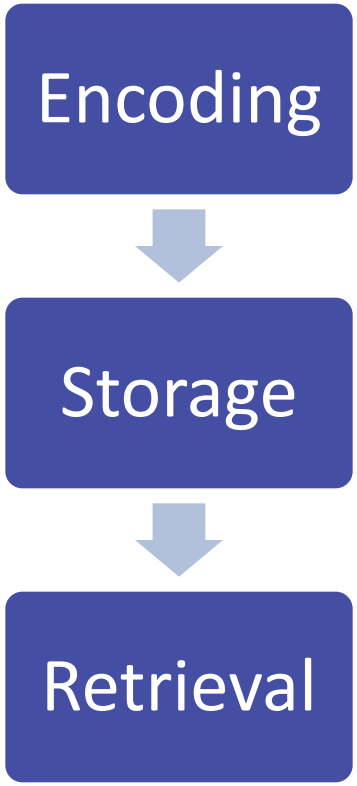
How Does Memory Work? An Information-Processing Model

Here is a simplified description of how memory works:



- **Encoding:** the information gets into our brains in a way that allows it to be stored
- **Storage:** the information is held in a way that allows it to later be retrieved
- **Retrieval:** reactivating and recalling the information, producing it in a form similar to what was encoded

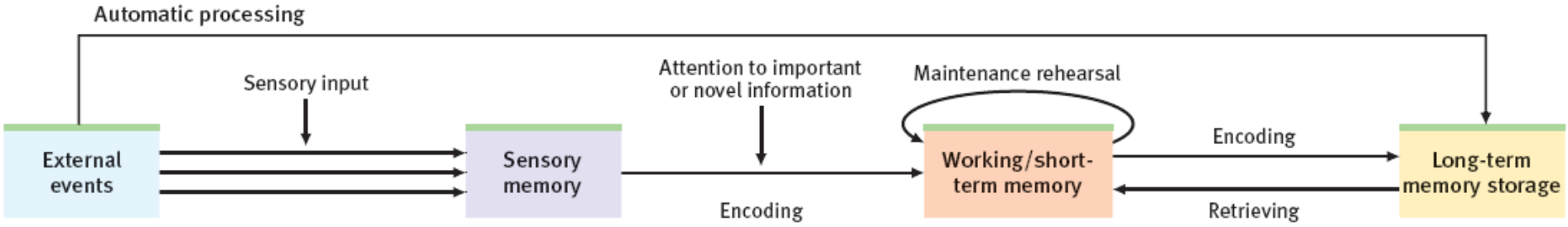
Models of Memory Formation

The Atkinson-Shiffrin Model (1968)

1. Stimuli are recorded by our senses and held briefly in **sensory memory**.
2. Some of this information is processed into **short-term memory** and encoded through *rehearsal* .
3. Information then moves into **long-term memory** where it can be retrieved later.

Modifying the Model:

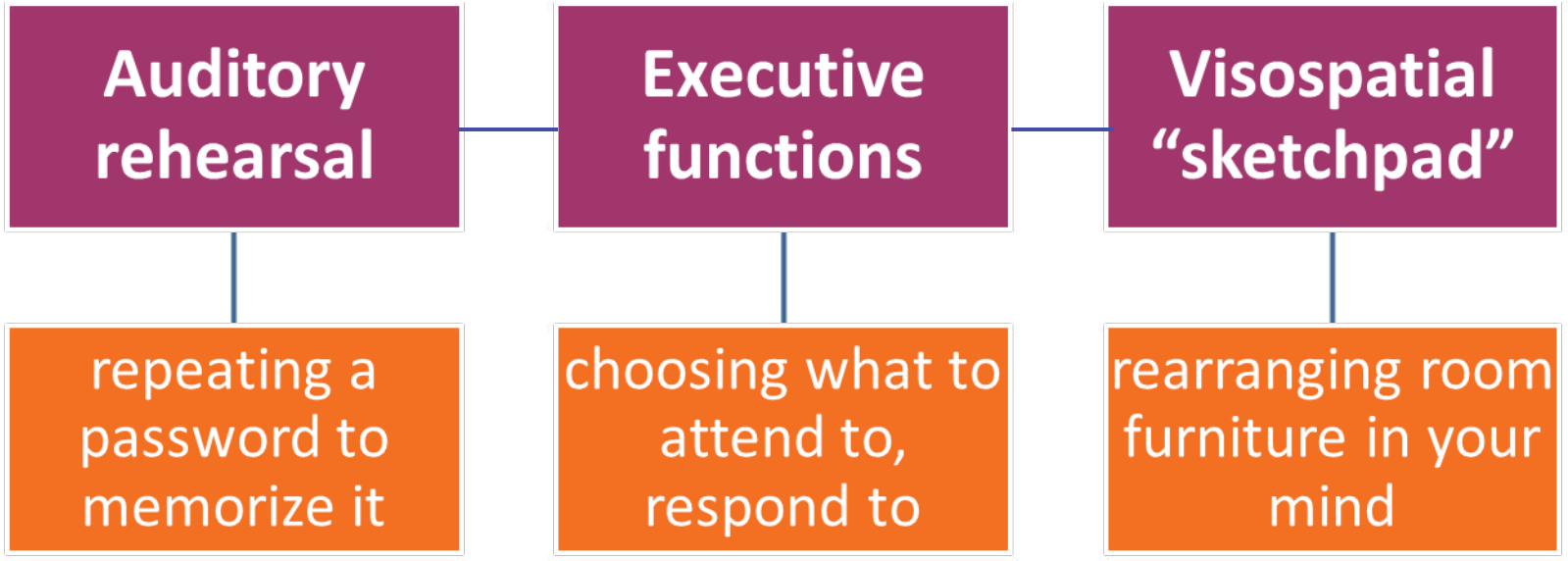
- More goes on in short-term memory besides rehearsal; this is now called **working memory**.
- Some information seems to go straight from sensory experience into long-term memory; this is **automatic processing**.



Working Memory: Functions

The short-term memory is “working” in many ways.

- It holds information not just to rehearse it , but to process it (such as hearing a word problem in math and doing it in your head).



Short-term memory integrates information from long-term memory with new information coming in from sensory memory.

Dual-Track Processing: Explicit and Implicit Memories

So far, we have been talking about **explicit/ "declarative" memories**. *These are facts and experiences that we can consciously know and recall*.

Our minds acquire this information through **effortful processing**. Explicit memories are formed through studying, rehearsing, thinking, processing, and then storing information in long-term memory.

Some memories are formed without going through all the Atkinson-Shiffrin stages. These are **implicit memories**, the ones we are not fully aware of and thus don't "declare"/talk about.

These memories are typically formed through **automatic processing**. Implicit memories are formed *without our awareness that we are building a memory*, and without rehearsal or other processing in working memory.

Automatic Processing

Some experiences go directly to long-term implicit memory

Some experiences are processed automatically into implicit memory, without any effortful/working memory processing:

- **procedural memory**, such as knowing how to ride a bike, and well-practiced knowledge such as word meanings
- **conditioned associations**, such as a smell that triggers thoughts of a favorite place
- information about **space**, such as being able to picture where things are after walking through a room
- information about **time**, such as retracing a sequence of events if you lost something
- information about **frequency**, such as thinking, “I just noticed that this is the third texting driver I’ve passed today.”

The Encoding and Processing of Memory: Sensory Memory

Sensory memory refers to the immediate, very brief recording of sensory information before it is processed into short-term, working, or long-term memory.

