Learning and Memory

Lecture 13

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How to be a better student

Yes, parents matter. Here's how
Spacing versus distributed learning

Information is better encoded when there is a longer delay between repetitions (spaced practice). Cramming for a test (massed practice) is not a good strategy. Your time is more efficiently spent spacing student sessions over multiple days.
Spacing versus distributed learning

**Fig. 1.** Structure of a typical study of spacing effects on learning. Study episodes are separated by a varying gap, and the final study episode and test are separated by a fixed retention interval.

- Melton (1970)
- Two repetitions of words spaced apart with different numbers of words presented between them
- Also varied speed of presentation
Spacing versus distributed learning

- Bahrick et al. (1993)

- How long the spacing effect lasts

- Subjects studied foreign vocabulary words every 12, 28, or 56 days for up to 4 years; each subject had the same number of repetitions

- Memory tested over next 5 years

Spacing versus distributed learning

“Although the interactive effects of gap and RI pose challenges for practical application, certain conclusions can nonetheless be drawn. If a person wishes to retain information for several years, a delayed review of at least several months seems likely to produce a highly favorable return on the time investment—potentially doubling the amount ultimately remembered compared with a less temporally distributed study schedule, with study time equated. Although this advice is in agreement with the earlier work of Bahrick (e.g., Bahrick et al., 1993), it is at odds with many conventional educational practices—for example, study of a single topic being confined within a given week of a course.”
Spacing versus distributed learning

- Why is spaced practice better?

- **Encoding variability:** Study sessions that are more distant in time are likely to occur in different contexts making for a richer representation of the memory

- Not just for episodic memory!

- Also improves retention of motor skills like typing, snowboarding, etc..

- but is it good for all types of learning?
Spacing versus distributed learning

Research Article

Learning Concepts and Categories

Is Spacing the “Enemy of Induction”?  
Nate Kornell and Robert A. Bjork  
University of California, Los Angeles

Spacing good for memory but might make it harder to detect commonalities if you are extracting a pattern from a set of examples.
Spacing versus distributed learning

Some items massed/some spaces MSSMMSSMMSSM

All paintings either space or massed depending on condition

Test: classify the painter of a novel Painting
Spacing versus distributed learning
Spacing versus distributed learning

Test: recognition (have you seen this artist work in the study phase?)
Spacing versus distributed learning

Key points

• Spacing was not the enemy of induction it was previously assumed to be

• People misjudge which conditions they have remembered better. **YOU DON’T UNDERSTAND HOW YOUR OWN MEMORY WORKS!**
Spacing versus distributed learning

- Do people actually prefer to self-study in accord with the spacing effect?

- **NO!** Well, many students cram for tests. This may simply reflect poor time management rather than lack of understanding of spacing effect.

- However, experiments show the people rate massed practice as a better way to learn a list (Simon & Bjork), and when given the option prefer massing their practice.

- “massing provides a sense of ease, which learners assume will translate to good memory on a later test, whereas spacing is often as ‘desirable difficult’” (Kornell & Bjork, 2008)
Testing (and generation) effect

- Information is better remembered when it is generated by a subject than when it is presented to a subject
- e.g., studying by generating the definitions of terms is more effective than reading the definitions of terms (flashcards)
- Maybe be related to levels of processing
Testing (and generation) effect

Slameka & Graf (1978)

- Had subject study pairs of words in two ways:
  - **Read**: subjects saw two words that were related by a rule and were asked to read them (e.g., are the words synonyms?)
  - **Generate**: subject saw one word along with the first letters of another word, were asked to generate a word that has a specific relationship with the first word
    - e.g., opposite HOT-C___
Testing (and generation) effect

<table>
<thead>
<tr>
<th>Condition 1</th>
<th>Condition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Read</strong></td>
<td><strong>Generate</strong></td>
</tr>
<tr>
<td>king - crown</td>
<td>king - cr___</td>
</tr>
<tr>
<td>horse-saddle</td>
<td>horse-sa___</td>
</tr>
<tr>
<td>lamp-shade</td>
<td>lamp-sh___</td>
</tr>
</tbody>
</table>

... ... ...

