Episodic Memory: Retrieval & Consolidation

July 11, 2016
Stephanie Gagnon
Announcements

• **Midterm** is Wednesday, July 20th in class

  • Will cover material up to (and including) Wednesday, July 13
  • Will cover any material discussed in lecture and assigned journal articles except ‘neuroanatomy primer’ section

• Karen is out of town but can be reached by email
Homework

• Memory in Action: Emotion and memory demonstration due 8 PM on Tuesday, July 12th
  • http://web.stanford.edu/class/psych136s/memoryinaction/index.html#emo-demo
  • Complete demo and answer the questions in your MIA document

• Reading Response: Talarico & Rubin et al. (2003) due 11:30 AM on Wednesday, July 13
  • http://web.stanford.edu/class/psych136s/reading/index.html#talarico
  • Read article and answer the response questions in your SJR document

• Looking ahead

  • MIA assignment due at 8 PM on Su, July 17th
  • Reading Response: Henkel (2014) due 11:30 AM on Monday, July 18
    • http://web.stanford.edu/class/psych136s/reading/index.html#henkel
    • Read article and answer the response questions in your SJR document
Last time

• Episodic memories are memories for our personal past that are enduring, consciously accessible, flexible, linked to contextual information, and rapidly acquired

• Episodic encoding is aided by many factors, including attention, how we process information, and when we process information
Episodic memory allows us to “traverse times and spaces far remote”

-William Blake
Demo!

You will see a series of adjectives.

If the adjective is preceded by ‘place’, imagine a place that is described that adjective

If the adjective is preceded by ‘read’, try to read the word out loud backward in your head
Demo!

place
Demo!

HAPPY
Demo!

place
Demo!
Demo!

DISMAL
Demo!

place
Demo!

LOUD
Demo!

read
Demo!

read
Demo!

WEAK
Demo!

place
Demo!

YOUNG
This time

• Factors affecting retrieval success
• Subsequent memory design
• Item vs. associative memory
• Neural basis of episodic retrieval
• Retrograde amnesia
• What is memory consolidation?
This time

- Factors affecting retrieval success
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- What is memory consolidation?
Testing episodic memory

• Subjects study a list of items
  • e.g., pictures, words

• Types of memory tests
  • Free Recall
    • Please tell me all of the items from the list that you saw before
    • Please tell what you discussed with your friend last night
  • Cued Recall
    • Please tell me which word on the list completes this stem: mot___
    • Please tell me what you discussed about music
  • Recognition
    • Did you see this item before: yes/no
    • Which of these topics did you discuss: forced-choice
Retrieval is cue-dependent

- Greater cue support (i.e., cued recall) results in superior remembering

Graf, Squire, & Mandler (1984)
Retrieval is cue-dependent

Name Recognition Test:
Louie Carrillo, Bobby Price
“old” “new”

Name Recall Test:
Remember as many names as possible:
“Bobby Hicks”… “Pat Carley”…

- Memory is **better when probed with a name cue** than when asked to **freely recall** names
- 50 years after HS graduation, 50% decline in recollection, but only 5-10% drop off in recognition!

Bahrick et al. (1975)
Retrieval is cue-dependent

- A is more similar to A’ than B (or B’); B is more similar to B’ than A (or A’)
- Memory better when tested in a similar condition to learning (A-A’/B-B’) relative to a dissimilar condition (A-B’/B-A’)

Roediger & Guynn (1996), Schab (1990)
Retrieval is context-dependent

- External context contains stimuli that become associated with the learned material.
- These contextual stimuli are useful cues for eliciting retrieval of these memories.

Godden & Baddeley, 1975
Retrieval is context-dependent

STUDY

TEST

PERFORMANCE

+ +

+ +
Retrieval is state-dependent

- Internal context or states also are associated with learned information
- Internal states serve as useful cues for eliciting retrieval of these memories

Mean number recalled

State at learning

Goodwin et al., 1969
Retrieval is mood-congruent

Cue–dependent nature of memory has important implications for mental health.