- We very briefly capture a **sensory memory**, analogous to *an echo or an image, of all the sensations we take in*.
- How brief? Sensory memory consists of about a 3 to 4 second **echo**, or a 1/20th of a second **image.**
- Evidence of **auditory** sensory memory, called "**echoic**" memory, can occur after someone says, "what did I just say?" *Even if you weren't paying attention, you can retrieve about the last eight words from echoic memory*.

Evidence of **Visual** Sensory (**Iconic)** Memory: George Sperling's Experiments

- George Sperling (b. 1934) exposed people to a 1/20th of-a-second view of a grid of letters, followed by a tone which told them which row of letters to pull from iconic memory and recall.
- Without the tone, people recalled about 50 percent of the letters; with the tone, recall for any of the rows was typically 100 percent.

To simulate Sperling's experiment, notice the three rows of letters below. Based on the color of the letters, you will know that you must recall one of the following rows:
top, middle or bottom.

J Y Q

P G S

V F M

Encoding Memory

Capacity of Short-Term and Working Memory

- If some information is selected from sensory memory to be sent to short-term memory, how much information can we hold there?
- George Miller (b. 1920) proposed that we can hold 7 +/-2 information bits (for example, a string of 5 to 9 letters).
- More recent research suggests that the average person, free from distraction, can hold about:
- **7 digits, 6 letters, or 5 words.**

Test:

Working Memory, *which uses rehearsal, focus, analysis, linking, and other processing*, has greater capacity than short-term memory. The capacity of working memory varies; some people have better concentration.

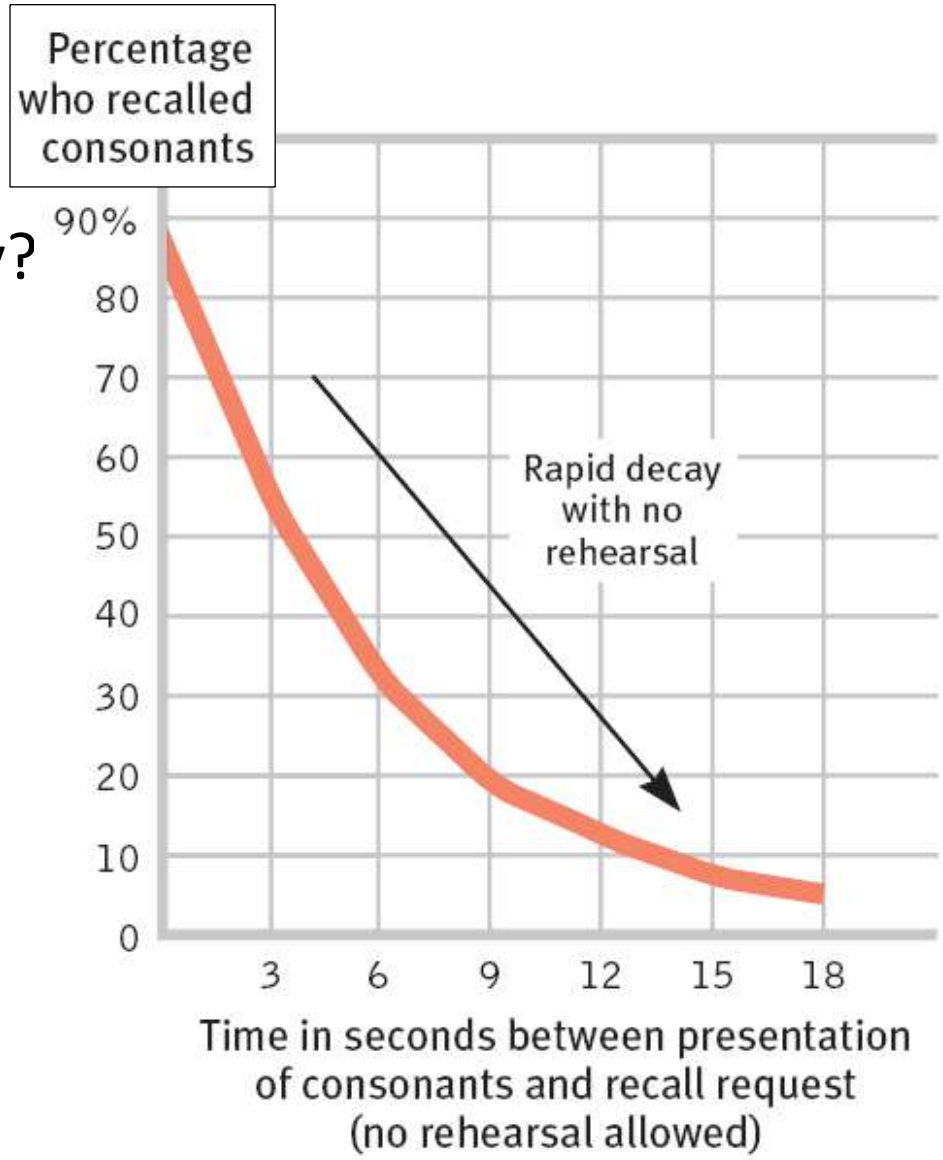
Test: see how many of these letters and numbers you can recall after they disappear. No need for a hyphen before the V.

Duration of Short-Term Memory (STM)

Lloyd Peterson and Margaret Peterson wanted to know the **duration** of short term memory? Their experiment (1959):

1. People were given triplets of consonants (e.g., “VMF”).
2. To prevent rehearsing, the subjects had to do a distracting task.
3. People were then tested at various times for recall.

Result: After 12 seconds, most memory of the consonants had decayed and could not be retrieved.



Encoding: Effortful Processing Strategies

If we have short-term recall of only 7 letters, but can remember 5 words, doesn't that mean we could remember more than 7 letters if we could group them into words?

- This is an example of an **effortful processing strategy**, *a way to encode information into memory to keep it from decaying and make it easier to retrieve*.
- Effortful processing is also known as **studying.**

Examples:

- Chunking (grouping)
- Mnemonics: images, maps, and peg-words
- Hierarchies/categories
- Rehearsal, especially distributed practice
- Deep processing
- Semantic processing
- Making information personally meaningful

→ **Can you remember this list?**

Effortful Processing Strategies

Chunking

- Why are credit card numbers broken into groups of four digits? Four "chunks" are easier to encode (memorize) and recall than 16 individual digits.

→ Memorize: ACPCVSSUVROFLNBAQ XIDKKFCFBIANA

- **Chunking:** *organizing data into manageable units*

XID KKF CFB IAN AAC PCV S SU VRO FNB AQ

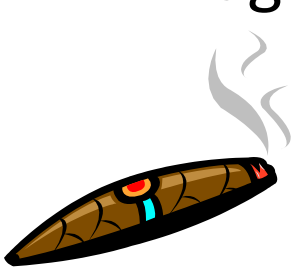
- **Chunking** works even better if we can assemble information into meaningful groups:

X IDK KFC FBI BA NAACP CVS SUV ROFL NBA Q

X IDK KFC FBI BA NAACP CVS SUV ROFL NBA Q

Effortful Processing Strategies
Mnemonics

- Read: plane, cigar, due, shall, candy, vague, pizza, seem, fire, pencil
- Which words might be easier to remember?
- Write down the words you can recall.
- Lesson: we encode better with the help of images.



A **mnemonic** is a memory "trick" that connects information to existing memory strengths such as imagery or structure.

A **peg word system** refers to the technique of visually associating new words with an existing list that is already memorized along with numbers. For example, "due" can be pictured written on a door, and door = 4.

Effortful Processing Strategies
Rehearsal and Distributed Practice

Massed Practice refers to cramming information all at once.

It is not time-effective.