**Cued Recall**

| king - _____ | king - cr___ |
| horse-_____  | horse-sa___  |
| lamp-_____   | lamp-sh___   |
Testing (and generation) effect

- Better able to recognize words they had generated than words they read
Testing (and generation) effect

- Retrieving information from memory results in stronger memories than repeated study opportunities
- e.g., preparing for a test by answering practice questions is more effective than re-reading or re-writing notes

Learning is typically identified with encoding or construction of knowledge, and retrieval is considered merely the assessment of learning that occurred in a prior experience. - Karpicke (2012)
Testing (and generation) effect

Karpicke & Roediger (2008)

- Compared whether studying or testing is better for memory
- Study Swahili-English word pairs (mashua - boat)
- After studying, given test (mashua - ?)
- Repeat the study and test sections but varied which words were included in study and test
Testing (and generation) effect

**Karpicke & Roediger (2008)**

- Conditions
  - **ST**: all word pairs were studied and testing in all sections until you got them all right
  - **SnT**: once you got a word correct in a test, it was dropped from later *study* blocks but was kept in later *test* blocks
  - **STn**: once you got a word correct in a test, it was dropped from later test blocks but kept in later study blocks
  - **SnTn**: once you got a word correct in a test, it was dropped from all later blocks.

Testing (and generation) effect

Karpicke & Roediger (2008)

Learned Equally well. One week Later....

Testing (and generation) effect

Roediger & Karpicke (2006)

- Students read educational text and recalled under three conditions
  - **SSSS**: repeated study over four sessions
  - **SSSR**: three study period one retrieval period
  - **SRRR**: one study three retrievals

Testing (and generation) effect

![Graph showing the proportion of idea units recalled over time.](image1)

**Fig. 2.** Mean proportion of idea units recalled on the final test after a 5-min or 1-week retention interval as a function of learning condition (SSSS, SSST, or STTT) in Experiment 2. The labels for the learning conditions indicate the order of study (S) and test (T) periods. Error bars represent standard errors of the means.

![Graph showing forgetting over one week.](image2)

**Fig. 3.** Forgetting over 1 week as a function of learning condition (SSSS, SSST, or STTT) in Experiment 2. The labels for the learning conditions indicate the order of study (S) and test (T) periods.

(Initial recall-final recall)/initial recall

Testing (and generation) effect

Karpicke & Blunt (2011)

- Measured whether testing would benefit the learning of scientific concepts
- Included several comparison conditions that differed in the depth of processing.
  - **Concept mapping:** an elaborative study method where you organize material and encode relationships among concepts.
Testing (and generation) effect

Karpicke & Blunt (2011)

Testing (and generation) effect

Karpicke & Blunt (2011)

Once again, people were bad at predicting what would help them learn!!
Take home message

- Two very important things you can do to improve memory: space and test!
- In every case people’s *intuitions* about how your memory works is different than what really works to improve your memory.
- Next time you say “I learn better like this” catch yourself... is that really true or is that just your feeling?
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

RECOGNITION

OLD or NEW?

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

Not just greater overall brain activity visible in fMRI during active encoding blocks but greater coordination between brain regions involved in memory encoding (e.g. hippocampus) and other regions.

what drives the effect?

meta-cognitive monitoring?
what drives the effect?