Internal state biases retrieval toward mood-congruent experiences, which can create “snowball” effects.

Teasdale & Russell, 1983
This time

- Factors affecting retrieval success
- **Subsequent memory design**
- Item vs. associative memory
- Neural basis of episodic retrieval
- Retrograde amnesia
- What is memory consolidation?
Measuring effective encoding

Subsequent memory paradigm (Brewer et al., 1998; Wagner et al., 1998)

Study Items

- PEAR
- LION
- LAMP
- ROCK

Brain Response

- Remembered
- Forgotten
- Forgotten
- Remembered

Later Memory

- Remembered
Measuring effective encoding

**Subsequent memory paradigm** (Brewer et al., 1998; Wagner et al., 1998)

<table>
<thead>
<tr>
<th>Study Items</th>
<th>PEAR</th>
<th>LION</th>
<th>LAMP</th>
<th>ROCK</th>
</tr>
</thead>
</table>

**Brain Response**
- Green: remembered
- Red: forgotten

**Later Memory**
- PEAR: remembered
- LION: forgotten
- LAMP: forgotten
- ROCK: remembered

**Positive subsequent memory effect:**
Regions showing a greater brain response for **later remembered** relative to **later forgotten** stimuli

**Negative subsequent memory effect:**
Regions showing a greater brain response for **later forgotten** relative to **later remembered** stimuli
Positive subsequent memory effects

Predict later remembering

Content
- Regions important for processing visual information
- Regions important for processing verbal information

Attention
- Regions important for top-down attention

Storage
- Medial temporal lobe

Kim et al., 2011
Negative subsequent memory effects

Predict later **forgetting**

**Attention**

Regions important for *bottom-up* attention

Regions associated with mind-wandering

Kim et al., 2011
This time

• Factors affecting retrieval success

• Subsequent memory design

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• Retrograde amnesia

• What is memory consolidation?
You will see a series of adjectives.

Decide if each adjective was one that you saw in the last part.

If you remember seeing it, did you imagine a place or pronounce it backward?
Demo!

SPOOKY
Demo!

LAME
Demo!

HOT
Demo!

HAPPY
Demo!

CHARMING
Demo!

LOUD
Demo!

WEAK
Demo!

GRAY
Demo!

CHILLY
Demo!

YOUNG
Demo!

DISMAL
Demo!

PLACE
happy
spooky
loud
young

READ
dismal
lame
hot
weak

NEW
old
chilly
charming
gray

Recognized
Item + Source
Item Only

Forgotten
Item and associative memory

Encoding

- His name is enzo!

Retrieval

- I’ve seen him before!

Item

- enzo

Associative

- enzo
Item and associative memory

- **Encoding**: His name is Enzo!
- **Retrieval**: I’ve seen him before!
- **Item**: MTL cortex
- **Associative**: Hippocampus
Quick recap

• The subsequent memory paradigm has revealed that activation in brain areas important for event content, top-down attention, and storage (MTL) is linked to successful memory encoding.

• Within the MTL, the hippocampus is especially important for gluing together multiple pieces of an event.
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Episodic memory

Encoding

sensory input
Episodic memory

Encoding

sensory input

hippocampus
Episodic memory

Retrieval

retrieval
cue

hippocampus
Episodic memory

Retrieval

retrieval cue

hippocampus
Episodic memory

Remembering as *Recapitulation*
- patterns of activation in *perceptual* and *conceptual* cortical areas at *encoding* are *cortically reinstated when remembering* those perceptual/conceptual event details.
Episodic memory

Key Points:
• Reinstatement is reactivation of cortical patterns that were present during encoding
• Emerges via hippocampal pattern completion and hippocampal-cortical interactions at retrieval
• Depends on establishment of cortical pattern at encoding
Retrieval in the MTL

