An Introduction to Learning

Lecture 12/14

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Levels of Processing

- Levels-of-Processing Hypothesis (Craik & Lockhart, 1972):
  - Information can be processed on a variety of levels, from the most basic (visual form), to phonology, to the deepest level (contextual meaning)

  The depth of processing helps determine the durability in LTM

<table>
<thead>
<tr>
<th>Level of Processing</th>
<th>Example</th>
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</thead>
<tbody>
<tr>
<td>1) Visual Form</td>
<td>“DOG” comprises the letters D, O, and G</td>
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<tr>
<td>2) Phonology</td>
<td>Rhymes with FOG</td>
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<tr>
<td>3) Semantics (Meaning)</td>
<td>A four-legged pet that often chases cats and chews on bones</td>
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</tbody>
</table>
Levels of Processing
Craik and Tulving (1975)

- **Task:**
  - Participants viewed words and were asked to make three different types of judgments:
    - Visual processing (e.g. “Is LOG in upper case?”)
    - Phonological (e.g. “Does DOG rhyme with LOG?”)
    - Semantic (e.g. “Does DOG fit in the sentence: ‘The ___ chased the cat?’”)
  - Finally, participants were asked to recognize the words they had seen before in a surprise test

- **Results:**
  - Words that were more deeply processed were more easily recognized
  - Particularly for questions with a “YES” response
Levels of Processing
Craik and Tulving (1975)

Task:
- Participants viewed words and were asked to make three different types of judgments:
  - Visual processing (e.g. “Is LOG in upper case?”)
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Results:
- Words that were more deeply processed were more easily recognized
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The crucial role of retrieval cues

- Depth of processing / elaborative encoding is only part of the story

- A major determinant of memory success is how well the retrieval cues at test **match** the processing that subjects did at study...

- The better the match, the better subjects’ recall will be
Transfer-Appropriate Processing

- **The Transfer-Appropriate Processing Principle:**
  - Recall is better if the processing requirements of the test match the processing conditions at encoding.

- Morris, Bransford, and Franks (1977) tested the principle:
  - **Task:**
    - Participants made either a phonological or semantic judgment about each item on a word list.
    - The learning was **incidental**: participants didn’t know they would have to later recall the words.
  - The final test was either:
    - A standard recognition test for the learned words.
    - A rhyming recognition test for learned words.
Transfer-Appropriate Processing
Morris, Bransford, and Franks (1977)

- **Results:**
  - Standard recognition test: Deeper processing led to better performance
  - Rhyming recognition test: Shallower rhyme-based encoding task led to better performance because it matched the testing situation

- **Conclusion:**
  - It only makes sense to talk about a learning method’s efficacy in the context of the type of final test
Techniques for measuring recollection and familiarity

One possibility: Just ask subjects to say whether they are responding based on familiarity or recollection...

If you recollect specific details, say “remember”

If you think it’s studied, but you don’t remember specific details, say “familiar”

Problem: Subjects get confused & start using “remember” and “familiar” to mean “strong memory” vs. “weak memory” instead of “remember specific details” vs. “don’t remember specific details”
Other techniques for measuring recollection and familiarity

Another technique involves analysis of receiver operating characteristic curves (ROC curves)

This technique involves making detailed assumptions about the distributions of memory strength values for studied items and lures
ROC Analysis

Key assumption: Familiarity is normally distributed for both studied items and lures

- Everything more familiar than (to the right of) the response criterion will be judged “old”
- Everything less familiar than the response criterion will be judged “new”
  - Hits (in green)
  - Misses (in red)

- Above, the same distribution with the focus has shifted to the lure distribution to highlight:
  - Correct rejections (in green)
  - False alarms (in red)

- D prime ($d'$) represents:
  - The standardized distance between the distributions
ROC Analysis

Signal Detection Theory in Memory

- A more liberal guesser will:
  - Have a response criterion shifted to the left
  - Accept more targets as “old” (i.e. hits)
  - Accept more lures as “old” (i.e. false alarms)

- A more conservative guesser will:
  - Have a response criterion shifted to the right
  - Have fewer hits
  - Have fewer false alarms
ROC curves are generated by sliding the response criterion from right to left and plotting hits and false alarms at each point.

