>Anterior medial parietal/posterior cingulate cortex (BA 31)</td>
<td>0, -46, 28</td>
<td>3.6</td>
</tr>
<tr>
<td>C5 – (C1 + C3)</td>
<td>Left temporal pole (BA 38)</td>
<td>-44, 16, -26</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>Ventromedial orbitofrontal region (BA 11)</td>
<td>2, -42, -22</td>
<td>4.1</td>
</tr>
<tr>
<td>C2 – (C1 + C3)</td>
<td>Right inferior parietal lobule (BA 40)</td>
<td>34, -44, 30</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Fig. 2 (A) Anterior medial parietal/posterior cingulate activation associated with having prior knowledge compared with not having a mental framework into which to fit low coherent stories. The activations are superimposed onto a template MRI scan and shown in sagittal section. (B) Activation of the left middle frontal gyrus (BA 10) associated with repetition of stories, shown in transverse section. (C) Posterior medial parietal (precuneus) activation associated with the repetition of stories, shown in sagittal section. (D) Activation of the medial ventral orbitofrontal cortex where activity increased with increasing comprehension, shown in transverse section.
Tse et al. Science (2007)

Apparatus

Probe Trial

Schema: spatial arrangement of 6 PAs
Acquisition of PAs

Cued-recall probe trials

Post-op retention

Post-op new training
How rapid?
Structure critical?

Inconsistent and consistent location/odor PAs
Cortical activation during new paired associate learning
Human recent and remote memory representations

Bonnici et al 2012, J Neuro
Open Questions

1. What counts as schema-consistent versus schema-inconsistent information?
Interactions between memory systems

Modern research topic: Interactions

Pavlov

Learning

Ebbinghaus

Memory

Experimental Methods!
Effects of choice on memory

- Instrumental conditioning is about making choices (e.g., explore-exploit distinction)

- Choice may also impact memory processes themselves

- Real-world paradigm might be students studying for a test... memory in this case is actually about acquiring/structuring information to be later retrieved... people have study strategies that maybe more or less effective.
What is the effect of active exploration on memory?


Yoked Design

Participant 1

Participant 2

6 study rounds, 1 minute each
20 second rest between rounds
2 minute break before final test
Memory Test

300 items tested for recognition, 150 old and 150 new
Spatial recall test was contingent on responding OLD
Results

**Recognition memory**

- Faded bars are for high confidence items only

**Spatial recall**

Results

Enhanced brain activation and hippocampal-cortical connectivity in Active vs Passive conditions

What drives the effect?

Meta-cognitive monitoring?
What drives the effect?
Coordination of attention?
Experiment 1: Replication

Spatial recall

Distance from studied location

ACTIVE
YOKED

Distance = 1.0

Mean difference = -.13
p = .01

Recognition

Proportion endorsed

ACTIVE
YOKED
OLD
NEW

N = 30
Mean difference = .10
p < .001
Experiment 2

Cue new study location

600ms

Experiment 3

Press spacebar to move

Cue new study location

600ms

Experiment 4

Cue new study location

Cue reveal

750ms

Press spacebar to reveal item

300ms

Experiment 1

Cueing of next location (all blocks)

 Experiment 2 3 4

Yes

Control selection of next item (self-directed blocks)

Yes

Control item duration (self-directed blocks)

Yes

Control duration of ISI (self-directed blocks)

Yes
Experiment 3: Follow a fixed path

Press spacebar to move

Cue new study location

600ms

Experiment:

<table>
<thead>
<tr>
<th>Queuing of next location (all blocks)</th>
<th>Control selection of next item (self-directed blocks)</th>
<th>Control item duration (self-directed blocks)</th>
<th>Control duration of ISI (self-directed blocks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Experiment 3: Results

Spatial recall

- Distance from studied location
- N = 32
- Mean difference = -.09
- p = .09

Recognition

- Proportion endorsed
- N = 32
- Mean difference = .06
- p = .01
Experiment 4: Press to reveal next item

Cue new study location

Press spacebar to reveal item

Cue reveal

750ms

300ms

<table>
<thead>
<tr>
<th>Experiment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cueing of next location (all blocks)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Control selection of next item (self-directed blocks)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Control item duration (self-directed blocks)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Control duration of ISI (self-directed blocks)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Experiment 3: Results

Spatial recall

Distance from studied location

<table>
<thead>
<tr>
<th>Distance from</th>
<th>ACTIVE</th>
<th>YOKED</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td></td>
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</tbody>
</table>

N = 30
Mean difference = -.03
p = .52

Recognition

Proportion endorsed

<table>
<thead>
<tr>
<th>Proportion endorsed</th>
<th>ACTIVE</th>
<th>YOKED</th>
<th>NEW</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td></td>
<td></td>
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<td>0.8</td>
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N = 30
Mean difference = .07
p = .01
Extremely “minimal” conditions of self-directed control still positively influence memory!
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Personalize the timing and “flow” of information possibly as important as choosing what to study!
Comprehension of a conversation overheard

Active Participant > Passive listener

Comprehension of a conversation overheard

Active Participant ≥ Listener who can pause and rewind tape > Passive listener

Self-directed learning also involves agency!

Could this be important?
Role of choice in enhancing memory

Murty et al., (2015)

“Press a button to reveal target memoranda”

Choice Condition: Participant selects which button to press.

Fixed Condition: Participant instructed to select red button.
Role of choice in enhancing memory

Cue: Choice > Fixed

*y = 14

Cue: Choice > Fixed

Striatum Beta-Parameters (a.u.)

Proportion Endorsed Old

* p=0.05, one-tailed

Murty et al, (2015)
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