- The **spacing effect** was first noted by Hermann Ebbinghaus in the late 1800s. You will develop better retention and recall, especially in the long run, if you use the same amount of study time spread out over many shorter sessions.
- This doesn't mean you have to study every day. Memory researcher Harry Bahrick noted that the longer the time between study sessions, the better the long-term retention, and the fewer sessions you need!

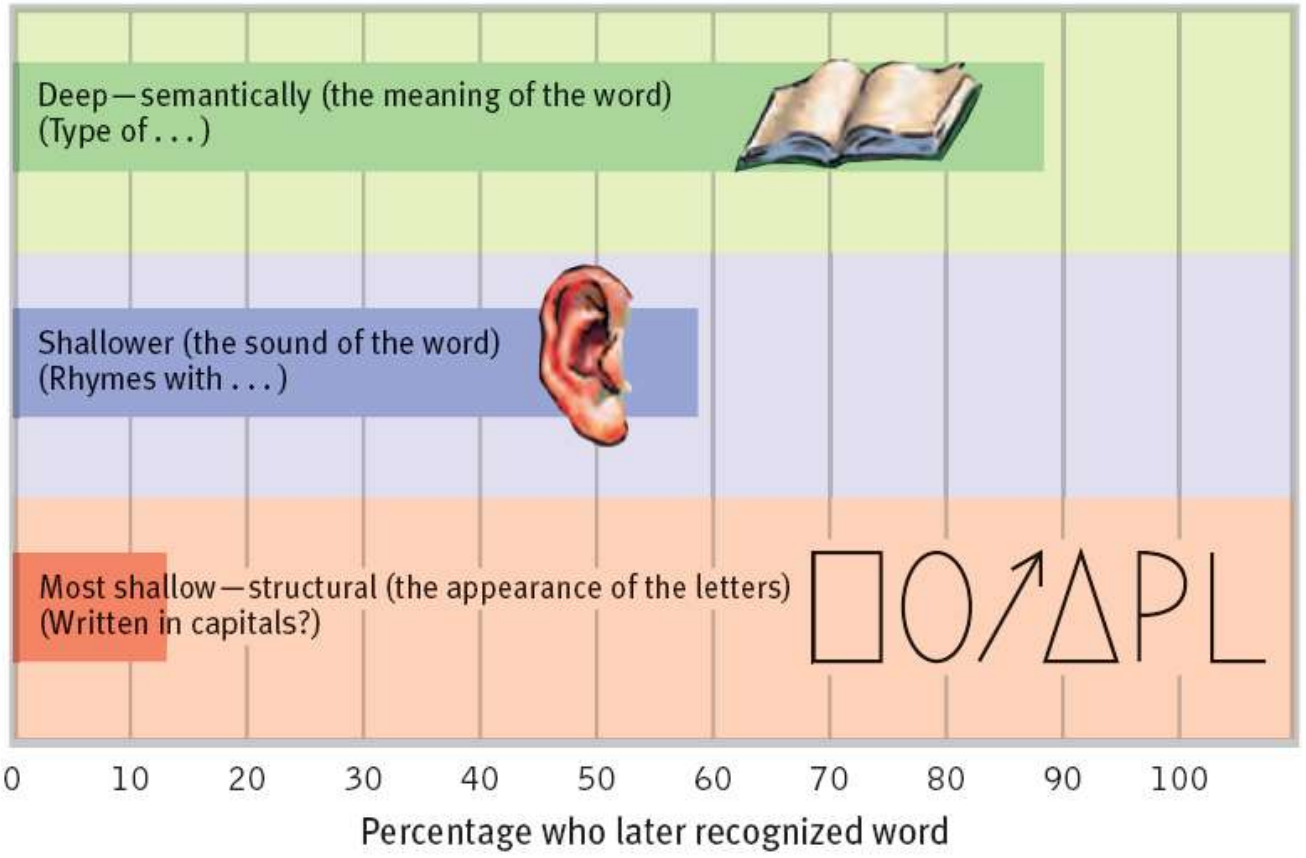
The best way to practice? Consider the **testing effect.** Henry Roediger (b. 1947) found that *if your distributed practice includes testing (having to answer questions about the material), you will learn more and retain more than if you merely reread.*

Effortful Processing Strategies

Deep/Semantic Processing

When encoding information, we are more likely to retain it if we deeply process even a simple word list by focusing on the **semantics (*meaning*)** of the words.

"Shallow," unsuccessful processing refers to memorizing the appearance or sound of words.



Effortful Processing

Making Information Personally Meaningful

Memorize the following words:

boldtrucktemper
greenrundrama
gluechipsknob
hardventrope

- We can memorize a set of instructions more easily if we figure out what they mean rather than seeing them as set of words.
- Memorizing meaningful material takes one tenth the effort of memorizing nonsense syllables.
- Actors memorize lines (and students memorize poems) more easily by deciding on the feelings and meanings behind the words, so one line flows naturally to the next.
- The **self-reference effect**, relating material to ourselves, aids encoding and retention.
- Now try again, but this time, consider how each word relates to you.

Memory Storage: Capacity and Location

- The brain is NOT like a hard drive. Memories are NOT in isolated files, but are in overlapping neural networks.
- The brain's long-term memory storage does not get full; it gets more elaborately rewired and interconnected.
- Parts of each memory can be distributed throughout the brain.

  → Memory of a particular 'kitchen table' may be a linkage among networks for 'kitchen,' 'meal,' 'wooden,' 'home,' 'legs,' and 'sit.'

Karl Lashley (1890-1958) showed that rats who had learned a maze retained parts of that memory, even when various small parts of their brain were removed.

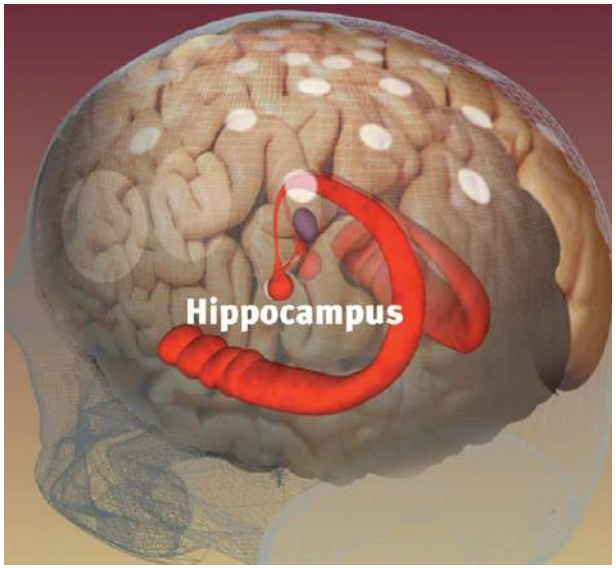
Memory Processing in The Brain

If memory is stored throughout the brain, how does it get in there, and how do we retrieve it and use it?

- There are different storage and retrieval/activation systems in the brain for **explicit**/ declarative memory and for **implicit**/ procedural memory.
- When emotions become involved, yet another part of the brain can mark/flag some memories for quicker retrieval.
- The storage occurs by changing how neurons link to each other in order to make some well-used neural networks of neurons easier to activate together.