Key point: The idea that studied and lure familiarity are normally distributed (with equal variance) results in an ROC curve that has a characteristic shape (curved & symmetric).
The second key assumption of ROC analysis is that distributions of memory strength values associated with **recolleciton** have a very different shape than the distributions of memory strength values associated with **familiarity**.
Recollection: Distribution of Memory Strength Values

- Percentage
- Memory Strength
- Studied Items
- Lures

Recollection

Probability of hits

Probability of false alarms
ROC Analysis, continued

Key point: The two processes yield differently shaped ROC curves

Familiarity: curved and symmetrical, goes through (0,0) and (1,1)

Recollection: Intersects the Y axis at some point > 0
How ROC Analysis Actually Works

- Run a recognition memory experiment
- **Manipulate criterion placement using payoffs**
  - Liberal criterion: High reward for hits, low penalty for FAs
  - Conservative criterion: Low reward for hits, high FA penalty
- For each criterion level, plot hits and false alarms
- Connect the dots to make an ROC curve
- See how much the ROC curve resembles the “ideal recollection” curve vs. the “ideal familiarity” curve
ROC Analysis in Rats

Fortin et al. (2004, *Nature*)
Recognition memory and the medial temporal lobes

The question of how different MTL structures contribute to recognition is surprisingly controversial.

In my previous lectures, I argued that the hippocampus is needed for retrieval of specific details (after a single study exposure) and that perirhinal cortex can support item familiarity judgments on its own.

If this is true, focal hippo damage should knock out recollection but leave familiarity intact.
Recognition memory and the medial temporal lobes

Results from human amnesics are inconsistent

Sometimes impairment is limited to recollection (sparing familiarity), sometimes it is not

Problem: Lesions in human amnesics are messy

Damage that appears to be limited to the hippocampus may also affect cortex

Solution: Study the effects of hippocampal damage in animals, where we have more control over the nature of the lesion

Use ROC analysis...
Finding: Hippocampal damage selectively knocks out the recollection component, leaving the familiarity component intact.
Vargha-Khadem et al. (1997) - looked at three patients (including “Patient Jon”) who suffered hippocampal damage in childhood due to oxygen deprivation; surrounding cortical regions were spared.

Recall of once-presented stimuli is terrible
study: window-reason; test: window-?

However, these patients do OK in school....?
Episodic/semantic

Vargha-Khadem et al. (1997) talk about these findings in terms of a dissociation between episodic memory and semantic memory.

Episodic memory = recall & recognition of events
Semantic memory = recall & recognition of facts

Based on OK school performance, they argue that semantic learning ability may be intact.

However, this conclusion is premature..

Well-controlled studies of semantic learning in these patients have revealed that semantic learning is impaired also (e.g., Gardiner, Brandt, Baddeley, Vargha-Khadem, & Mishkin, 2008, Neuropsychologia).
Episodic/semantic

Episodic and semantic memory are closely intertwined

Contrary to claims made in the Vargha-Khadem article, it is impossible to knock out episodic memory without there being some effect on semantic memory

All fact memories start out as (hippocampally-dependent) episodic memories

If a person is exposed to the fact many times (either because of many “real world” exposures, or because of hippocampal replay), the fact eventually sinks in to cortex and becomes a semantic memory.
Explaining the Vargha-Khadem Results

Overall: The patients’ good performance in school validates the idea that cortex is an enormously powerful learning system when given repeated exposure to study materials...

Studies of patients with big lesions showed that, if you have some sparing of cortex, you can do some memorization of new facts

The Vargha-Khadem study shows that, if you have a lot of sparing of cortex, you can do a lot of memorization of new facts
In the patients studied by Vargha-Khadem et al. (1997), item recognition is OK, even after 1 study exposure:

- study:
  - banana
  - moose
  - telephone

- test:
  - eardrum?
  - banana?