Coordination of attention and effort?
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: follow a fixed path

Press spacebar to move

Cue new study location

Control selection of next item
Control item duration
Cue next location (all blocks)
Control onset of next item

<table>
<thead>
<tr>
<th></th>
<th>Exp 1</th>
<th>Exp 2</th>
<th>Exp 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control selection of next item</td>
<td>★</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control item duration</td>
<td>★</td>
<td>★</td>
<td></td>
</tr>
<tr>
<td>Cue next location (all blocks)</td>
<td>★</td>
<td>★</td>
<td>★</td>
</tr>
<tr>
<td>Control onset of next item</td>
<td></td>
<td></td>
<td>★</td>
</tr>
</tbody>
</table>
experiment 2: 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 3: press to reveal next item

<table>
<thead>
<tr>
<th>Control Selection of Next Item</th>
<th>Exp 1</th>
<th>Exp 2</th>
<th>Exp 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Item Duration</td>
<td>⭐</td>
<td>⭐</td>
<td></td>
</tr>
<tr>
<td>Cue Next Location (all blocks)</td>
<td>⭐</td>
<td>⭐</td>
<td></td>
</tr>
<tr>
<td>Control Onset of Next Item</td>
<td></td>
<td></td>
<td>⭐</td>
</tr>
</tbody>
</table>
experiment 3: results

Spatial recall

Distance from studied location

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

Recognition

Proportion endorsed

N = 30
Mean difference = .07
p = .01
Does it extend to children (and long term memory)?

- 26 6-8 year old children
- Told to memorize a grid of icons in preparation for a later test
- 2 “active” grids, 2 “yoked”
- Recognition memory tested immediately and after a 1 week delay

Results

Number of objects correctly recognized

Test

Retest

Active

Yoked
The effect of free choice on memory


“Press a button to reveal target memoranda”

**Choice Condition:** Participant selects which button to press.

**Fixed Condition:** Participant instructed to select red button.

---

**Cue 1 s**  
**Fixation 2-4 s**  
**Encoding: Decision 2 s**  
**Encoding: Object 2 s**
Cue-Evoked Striatum

Encoding-Evoked Perirhinal

** p<0.05, two-tailed, * p < 0.05 one-tailed

* coordinates from Staresina, Duncan, & Davachi, 2010
How to avoid interference?

Shereshevskii: A case study in distinctive encoding

- Subject of “The Mind of a Mnemonist” by A. Luria

- Newspaper reporter with apparently unlimited capacity for memorization

- Experienced synesthesia: e.g., words evoke visual impressions, and sometimes sensations of taste and touch

- Synesthesia led to hyper-distinctive encoding

- Reduces interference

- Incredible memory for details but problems categorizing & generalizing
Mnemonic techniques = techniques for improving recall

Almost all mnemonic systems work by fostering distinctive encoding

Peg-word mnemonic:

one is a bun
two is a shoe
three is a tree
four is a door
five is a hive
six is sticks
seven is heaven
eight is a gate
nine is wine
ten is a hen
Mnemonics

Peg-Word Mnemonic

one is a bun
two is a shoe
three is a tree
four is a door
five is a hive
six is sticks
seven is heaven
eight is a gate
nine is wine
ten is a hen
Mnemonics

Peg-Word Mnemonic

one is a bun  donkey
two is a shoe  cup
three is a tree  elephant
four is a door  stocking
five is a hive  fire engine
six is sticks  ring
seven is heaven  caterpillar
eight is a gate  saucepan
nine is wine  rabbit
ten is a hen  top hat
Mnemonics

Peg-Word Mnemonic

one is a bun
two is a shoe
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Mnemonics - summary

Effective mnemonics require two things:

- Subjects need to form distinctive memory traces -- distinctiveness prevents the memory traces from getting confused with (or overwriting) one another.

- Subjects need a way of finding these distinctive traces.

- Peg-word gives us a way:
  One is a bun
  Two is a shoe...
Availability and Accessibility

- Availability: Is the memory retrievable in principle?

- Accessibility: Assuming that the memory is retrievable in principle, can it be retrieved?

For the peg-word mnemonic:

- Distinctive encoding ensures that the memory is available

- Structured retrieval probes ensure that the memory can be accessed
Method of Loci

Come up with a familiar route, comprised of multiple places (loci)

For example: The route from this classroom to my office

Start in the classroom
Walk to the elevator
down the hall
Into my lab
Into my office

Stash mental images of to-be-remembered stimuli at different places on the route

Example: Remember grocery list of strawberries, milk, bread, chicken, grapes
Methods of memory masters

Memory champions can memorize random digit sequences that are hundreds of digits long. How?