Explicit Memory Processing

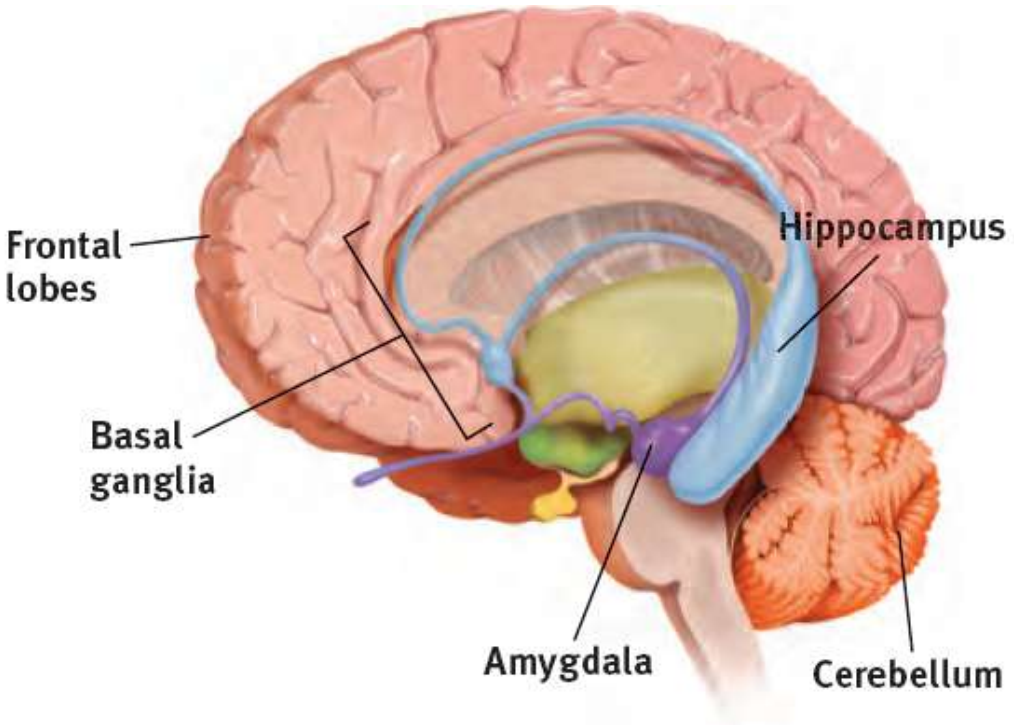
Explicit/declarative memories include *facts, stories, and meanings of words* such as the first time riding a bike, or facts about types of bicycles.



- **Retrieval and use** of explicit memories, which is in part a working memory or executive function, is directed by the frontal lobes.
- **Encoding and storage** of explicit memories is facilitated by the hippocampus. Events and facts are held there for a couple of days before **consolidating**, *moving to other parts of the brain for long-term storage*. Much of this consolidation occurs during sleep.

The Brain Stores Reactions and Skills
Implicit Memory Processing

Implicit memories include skills, procedures, and conditioned associations.

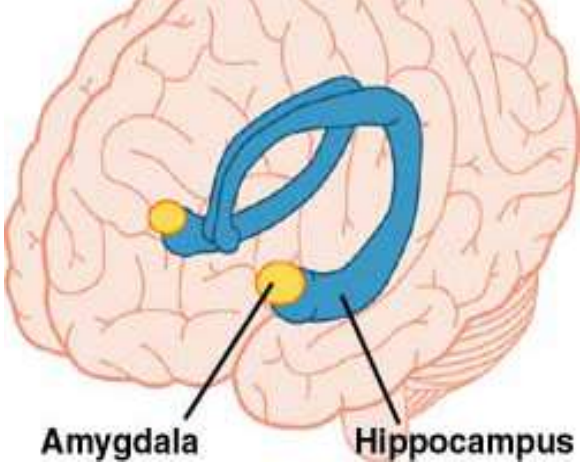


- **The cerebellum** ("little brain") forms and stores our conditioned responses. *We can store a phobic response even if we can't recall how we acquired the fear*.
- The **basal ganglia**, next to the thalamus, controls movement, and forms and stores procedural memory and motor skills. *We can learn to ride a bicycle even if we can't recall having the lesson.*

Emotions and Memory

- Strong emotions, especially stress, can strengthen memory formation.
- **Flashbulb memories** refer to emotionally intense events that become "burned in" as a vivid-seeming memory.
- Note that flashbulb memories are not as accurate as they feel.
- Vividly storing information about dangers may have helped our ancestors survive.

Emotions, Stress Hormones, the Amygdala, and Memory



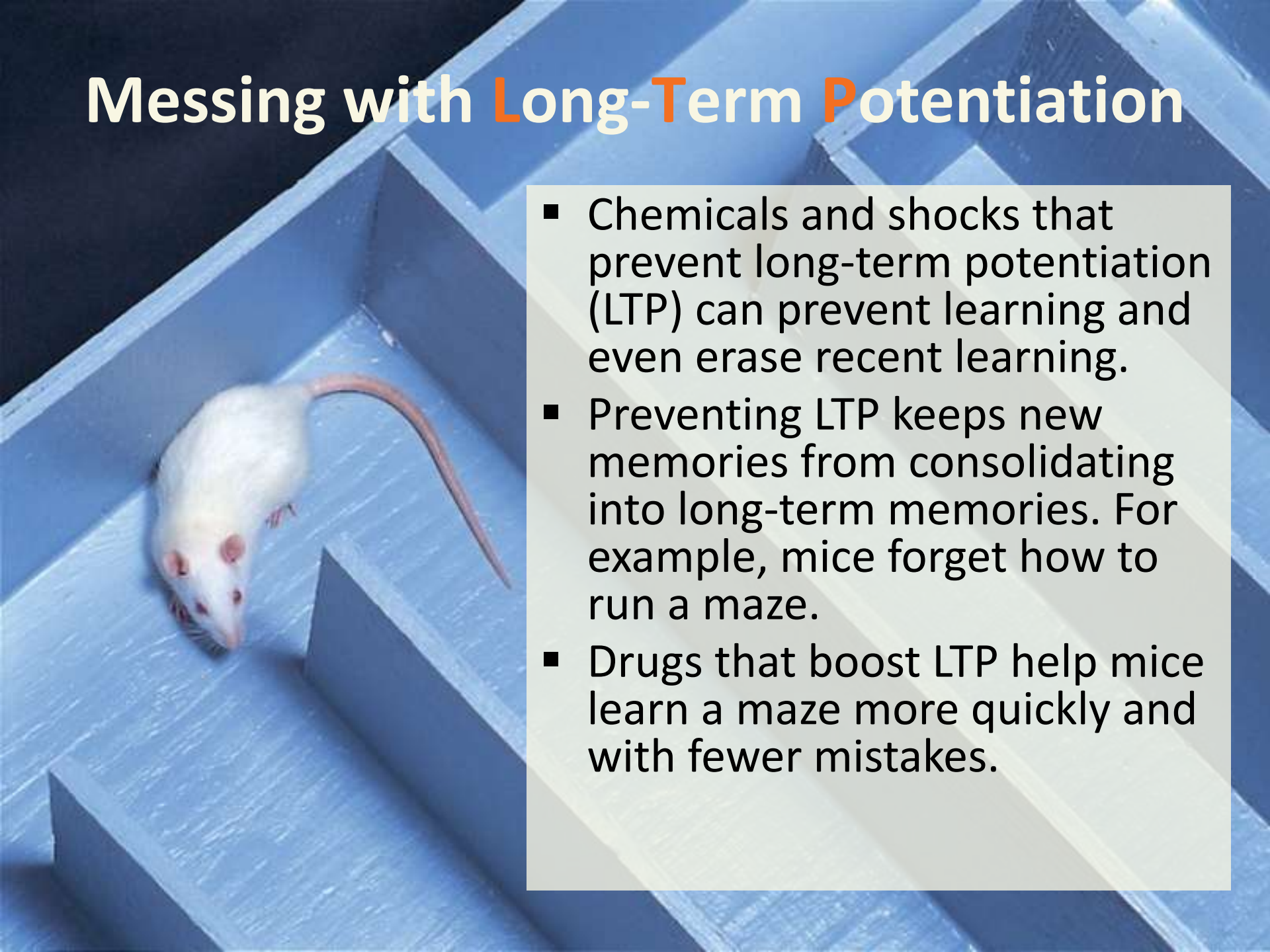
How does intense emotion cause the brain to form intense memories?

