Consolidation of Memories

Psychology 355: Cognitive Psychology
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05/05/2016: Lecture 06-4

Note: This Powerpoint presentation may contain macros that I wrote to help me create the slides. The macros aren’t needed to view the slides. You can disable or delete the macros without any change to the presentation.
• Consolidation of memories

• Standard model of consolidation
  (Alternative theory: The multiple trace model of consolidation)

• Disruption of memory reconsolidation as a treatment for PTSD

Lecture probably ends here
Consolidation of Memories

- Recently created memories are typically fragile.
  - Without additional retrievals, they are often too weak to retrieve.
  - A concussion soon after learning can cause permanent loss of a memory.
  - Fragility of new memories implies that it takes cognitive processing after the initial experience to create a strong memory.

Goldstein, Figure 7.16
Typical pattern of retrograde amnesia. The recent past is the least consolidated - it is the most likely to be lost. More distant past is more consolidated - it is more likely to be preserved.

- Consolidation is the process by which a memory is transformed from an unstable state to a more permanent state.
What Is Happening During Memory Consolidation?

Changes are happening at two levels:

- **Synaptic Consolidation:**
  Repeated experience causes changes at the level of the synapse.
  ♦ These changes occur quickly, over a matter of minutes.

- **Systems Consolidation:**
  Repeated retrievals cause changes in the organization of neural circuits that represent memories.
  ♦ These changes occur gradually, over days, months or even years.
Long-Term Potentiation (LTP): Structural changes at synapse result in increased firing to the same stimulus.
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System Consolidation: The Time Course of Memory Formation

Figure 7.15 (p. 195) attempts to explain the role of the hippocampus in the encoding and consolidation of memories.
The Time Course of Memory Formation

Initial Encoding of Current Experience

Cortical Areas

Hippocampus

Cortical Areas

Hippocampus

Cortical Areas

Hippocampus

Time

Same Diagram – Emphasis Rectangle on Middle
The Time Course of Memory Formation

Retrieval of Episodic Memory

Cortical Areas

Hippocampus

Time

Same Diagram – Emphasis Rectangle on Right
The Time Course of Memory Formation

Retrieval (After Much Learning) of Episodic Memory

Transition to Diagrams That Show the Same Process But With Different Graphics
The next slides display the same ideas as the preceding slides, but with more informative graphics.

The next set of slides show:

The Standard Model of Memory Consolidation
This slide is based on instructional material that was downloaded from the Pearson Publishers website (http://vig.prenhall.com) for Smith & Kosslyn (2006; ISBN 9780131825086).

1: Processing of current information activates different brain areas in occipital, parietal, temporal and frontal cortex.

2: Multiple brain activations spread to hippocampus (convergence zone).

Somehow, hippocampus binds multimodal inputs together and encodes long-term memory.
3: At time of recall, partial cues stimulate some brain areas that were also activated at encoding.

4: Activation spreads to the hippocampus.

5: Somehow, the hippocampus triggers pattern completion (partial reactivation of original activation pattern).
Reactivation Before & After Consolidation

Reactivation Hypothesis:
(Goldstein, p. 195)

Episodic retrieval involves reinstatement of activations that were present during encoding.

Hippocampus plays an important role in reactivation.
Standard Model of Consolidation:

Retrieval BEFORE consolidation has been completed.

Retrieval AFTER consolidation has been completed.

Multiple Trace Model of Consolidation
Multiple Trace Model of Consolidation

• Multiple trace model is opposed to the standard model of consolidation.

• According to this model, the hippocampus is involved in retrieval of remote episodic memories as well as recent episodic memories, but only if they are not *semanticized*.

• Semanticization of Episodic Memories & the Remember/Know Distinction
  ♦ Hippocampus is active during retrieval of remote episodic memories that the subjects "remember", but not during the retrieval of memories that the subjects "know" are true, but don't "remember".