One sample strategy:

Take the digit sequence & break it into 6 digit chunks

For each 6 digit chunk:

The first 2 digits correspond to a **person**
The second 2 digits correspond to an **action**
The third 2 digits correspond to an **object**

e.g., 235637
person #23 (e.g. Todd)
action #56 (e.g. jumping)
object #37 (e.g. turtle)
Methods of memory masters

- Next step: Method of loci

- Stash the images in different loci along the route (e.g. put image of Todd jumping on a turtle in the office..)

- To recall the digit sequence, restart the route
- Look in each location
- Read out the image that’s stored there
The experiment we did, the words weren’t obviously related in a meaningful way. However, meaning obviously plays an important role in our memory.
Carefully study the following paragraph

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. (p. 719)
Anyone want to try to recall it?
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. (p. 719)
Any easier?
Encoding and meaning

- Example from Bransford & Johnson (1972)
- It is hard to remember facts without an appropriate interpretation (known scientifically as a “memory schema”) in place.
2 Why do we forget?
Retrieval from long-term memory
Depending on interference, retrieval cues, moods, and motives, some things get retrieved, some don’t

Long-term storage
Some items are altered or lost

Short-term memory
A few items are both noticed and encoded

Sensory memory
The senses momentarily register amazing detail

Forgetting can occur at any memory stage!!
The “seven sins” of memory

- Transience
- Absent-mindedness
- Blocking
- Misattribution
- Suggestibility
- Bias
- Persistence
Sin #1

Transience
One experiment: Read list of 20 words, waited for a while, then tested his memory (recording which he got write and wrong).

Repeated until perfect memory

LEARNING, DELAY, TEST, RELEARNING... all variables of importance in studies today
The forgetting curve

Rapid forgetting of some information relatively soon after Ebbinghaus learned the nonsense syllables.

Very little memory loss of the remaining information over the course of the following several weeks.

Average percentage of information retained

Interval between original learning of nonsense syllables and memory test

0 10 20 30 40 50 60 70 80 90 100%

20 mins 1 hour 8 hours 24 hours 2 days 6 days 31 days
Ebbinghaus found that the more times he practiced a list of nonsense syllables on day 1, the fewer repetitions he required to relearn it on day 2.

Said simple, the more time we spend learning new information the more we can retain.
Forgetting as retrieval failure

- Retrieval - process of accessing stored information
- Sometimes info IS encoded into LTM, but we can’t access it.
How do people remember?

- Remembering is so commonplace to almost be obvious... it is our ability to use past experience to inform our current experience.

- It has long been recognized that there a really multiple forms of remembering.
Recognition and Recall as Two Forms of Remembering

• Even if we have some *intuition* of how they might be different, the scientific question is how do these forms of memory retrieval or remembering differ from one another?

• What are the INFORMATION PROCESSING STEPS involved in either type of retrieval?
One Hypothesis: The Generation-Recognition Theory

- According to this theory there is really only one process of remembering and it is RECOGNITION.

- RECOGNITION is a simple process... presentation of a stimulus either externally (in the world) or internally (and idea that comes to mind) causes activation of other concepts in your head.

- Successful RECOGNITION happens when the presented cues activate a concept.
One Hypothesis: The Generation-Recognition Theory

- The process of recognition

Spencer (aka dimwit)
One Hypothesis: The Generation-Recognition Theory

- The process of recognition
One Hypothesis: The Generation-Recognition Theory

- How does recall work then?

Grandma’s phone number

512-563-2345
512-832-2856
614-452-5782
419-034-2944
One Hypothesis: The Generation-Recognition Theory

• How does recall work then?