1. Emotions can trigger a rise in stress hormones.
2. These hormones trigger activity in the amygdala, located next to the memory-forming hippocampus.
3. The amygdala increases memory-forming activity and engages the frontal lobes and basal ganglia to "tag" the memories as important.

As a result, the memories are stored with more sensory and emotional details.

- These details can trigger a rapid, unintended recall of the memory.
- Traumatized people can have intrusive recall that is so vivid that it feels like re-experiencing the event.

Messing with Long-Term Potentiation

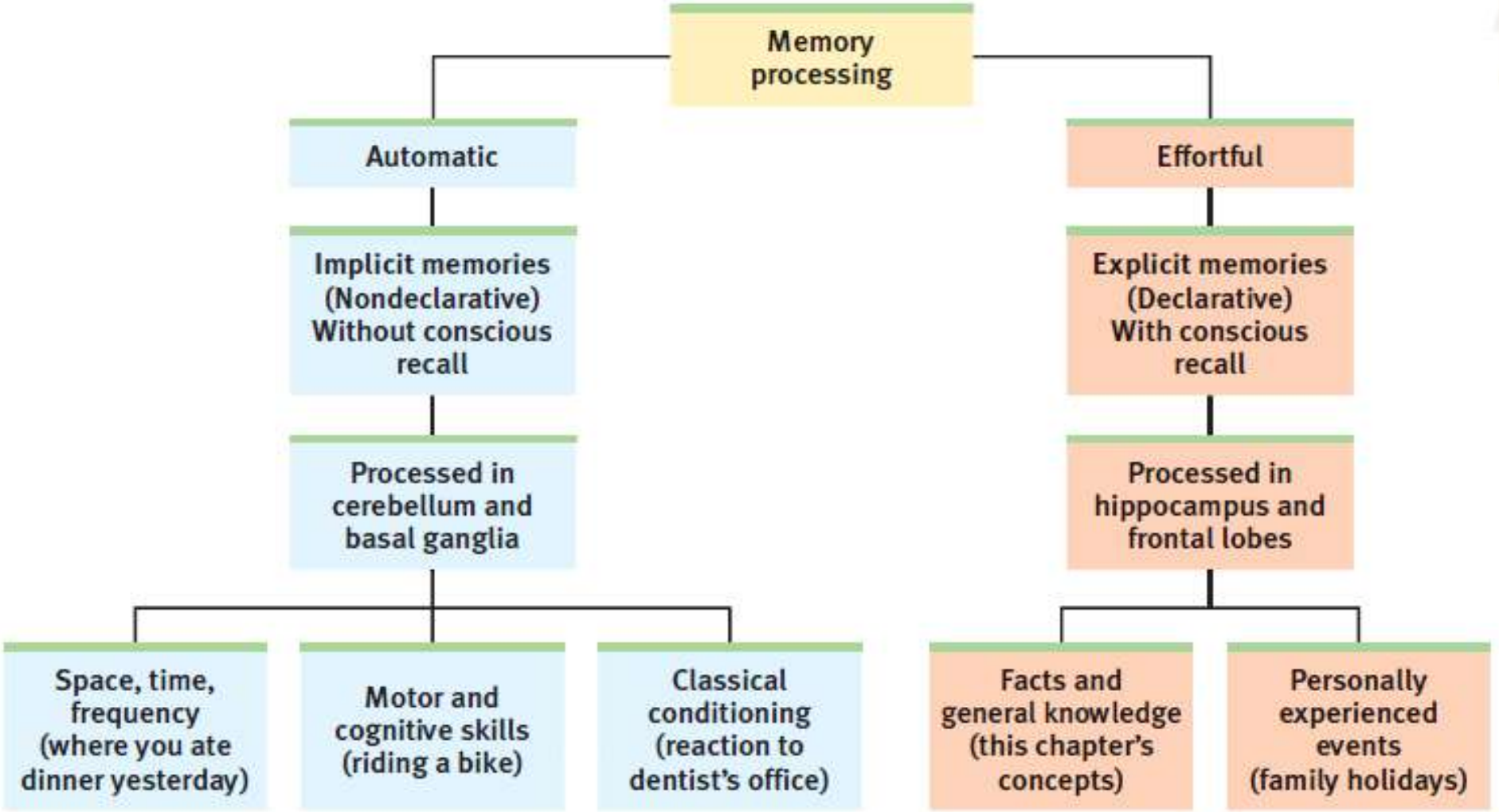


- Chemicals and shocks that prevent long-term potentiation (LTP) can prevent learning and even erase recent learning.
- Preventing LTP keeps new memories from consolidating into long-term memories. For example, mice forget how to run a maze.
- Drugs that boost LTP help mice learn a maze more quickly and with fewer mistakes.

Possible FR

- Explain the difference between retrograde and anterograde amnesia
- Explain how mnemonic devices improve memory
- Identify the different areas of the brain associate with memory
- How does Herman Ebbinghaus explain why people forget information
- Differentiate between, retroactive and pro

Summary:
Types of Memory Processing



Memory Retrieval

- **Recall**: some people, through practice, visual strategies, or biological differences, have the ability to store and recall thousands of words or digits, reproducing them years later ("fill-in-the-blank")
- **Recognition:** the average person can view 2500 new faces and places, and later can notice with 90 percent accuracy which ones they've seen before ("multiple choice")
- **Relearning:** some people are unable to form new memories, especially of episodes; although they would not recall a puzzle-solving lesson, they might still *solve the puzzle faster each lesson*

Lessons from each of these demonstrations:

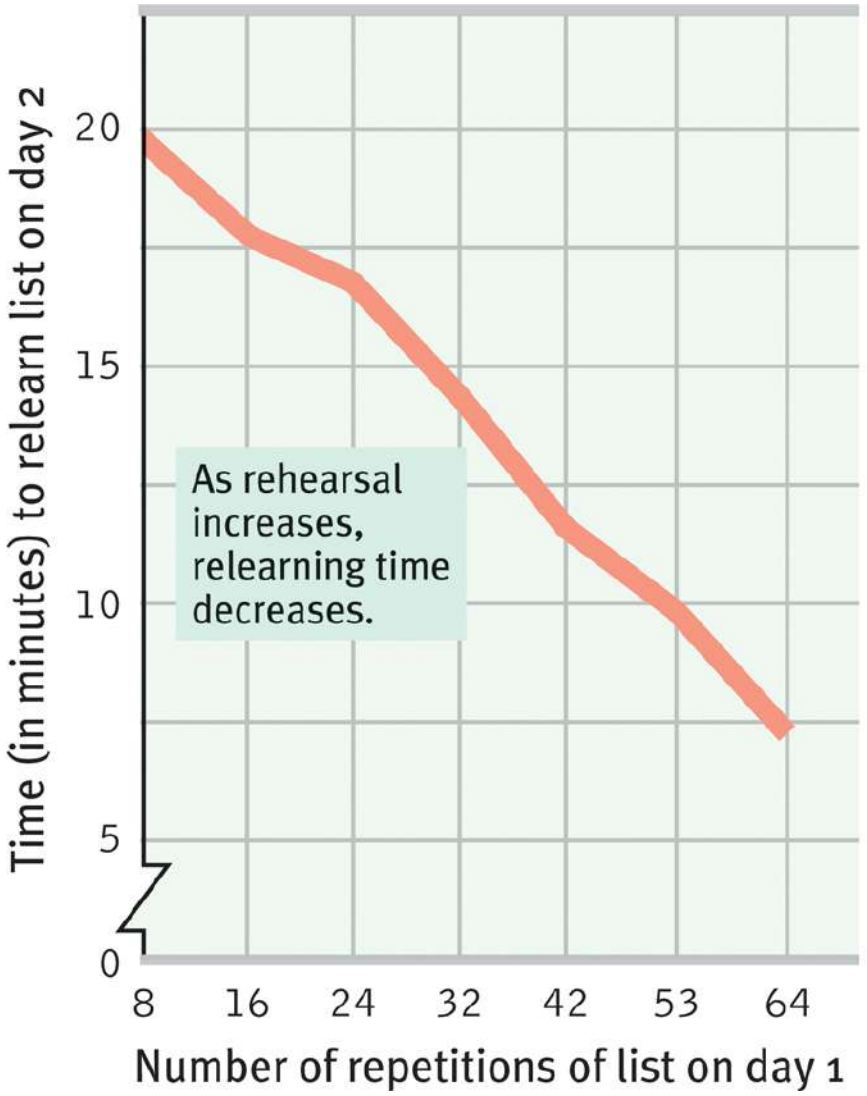
1.our **storage** and **recall** capacity is virtually unlimited