Animal studies also support the idea that focal hippocampal damage does not disrupt item recognition.

In animals, recognition memory is typically tested using a delayed nonmatching to sample (DNMS) procedure.
Figure 3  Delayed nonmatching-to-sample (DNMS) task. Trial 1: The monkey is presented with a sample object covering a food reward (+) in the central well of the testing tray. After a delay, during which the test tray is obscured, the sample object and a novel choice object are presented simultaneously covering the lateral wells, but the novel object is now rewarded (i.e., nonmatch-to-sample). After a brief intertrial interval (ITI), the next trial begins. Trial 2: For this and all subsequent trials, a new pair of objects serves as the sample and choice (i.e., trial unique).
Figure 4  Performance of monkeys with damage to the medial temporal lobe on DNMS, when delays are increased from 30 to 120 s or the number of to-be-remembered objects is increased from three to ten. N, unoperated controls; A, animals with aspiration lesions of the amygdala; H, animals with aspiration lesions of the hippocampal formation; A + H, animals with combined amygdala and hippocampal lesions. Adapted from Mishkin M (1978) Memory in monkeys severely impaired by combined but not by separate removal of amygdala and hippocampus. Nature 273(5660): 297–298, with permission from Macmillan Journals Ltd.
Item Recognition

- If the hippocampus is not the key structure for item recognition memory, which structure(s) is most responsible for item recognition?

- Perirhinal cortex!

Big lesions that encompass perirhinal cortex lead to poor recognition memory; subjects with spared perirhinal cortex show better item recognition memory.
Figure 5  Effects of entorhinal (Erh), perirhinal (PRh), and rhinal (Rh; Erh + PRh) lesions on DNMS performance as compared to unoperated (N) animals. Adapted from Meunier M, Bachevalier J, Mishkin M, and Murray EA (1993) Effects on visual recognition of combined and separate ablations of the entorhinal and perirhinal cortex in rhesus monkeys. J. Neurosci. 13: 5418–5432, with permission from the Society for Neuroscience.
Item Recognition

**Puzzle:** How do we explain the finding of good recognition memory (after a single study exposure) in people and animals with focal hippocampal damage?

The cortex learns incrementally.

Good recognition in these subjects after one study trial seems to contradict this “incremental learning” principle.
Even though cortex learns incrementally, repeated presentation of a stimulus leads to predictable changes in the overall structure of cortical representations...
Cortical Recognition

Repeating stimuli makes their representations **sharper**

=> novel stimuli **weakly** activate a **large** number of units

=> repeated stimuli **strongly** activate a **small** number of units

There is less overall activity in the upper (perirhinal) layer for repeated vs. novel stimuli
Forgetting

What are the reasons why we fail to remember things?

Trace decay?

Today we will focus on interference: Learning about one thing can mess up your memory for other things.

We will show that some kinds of forgetting that appear to be attributable to trace decay may, in fact, be caused by interference.
Interference

Two mechanisms for interference:

New memories might overwrite or damage old memories

Even if new & old memories co-exist peacefully, you might still end up getting competition at retrieval
Competition Assumption (Anderson, Bjork, & Bjork, 1994):
- A cue activates all of its associates to some degree
- The activated associates compete for access to awareness
- Competitors are any associates other than the target memory

Interference:
- Increases with the number of competitors a target has
- cue-overload principle:
  - The tendency for recall to decrease with the number of to-be-remembered items paired with the same cue

Adapted from Anderson and Neely (1996).
Proactive Interference

- Studied in the lab using the AB-AC interference paradigm

- Forgetting increases as a function of the number of previously studied lists

- Especially if the learning experiences are similar (e.g. share a cue)
Retroactive Interference

- Baddeley and Hitch (1977):
  - Task:
    - Rugby players were asked to recall the names of teams they played earlier in the season
  - Control:
    - Some players missed certain games, leaving a measure of forgetting due to decay as opposed to interference from intervening games
  - Results:
    - Time wasn’t a good predictor of forgetting
    - Forgetting increased with the number of intervening games; new learning can interfere with old memories