GENERATED LIST

512-563-2345
512-832-2856
614-452-5782
419-034-2944

RECOGNIZE

512-832-2856!!!!
Sin #2

Absent mindedness
Memory and attention
Memory and attention

- The shaded regions indicate low confidence.
Memory and attention

Experiment 2
- Cue new study location
- 600ms

Experiment 3
- Cue new study location
- Press spacebar to move
- 600ms

Experiment 4
- Cue new study location
- Cue reveal
- 750ms
- Press spacebar to reveal item
- 300ms

Table:

<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>
## Memory and attention

### Table 1: Recognition test results

<table>
<thead>
<tr>
<th>Experiment</th>
<th>N</th>
<th>$M(SD)$</th>
<th>$M(SD)$</th>
<th>$M(SD)$</th>
<th>$M(SD)$</th>
<th>t</th>
<th>p</th>
<th>95% CI</th>
<th>Cohen's $d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp 1 (Replication)</td>
<td>30</td>
<td>.11 (.08)</td>
<td>.71 (.19)</td>
<td>.61 (.16)</td>
<td>.10 (.10)</td>
<td>5.67</td>
<td>&lt;.001</td>
<td>.06—.13</td>
<td>1.03</td>
</tr>
<tr>
<td>Exp 2 (Attentional cueing)</td>
<td>30</td>
<td>.13 (.10)</td>
<td>.71 (.16)</td>
<td>.64 (.18)</td>
<td>.07 (.13)</td>
<td>2.70</td>
<td>.01</td>
<td>.02—.11</td>
<td>0.49</td>
</tr>
<tr>
<td>Exp 3 (Follow a fixed path)</td>
<td>32</td>
<td>.12 (.09)</td>
<td>.70 (.19)</td>
<td>.64 (.22)</td>
<td>.06 (.12)</td>
<td>2.86</td>
<td>.01</td>
<td>.02—.10</td>
<td>0.50</td>
</tr>
<tr>
<td>Exp 4 (Press to reveal)</td>
<td>30</td>
<td>.09 (.07)</td>
<td>.71 (.16)</td>
<td>.64 (.20)</td>
<td>.07 (.13)</td>
<td>2.71</td>
<td>.01</td>
<td>.02—.12</td>
<td>0.50</td>
</tr>
</tbody>
</table>
Sin #3

Blocking
Tip of the tongue phenomena

- TOT—involves the sensation of knowing that specific information is stored in long-term memory but being unable to retrieve it.
- Can’t retrieve info that you absolutely know is stored in your LTM.

It is on the tip of my tongue.

```
Retrieval Failure
```

```
It is on the tip of my tongue.
```
Carefully study the following sentences

The friends gathered at an English pub to watch the debate but were late due to traffic.

The harassed customer bought strawberry jam at the supermarket.

Kittens are known to tear up curtains in your house.

The yellow school bus carried us to and from the hotel so to avoid parking problems.
Ignore the adjective and indicate if the noun was present in the sentences you studied

strawberry jam
raspberry jam
traffic jam
Figure 7.2. Light and Carter-Sobell's (1970) study showed that biasing the meaning of a noun at recall hurts recognition performance.
Encoding and meaning

- We don’t simply remember words... memory is tied to the meaning of the material to us when we study it.

- Again, consistent with the encoding specificity hypothesis examined in our experiments: what enters into memory depends on how it was studied.

- Ok, but is this last one surprising? (i.e., seems obvious we have two representations of “jam” in memory)
Study

(Barclay, Bransford, Franks, McCarrel, & Nitsch, 1974)

The man lifted the piano

Or

The man tuned the piano
<table>
<thead>
<tr>
<th><strong>Study</strong></th>
<th><strong>Test cues</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The man lifted the piano</td>
<td>something heavy</td>
</tr>
<tr>
<td>Or</td>
<td>-and-</td>
</tr>
<tr>
<td>The man tuned the piano</td>
<td>something with a nice sound</td>
</tr>
</tbody>
</table>
The man lifted the piano
Or
The man tuned the piano

something heavy
-and-
something with a nice sound
Piano
- Has Keys
- Sounds nice
- Heavy

Horses running on a beach?