2.our capacity for **recognition** is greater than our capacity for recall

3.relearning can highlight that memories are there even if we can't recall forming them

Relearning Time as a Measure of Retention

- In the late 1800s, Hermann Ebbinghaus studied another measure of memory functioning: how much time does it take to relearn and regain mastery of material?
- He studied the memorization of nonsense syllables (THB YOX KVU EHM) so that depth of processing or prelearning would not be a factor.
- The more times he **rehearsed** out loud on day 1, the less time he needed to **relearn**/memorize the same letters on day 2.



Priming:

Retrieval is Affected by Activating our Associations

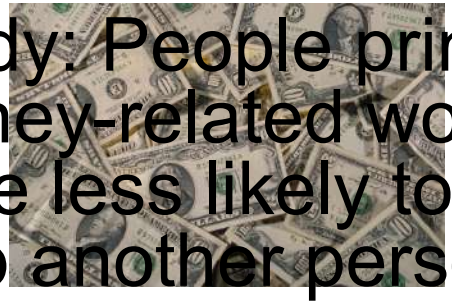
- **Priming** triggers a thread of associations that bring us to a concept, just as a spider feels movement in a web and follows it to find the bug.
- Our minds work by having one idea trigger another; this maintains a flow of thought.

Priming Example: Define the word "bark."

Now what is the definition of "bark"?

The Power of Priming

- Priming has been called “invisible memory” because it affects us unconsciously.
- In the case of tree “bark” vs. dog “bark,” the path we follow in our thoughts can be channeled by priming.
- We may have biases and associations stored in memory that also influence our choices.



Study: People primed with money-related words were less likely to then help another person.

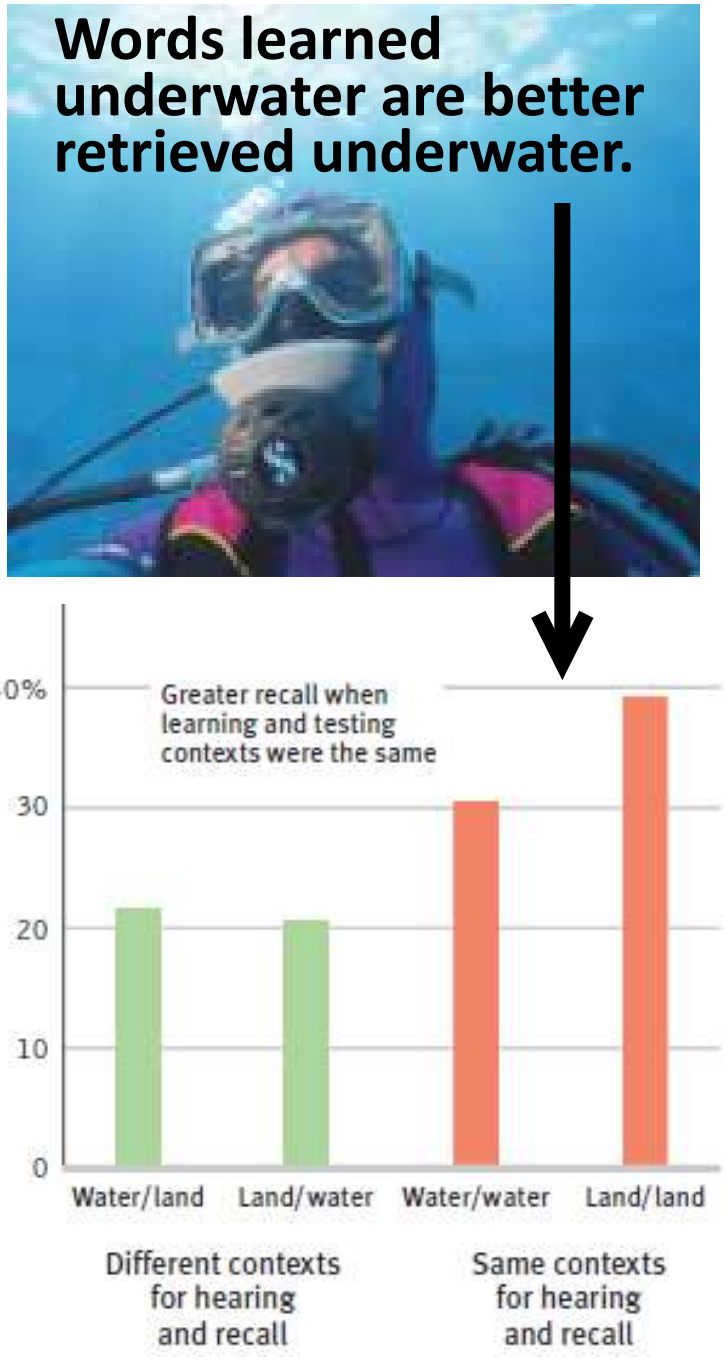
Study: Priming with an image of Santa Claus led kids to share more candy.

Study: p primed with a r hild poster th misinterp ambiguous hild interactions

Context-Dependent Memory

- Part of the web of associations of a memory is the **context**. *What else was going on at the time we formed the memory?*
- **We retrieve a memory more easily when in the same context as when we formed the memory.**

  → Did you forget a psychology concept? Just sitting down and opening your book might bring the memory back.



State-Dependent Memory

- Our memories are not just linked to the **external** context in which we learned them.
- Memories can also be tied to the **emotional state** we were in when we formed the memory.
- **Mood-congruent memory** *refers to the tendency to selectively recall details that are consistent with one's current mood.*

  → This biased memory then reinforces our current mood!