- **Electrocorticography**: electrodes are implanted in the brains of epilepsy patients while they’re in the hospital; get high spatial resolution data (single cells), and high temporal precision (millisecond level)
Retrieval in the MTL

cortex

hippocampus

pattern completion

cortical reinstatement

time

Encoding

Retrieval
Retrieval in the MTL

Hippocampus
“binding of items & contexts”

Entorhinal cortex

Perirhinal cortex
“items”

Parahippocampal cortex
“context”

Neocortical input

“what”
“where”

LaRocque & Wagner (2015)
Retrieval in the MTL

Encoding

Free recall

The patient was then asked to think about the clips and say what came to mind. The neuron began firing rapidly a second or two before the patient named the Simpsons.

Retrieval in the MTL

Example entorhinal cell

Encoding

Raster plots

Free Recall

Gelbard-Sagiv et al. (2008)
Retrieval in the MTL

Encoding

An episode from the cartoon “The Simpsons”


Free Recall

The Simpsons


“Clicking sound” = a single spike from entorhinal neuron

Gelbard-Sagiv et al. (2008)
Cortical Reinstatement

Encoding/Perceive:

- visual word paired with picture or sound

Retrieval:

- visual word
- remember picture or sound

encoding/Perceive:

- visual word paired with picture or sound

retrieval:

- visual word
- remember picture or sound

PICTURES

Perceive

Retrieve

- visual cortex

SOUNDS

Perceive

Retrieve

- primary auditory cortex

(Wheeler et al. 2000)
This time

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• **Anterograde amnesia**: Inability to encode new episodic and semantic memories post-MTL injury

• **Retrograde amnesia**: Temporally-graded disruption of episodic and semantic memories encoded pre-MTL injury (Ribot gradient)
Retrograde amnesia

• **Retrograde amnesia**: Temporally-graded (Ribot gradient) disruption of episodic and semantic memories encoded pre-injury to the MTL
This time

• Factors affecting retrieval success
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• What is memory consolidation?
Standard consolidation theory

• **Consolidation**: process that transforms a memory trace into a durable representation that is independent of the MTL

• The cortex learns more slowly than the MTL, but is also capable of storing memories
  • Repeatedly remembering your high school graduation will reactivate cortical areas related to what you saw, heard, smelled, etc., and repeated co-activation of these areas allows the cortex to bind features together in memory

• **Temporally graded retrograde amnesia**: more recently acquired memories haven’t been consolidated yet
Standard consolidation theory

time

injury
Standard consolidation theory

time

injury
MTL damage impairs recent memories still undergoing consolidation, but memories that are already fully consolidated (in the cortex) remain intact.
Sleep-dependent replay
Sleep-dependent replay

- When mouse is walking along a track, hippocampal “place cells” selectively fire at locations in space

Louis & Wilson (2001)
During REM sleep, see organized hippocampal replay of patterns experienced during the day.

Louis & Wilson (2001)
Sleep-dependent replay

- During REM sleep, compressed replay of hippocampal patterns might facilitate consolidation to the cortex (e.g., visual cortex)

Mehta (2007)
Two views of consolidation

- Standard consolidation theory
- Multiple trace theory
Multiple trace theory

- MTL helps organize distributed semantic facts into episodic memories
- True episodic memories are never fully independent of the MTL
- Spared memories in temporally-graded retrograde amnesia are no longer true episodes (autobiographical semantic knowledge)
This time

- **Factors affecting retrieval success.** Cues, external context, internal state, and mood

- **Subsequent memory design.** Increased activity in MTL, top-down attention, and content regions during encoding is predictive of later remembering

- **Item vs. associative memory.** MTL cortex vs. hippocampus engagement during encoding

- **Neural basis of episodic retrieval.** Hippocampal pattern completion, hippocampal-cortical interactions, cortical reinstatement

- **Retrograde amnesia.** Damage to the MTL (patient E.P.), temporally-graded disruption of declarative memory, Ribot gradient

- **What is memory consolidation?** Standard consolidation theory, sleep-dependent replay, multiple trace theory
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