  ♦ Intuitive ideas: Over time, memories can become facts (as opposed to retrieval of experiences). Retrieval of facts may not involve the hippocampus to the same degree as retrieval of experiences.
    ○ This is called the semanticization of memories (transformation of a memory from being episodic to being semantic).
• Fact to be discussed later in this lecture:
  ♦ When a memory is retrieved, it is vulnerable to change.
  ♦ After retrieval of a memory, it is necessary to store the memory again to return it to a permanent state.

• **Consolidation** refers to processes that change an initially encoded memory into a permanent memory.

• **Reconsolidation** refers to processes that restore a memory to a more permanent form after it has been retrieved.

Sometimes consolidation & reconsolidation are referred to together as “consolidation.”
Interestingly Enough, ..... 

• Sleep (dreaming?) plays a functional role in promoting consolidation.
  ♦ Rat brain cells that fire together while exploring a location also show increased firing during subsequent sleep. Not true of other cells that did not fire during exploration.
  ♦ Disruption of dreaming seems to disrupt consolidation.
  ♦ Similar effects with humans who are learning to play tetris.

• Some evidence suggests that if a subject expects to be tested on Topic A but not on Topic B, then sleep (possibly, dreaming) enhances future memory of Topic A more than Topic B.

• Role of sleep in consolidation is not understood, but there seems to be a significant relationship between sleep and consolidation.
Consolidation & reconsolidation ...

... long-term memory representations become more stable over time;

... hippocampus plays a central role in retrieval of incompletely consolidated memories;

... over time, retrieval of memories becomes independent from the hippocampus and other medial temporal lobe activity.
Memories Representations Are Malleable At Time of Retrieval

• Hypothesis:
  When memories are retrieved, they are vulnerable to change.

• Under special circumstances, when memories are retrieved, memories can be altered, even wiped out.
  ♦ Can these ideas be used to develop a treatment for PTSD?
Undoing Fear Conditioning in the Rat


• If a tone is paired with an electric shock, a rat will learn to freeze when it hears the tone (classical conditioning of fear).

• Anisomycin – antibiotic that inhibits protein synthesis that is required in the formation of new memories.

• Administering anisomycin to a rat can cause it to fail to learn.
**Experimental Design**

**Condition 1:**
Day 1: Tone + Shock + anisomycin  
Day 2: No drug; no tone; no shock  
Day 3: Does not freeze to tone  
(shows no learning)

**Condition 2:**
Day 1: Tone + Shock  
Day 2: Drug; no tone; no shock  
Day 3: Freezes to tone  
(shows learning)

**Condition 3:**
Day 1: Tone + Shock  
Day 2: Drug + tone, no shock.  
Day 3: Does not freeze to tone  
(shows no learning)

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**Figure 7.20**
**Condition 1:**
Day 1: Tone + Shock + anisomycin
Day 2: No drug; no tone; no shock
Day 3: Does not freeze to tone
   (shows no learning)

**Condition 2:**
Day 1: Tone + Shock
Day 2: Drug; no tone; no shock
Day 3: Freezes to tone
   (shows learning)

**Condition 3:**
Day 1: Tone + Shock
Day 2: Drug + tone, no shock.
Day 3: Does not freeze to tone
   (shows no learning)
Summary of Main Finding

Condition 1:
Day 1: Tone + Shock + anisomycin
Day 2: No drug; no tone; no shock
Day 3: Does not freeze to tone
(shows no learning)

Combining drug with tone & shock on Day 1 prevents fear conditioning.

Condition 2:
Day 1: Tone + Shock
Day 2: Drug; no tone; no shock
Day 3: Freezes to tone
(shows learning)

Drug on Day 2 does not undo fear conditioning.

Condition 3:
Day 1: Tone + Shock
Day 2: Drug + tone, no shock.
Day 3: Does not freeze to tone
(shows no learning)

Combining drug with retrieval of fear conditioning on Day 2 undoes fear conditioning.
Retrieve makes the fear conditioning from Day 1 vulnerable to change. Combining retrieval with drug prevents reconsolidation of memory of fear conditioning, thereby causing loss of conditioning.