Conclusion: forgetting is caused by interference, not trace decay
Interference: Brown-Peterson Paradigm

- simple paradigm for looking at interference effects
- present triplets of stimuli
- have people count backwards for some interval
- recall the most recently presented triplet
Interference: Brown-Peterson Paradigm

- 3 words will appear (e.g., apple orange banana)

- then you will see a 4-digit number (e.g., 2764)

- when the 4 digit number appears, start counting down by 7s from that number until I say stop
Brown-Peterson Demo

Pontiac Lexus Mazda
Brown-Peterson Demo

1721
Brown-Peterson Demo

Pontiac Lexus Mazda
Brown-Peterson Demo

Subaru Honda Volvo
Brown-Peterson Demo

9853
Brown-Peterson Demo

Subaru Honda Volvo
Brown-Peterson Demo

Isuzu Buick Nissan
Brown-Peterson Demo

1533
Brown-Peterson Demo

Isuzu Buick Nissan
Brown-Peterson Demo

2206
Volkswagen Pontiac Mitsubishi
Acura Ferrari Oldsmobile
Brown-Peterson Demo

5428
Acura Ferrari Oldsmobile
Brown-Peterson Demo

Chevrolet Saab Cadillac
Brown-Peterson Demo

6612
Brown-Peterson Demo

Chevrolet Saab Cadillac
Brown-Peterson Demo

sparrow eagle bluejay
Brown-Peterson Demo

sparrow eagle bluejay
Important BP Findings

- Improved performance with category switch

- Suggests that proactive interference is contributing to forgetting

- Some studies have looked at within-subject delay manipulations: short delay vs long delay

Increasing delay between study & test hurts performance

Evidence for decay....???

However, no effect of delay on the first trial

Suggests that decay is not occurring
If decay isn’t contributing to forgetting, then why does increasing the retention interval hurt performance (on trials after the first one)?

Put another way: How can we get time-dependent forgetting in the absence of decay?
The constellation of thoughts in our heads drifts over time...
Items presented at a particular time get associated with active contextual elements

If you study “printer” at 9:42, it gets associated with “hungry”, “work”, and “switch at 96th St”
If you want to figure out what you studied recently, cue memory with the current set of contextual elements.

If, at 9:43, you want to recall recently studied items, cue with “hungry” and “switch at 96th St.”
Because (earlier) you associated “printer” with “hungry” and “switch at 96th St”, cuing with “hungry” and “switch at 96th St” should trigger recall of “printer”
In the Brown-Peterson test, we have multiple study and test phases (S1, T1, S2, T2, etc.)

Each study list gets associated with the currently active contextual elements

e.g., S1 gets associated with “itchy”, “Work”, and “switch at 96th St”
Goal: you want to recall the most recent study list
T2: Cue with the current context “Work, hungry, 96th St”

There is a competition between S2 and S1:
S2 was associated with $3/3$ current contextual elements
S1 was associated with $2/3$ current contextual elements
... so S2 wins the competition
Now we can begin to address delay effects in the Brown-Peterson paradigm
This diagram illustrates the short-delay condition

S2 is recalled well because it matches the current context better than S1
In this diagram, T2 is a long-delay trial

If you wait long enough, most of the active contextual elements will change

In this case, both S1 and S2 are equally poor matches to the current context (1/3 features), so recall will be poor
Summary:
Items are associated with contextual features at study
We use the current context as a retrieval cue

According to the theory presented here, there is no effect of the passage of time *per se*: traces do not passively decay
Still, we end up getting better recall for recently presented items because the passage of time is correlated with contextual match.

Events that occurred more recently will have more contextual features in common with the retrieval cue, so their memory traces will be more strongly activated by the cue.
In the short-delay condition, contextual match to T2 is better for S2 vs. S1, so you get good recall.
In the long-delay condition, contextual match to T2 is equivalently poor for S2 vs. S1, so you get poor recall

Telephone poles analogy (Crowder, 1976)
The fact that delay does not affect recall on the first trial can be explained in terms of the idea that recall is a competitive process.