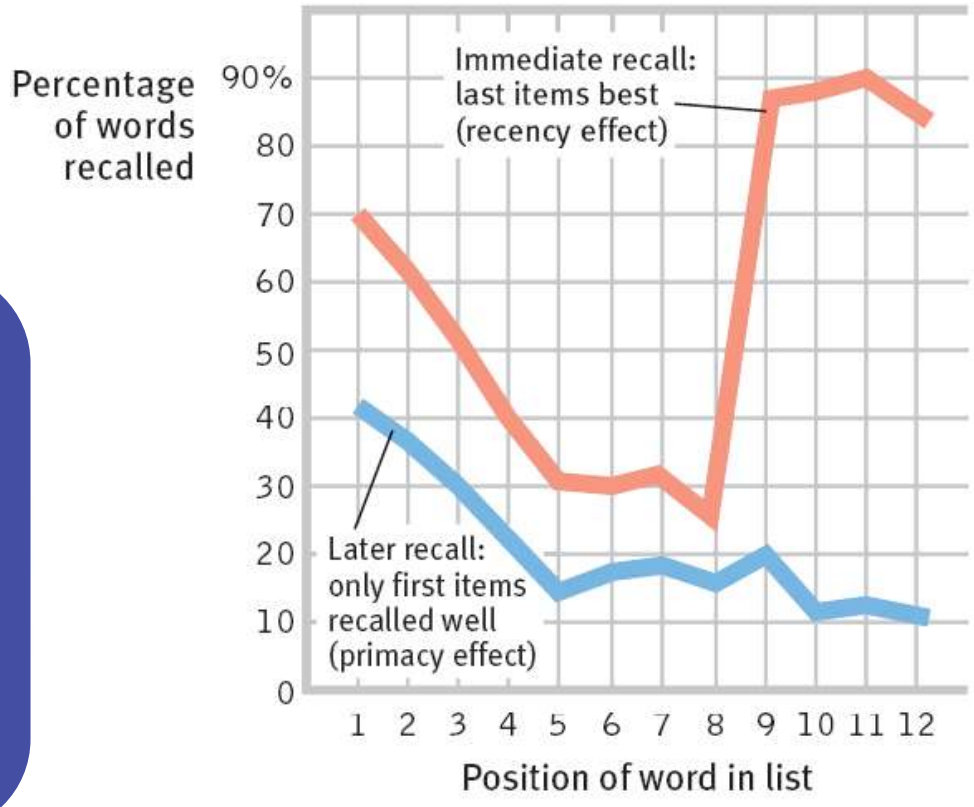
Memories can even be linked to physiological states:

"I wonder if you'd mind giving me directions. I've never been sober in this part of town before."

The Serial Position Effect

Priming and context cues are not the only factors which make memory retrieval selective.

The serial position effect refers to the tendency, when learning information in a long list, to *more likely recall the first items* (**primacy effect**) *and the last items* (**recency effect**).



In what situation is the recency effect strongest?

Which words of your national anthem are easiest to recall?

“Forgetfulness is a form of freedom.”
Khalil Gibran

Jill Price, patient “A.J.”

- Jill Price (b. 1965) has hyperthymesia; she not only recalls everything, but is unable to forget anything.
- For Jill, both the important and the mundane are always accessible, forming a “running movie” of images and information that run simultaneously with current stimuli.
- She has said, “I’ll be talking to someone and [also] seeing something else…”

Another possible problem if we were unable to forget: we might not focus well on current stimuli because of intrusive memories.

The Brain and the Two-Track Mind: The Case of Henry Molaison ("H.M.")

- In 1953, the removal of H.M.'s hippocampus at age 27 ended his seizures, but also ended his ability to form new explicit memories.
- H.M. could learn new skills, procedures, locations of objects, and games, but had no memory of the lessons or the instructors. Why?
- H.M. also retained memories from before the surgery. What is his condition called?

H.M., like another such patient, "Jimmy," could not understand why his face looked older than 27 in the mirror. Why not?

The Two Types of Amnesia

Retrograde amnesia *refers to an inability to* ***retrieve*** *memory of the past.*

- Retrograde amnesia can be caused by head injury or emotional trauma and is often temporary.
- It can also be caused by more severe brain damage; in that case, it may include anterograde amnesia.

Anterograde amnesia refers to an *inability to* ***form*** *new long-term declarative/ explicit memories.*

- H.M. and Jimmy lived with no memories of life after surgery.
- See also the movie *Memento.* Most other movie amnesia is retrograde amnesia.

Penny Memory Test

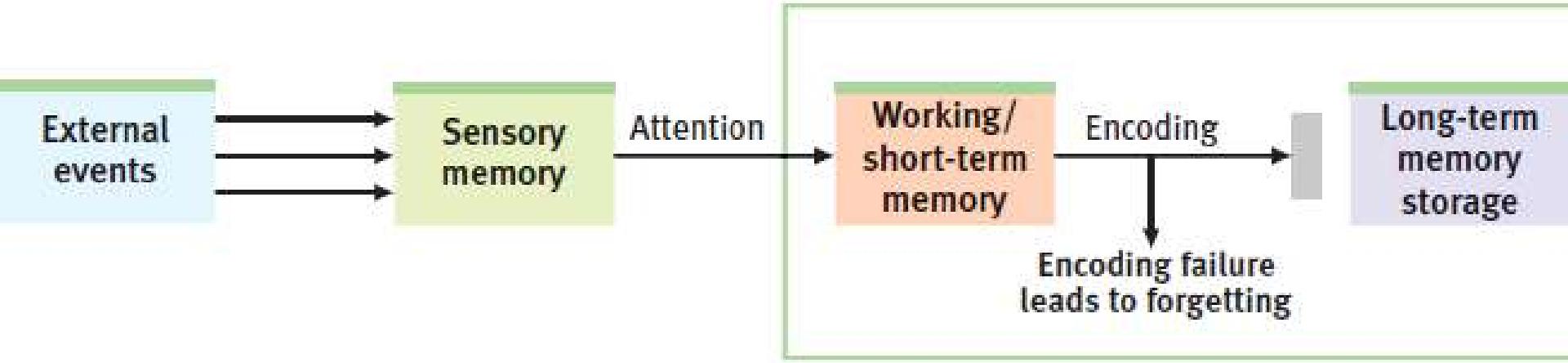
Which of these has the design of an actual U.S. cent?

Retrieval test: what words and numbers, in which locations, are on the front of a U.S. one cent coin? This should be easy because it was in the book.

Recognition test: choose the correct design from among these pictures:

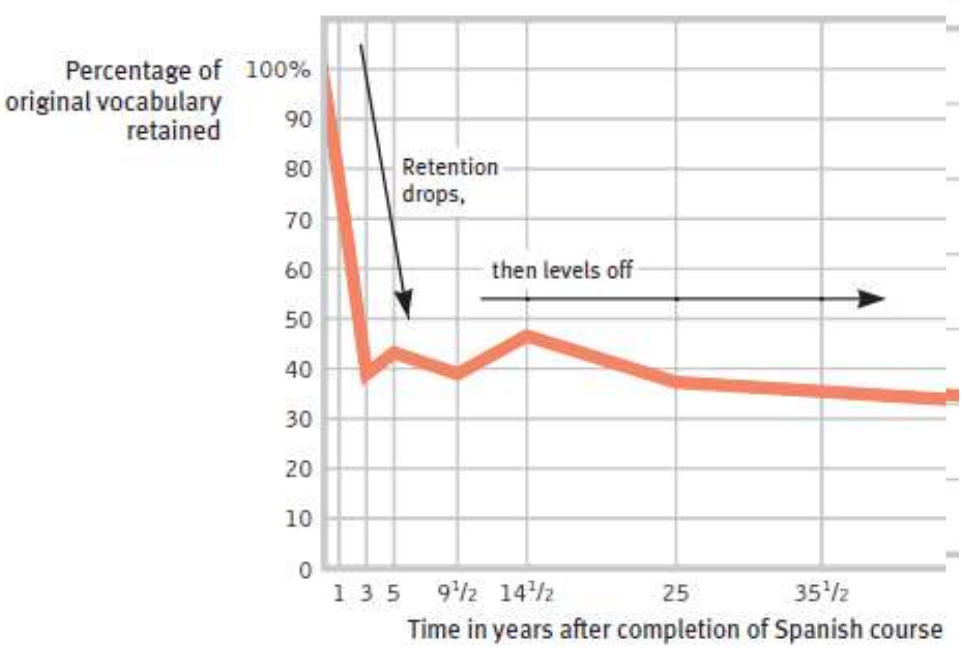
Encoding Failure

- If we got the penny image wrong, did we fail to **retrieve** the information?
- It could be that we never paid attention to the penny details and didn't select them from sensory memory to hold in working memory.
- Even if we once looked at the penny and paid attention to it, we still didn't bother rehearsing it and **encoding** it into long term memory.