Lang Lang
Piano
- Sounds nice
- Has Keys
- Heavy

Horses running on a beach?

Lang Lang
Sin #4

Misattribution
Varieties of misattribution

- **Source memory confusions** - correctly remember an item or fact but attribute it to an incorrect source.
  - Stronger in older adults (has implications for medication recommendations!)

- **Cryptomnesia** - Attribution of a spontaneous idea despite it being a memory
  - Unintentional plagiarism
  - Fluency effects on memory
Varieties of misattribution

- Roediger & McDermott (1995) effect - false memory after studying lists of related words
  - Study 15 thematically related words (e.g., fruits) and later falsely remember fruits that were not presented (e.g., banana, if it didn’t occur in original list).

Recall: ~ 40% recalled “sleep”
Recognition: Remembering the lure (sleep) during recall strengthened participants memories of the lure during recognition
  - Participants claimed to “remember” the lure rather than merely “know” it had been on the list

Content vs. technical accuracy?
Sin #5

Suggestibility
Misinformation Effect

- Elizabeth Loftus work on eyewitness testimony and suggestion
- Incorporating misleading information into one’s memory of an event

- Subjects shown video of an accident between two cars
- Some subjects asked: How fast were the cars going when they smashed into each other?
- Others asked: How fast were the cars going when they hit each other?

Leading question: “About how fast were the cars going when they smashed into each other?”

Memory
## Results

### Accident

Leading question:

“About how fast were the cars going when they smushed into each other?”

### Memory

<table>
<thead>
<tr>
<th>Word Used in Question</th>
<th>Average Speed Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>smashed</td>
<td>41 m.p.h.</td>
</tr>
<tr>
<td>collided</td>
<td>39 m.p.h.</td>
</tr>
<tr>
<td>bumped</td>
<td>38 m.p.h.</td>
</tr>
<tr>
<td>hit</td>
<td>34 m.p.h.</td>
</tr>
<tr>
<td>contacted</td>
<td>32 m.p.h.</td>
</tr>
</tbody>
</table>
Sin #6
Bias

Sin #7
Omission
Reconstructive memory and semantic integration

- Bartlett (1932)
- Interested in studying memory for meaningful material
- Subjects read a tale “War of the Ghosts” and then re-told it several times
- Looked at progressive changes in what subjects remembered about the story
Bartlett (1932)

- Omissions:
  - Poor recall for many of the details (specific names, or events)
  - Minor events were omitted (recall for main plot and sequence of events was not too bad)
  - Shorter than the original

- Normalizations:
  - Tendency to add and alter the stories to make them more conventional or reasonable (top-down processing)
Bartlett (1932)

- Human memory for this type of material is NOT reproductive
  - A highly accurate, verbatim recording of an event
- Rather, it is reconstructive
  - Altered during BOTH storage and retrieval
  - Combining elements from the original material with existing knowledge
Anderson’s Rational Approach to Cognition

• Why do we see the regularities that we see in various Cognitive tasks?

• One answer:
  – Because of characteristics of the mechanisms of human thought

• Another answer:
  – Because the regularities represent the optimal response to the characteristics of the environment
Why do we forget?

• Is it because our memory is imperfect?

• Or

  • It costs us something to keep information around and accessible in our brain?

  • Information from a long time ago is less likely to be useful or needed again compared to information we’ve been exposed to recently.
Power Law of Forgetting (Anderson and Schooler, 1991)

\[ P = AT^{-b} \quad \text{or:} \]
\[ \log(P) = \log(A) - b \log(T) \]
Which topic is most likely to be in tomorrow’s paper?

- **Two headlines from 100 days ago:**
  - Hillary Clinton admitted to hospital with blood clot
  - US Government approaching the fiscal cliff (tax hikes and sequestration)

- **Two headlines from yesterday**
  - Margaret Thatcher passed away
  - North Korean is threatening the United States and South Korea
Power Law of Recurrence