Because memory is a competitive process, what matters most is the relative contextual match between S1 and T, rather than the absolute level of match.
Increasing delay reduces the **absolute** amount of study-test contextual match (in this case, from 3 features to 2)

However, **relative** to other traces in your brain (relating to other things, besides Brown-Peterson) S1 is still by and far away the best-matching trace, so recall should be good
Memory Search

• Free recall

etc...
Reinstating Context

96th St

itchy

exams

hungry

9:40 9:41 9:42 9:43

96th St

itchy

exams

hungry

9:40 9:41 9:42 9:43
Reinstating Context

96th St

itchy

exams

hungry

9:40 9:41 9:42 9:43

shark computer bat test
Initiate recall by cuing with the current context: “hungry, 96th St”

Given this cue, you end up recalling “bat”

You also recall **other contextual elements** associated with bat: “exams”
Step 2: Take retrieved contextual elements and incorporate them into your retrieval cue: “hungry, exams, 96th St”

With “exams” in your retrieval cue, you can now recall “computer”, plus a new contextual element “itchy”
Step 3: Incorporate “itchy” in your retrieval cue

Now you can recall “shark”

Using retrieved context as a retrieval cue allows you to bootstrap your way backwards in time...
Contextual Reinstatement

• What is the empirical evidence for contextual reinstatement?
<table>
<thead>
<tr>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
<th>7th</th>
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</thead>
<tbody>
<tr>
<td>notebook</td>
<td>skull</td>
<td>leaf</td>
<td>watch</td>
<td>shark</td>
<td>bat</td>
<td>computer</td>
</tr>
</tbody>
</table>
Conditional Response Probability

1st 2nd 3rd 4th 5th 6th 7th

notebook skull leaf watch shark bat computer
Conditional Response Probability

Given that you just recalled the 4th item on the study list, what are the odds that the next item you recall will be the 3rd, or 5th, or 2nd, or 6th...?
Conditional Response Probability

lag:  -3  -2  -1  0  +1  +2  +3
1st  2nd  3rd  4th  5th  6th  7th

notebook  skull  leaf  watch  shark  bat  computer

(Graph from Kahana, 1996)
### Conditional Response Probability

<table>
<thead>
<tr>
<th>lag:</th>
<th>-3</th>
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<th>-1</th>
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Notebook skull leaf watch shark bat computer

#### Key finding:
Successive recalls come from nearby serial positions, in both the forward and backward directions.

(Graph from Kahana, 1996)
Conditional Response Probability

- Can this pattern be explained in terms of conjoint rehearsal?
Conditional Response Probability

• Can this pattern be explained in terms of conjoint rehearsal?
  – No, it is found even when a long, arithmetic-filled delay is placed between items at study
  – So what is going on?
Reinstating Context

- 96th St
- itchy
- exams
- hungry
- weather

- 9:40
- 9:41
- 9:42
- 9:43

- notebook
- skull
- leaf
- watch
- shark
- bat
- computer
Reinstating Context

exams

hungry

weather

96th St

notebook    skull    leaf    watch    shark    bat    computer
Reinstating Context

exams
hungry
weather

96th St
itchy

9:40 9:41 9:42 9:43

notebook skull leaf watch shark bat computer
Recency effect: Better recall of items from the end of the list

Hypothesis: This occurs because *contextual match* is better for items from the end of the list
A slightly different task: **judgments of recency**
Which was presented more recently: shark or skull?

Use the words to cue for contextual info
Recency Judgments

shark retrieves “hungry, weather, exams, 96th St”
skull retrieves “exams, itchy, 96th St”

**compare retrieved context to current context:**
“weather, 96th St”
Recency Judgments

shark: “hungry, weather, exams, 96th St”
skull: “exams, itchy, 96th St”
current: “weather, 96th St”

**Contextual match** is higher for shark, so shark is probably more recent...