Nader et al. (2000) state that the memory trace is "labile" during retrieval, i.e., its form can be changed at that time.
The following slides pertaining to the treatment of PTSD are the same as the ones that were displayed in class, but an improved version of these slides will be presented on Monday 05/09/2016. You should use the Monday slides because they are more clear.
Using the Fragility of Memories During Retrieval to Treat PTSD


• Post-traumatic stress disorder (PTSD): Strong fear and stress responses are evoked by reminders of the initial traumatic event.

• Brunet et al. asked whether human PTSD patients can lose or at least diminish their fear and stress conditioning by techniques that are similar to Nader et al.'s demonstration that rats can lose their fear conditioning.
  ♦ Study used propranolol, a drug that is used to prevent traumatic memories if administered immediately following a traumatic event. Propranolol reduces the fear & stress conditioning of trauma.
Brunet et al.'s Study of PTSD Subjects

- PTSD patients: Childhood sexual abuse, motor vehicle accident, rape, being taken hostage.
  - Comorbid mental disorders included: major depressive disorder, panic disorder, social phobia, bulimia, generalized anxiety disorder.

- Two scripts were prepared for each patient that described the events that produced the trauma for that patient.

- 19 PTSD patients were randomly assigned to either a treatment condition or a placebo control condition.
  - Both Conditions: Patient hears a 30-second recording describing their traumatic experience.
  - Treatment Condition: Patient is injected with propranolol immediately following recording.
  - Control Condition: Patient is injected with a placebo that has no active ingredients.
Test of Treatment

- One week later, the patients listened to a taped version of the scripts that described their traumatic experience, and are asked to imagine the traumatic events while listening to the tape.
  - Physiological measures of stress and anxiety are taken while patients listen to the tape.

- Question: When the patients hear the taped version of traumatic experience, will they experience fear, anxiety, etc. of PTSD?
  - I.e., has the drug treatment reduced or eliminated their tendency to associate fear responses with these memories.
HUMAN

Traumatic experience

Listen to taped description of traumatic experience

Injection of propranolol immediately after recall

Later, will the human seem to have unlearned the fear conditioning to the traumatic memories?

RAT

Tone + shock conditioning in the rat

Rat hears tone without the shock

Injection of anisomycin immediately after rat hears tone

Later, the rat seems to have unlearned the fear conditioning to the tone.
Brunet et al. Results

- Grey = placebo group; Black = propranolol group
- Result: Therapy reduces original fear conditioning.
Brunet et al. Results

- Grey = placebo group; Black = propranolol group
- Result: Therapy reduces original fear conditioning.

Y-Axis Are Z-Scores Relative to Base Rate

Heart Rate

Skin Conductance

Corrugator EMG

Tensing of Frowning Muscles

Return to Malleability of Memory During Retrieval
Thursday, May 05, 2016: The Lecture Ended Here
Malleability of Memories During Retrieval

• Learned associations can be lost during retrieval
  ♦ Rats unlearned tone-shock connection
  ♦ Humans unlearn (to some degree) the association between a traumatic episodic memory and the emotional response

• Consolidation & Reconsolidation – memories can be strengthened during retrieval
  ♦ Practice testing (retrieval) produces better future recall

• Do these results contradict each other? No!

• Stored representations can change during retrieval.
  ♦ Usually the change makes the memory stronger, better organized, more linked to other memories, especially to retrieval cues.
  ♦ The opposite can also happen, e.g., rats unlearn their fear conditioning, or humans become desensitized to memories of trauma. This special case is based on the injection of drugs that would not normally be present.
Conclusion re Consolidation

• Consolidation occurs through reactivation of memories, followed by re-encoding of the memories.

• Hippocampus plays a major role in reactivation for recent memories. After the memories have been consolidated, the hippocampus plays a reduced role in retrieval of memories.

• Memories are malleable during or shortly after retrieval.