Storage Decay

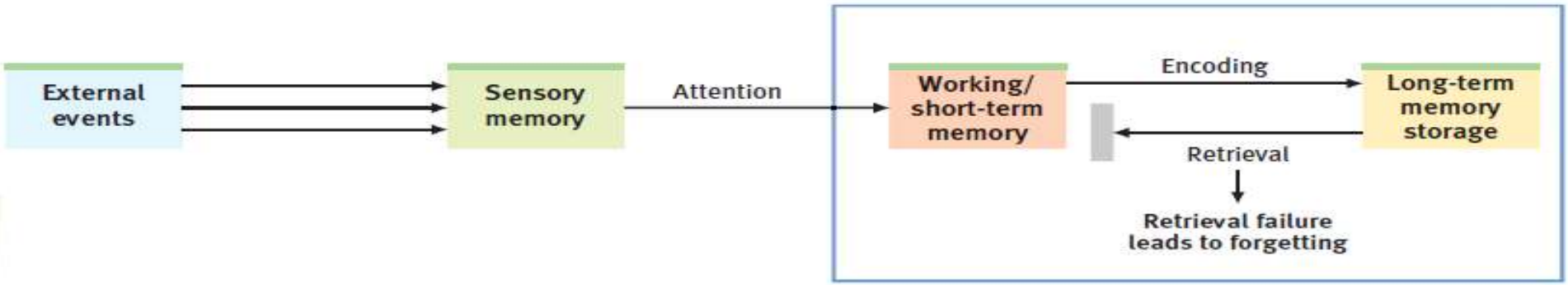
- Material encoded into long term memory will decay if the memory is never used, recalled, and re-stored.
- Decay is LTP in reverse (or like pruning). Unused connections and networks wither while well-used memory traces are maintained.



- Decay tends to level off. Memory for both nonsense syllables and Spanish lessons decays rapidly.
- However, what hasn't decayed quickly tends to stay intact long-term.

Tip of the Tongue: Retrieval Failure

- Sometimes, the memory itself does not decay. Instead, what decays are the associations and links that help us find our way to the stored memory.
- As a result, some stored memories seem just below the surface: “I know the name...it starts with a B maybe…”
- To prevent retrieval failure when storing and rehearsing memories, you can build multiple associations, linking images, rhymes, categories, lists, and cues.

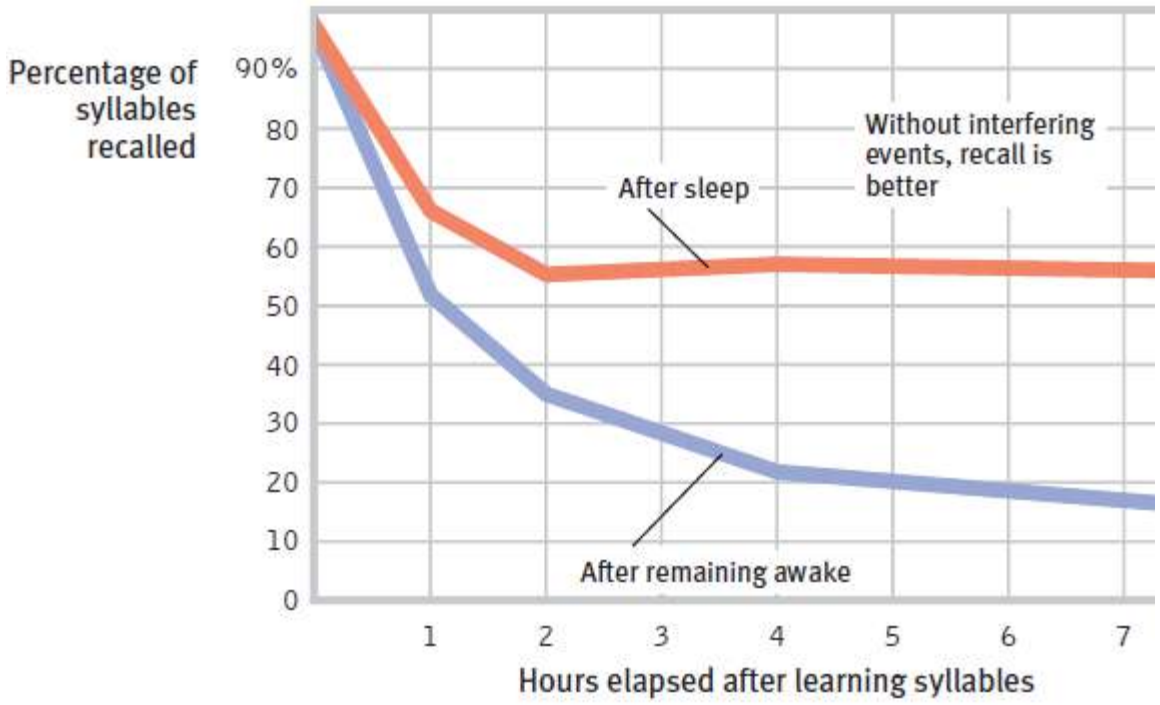


Interference and Positive Transfer

- Another downside of **not** forgetting is that old and new memories can **interfere** with each other, *making it difficult to store new memories and retrieve old ones*.
- Occasionally, the opposite happens. In **positive transfer**, old information (like algebra) makes it easier to learn related new information (like calculus).
- **Proactive interference** *occurs when past information interferes* (in a *forward-acting* way) *with learning new information*.
  - You have many strong memories of a previous principal, and this memory makes it difficult to learn the new principal's name.
  - You had to change email passwords, but you keep typing the old one and can't seem to memorize the new one.

Retroactive Interference and Sleep

Retroactive interference *occurs when new stimuli/learning interferes with the storage and retrieval of previously formed memories*.



- In one study, students who studied right before eight hours of sleep had better recall than those who studied before eight hours of daily activities.
- The daily activities **retroactively interfered** with the morning's learning.

Motivated Forgetting

- Memory is fallible and changeable, but can we practice **motivated forgetting**, *that is, choosing to forget or to change our memories*?
- Sigmund Freud believed that we sometimes make an *unconscious* decision to **bury** our anxiety-provoking memories and *hide them from conscious awareness*. He called this **repression**.
- New techniques of psychotherapy and medication interventions may allow us to "erase" (prevent reconsolidation of) recalled memories.

Motivated forgetting is not common. More often:

1. recall is full of errors.
2. people try not to think about painful memories. If they fail to rehearse those memories, the memories can fade.

Why is our memory full of errors?

- Memory not only gets forgotten, but it gets **constructed** (*imagined, selected, changed, and rebuilt)*.
- Memories are altered every time we "recall" (actually, reconstruct) them. Then they are altered again when we **reconsolidate** the memory (using working memory to *send them into long term storage*).
- Later information alters earlier memories.
- No matter how accurate and video-like our memory seems, it is full of alterations.

Ways in which our memory ends up being an inaccurate guide to the past:

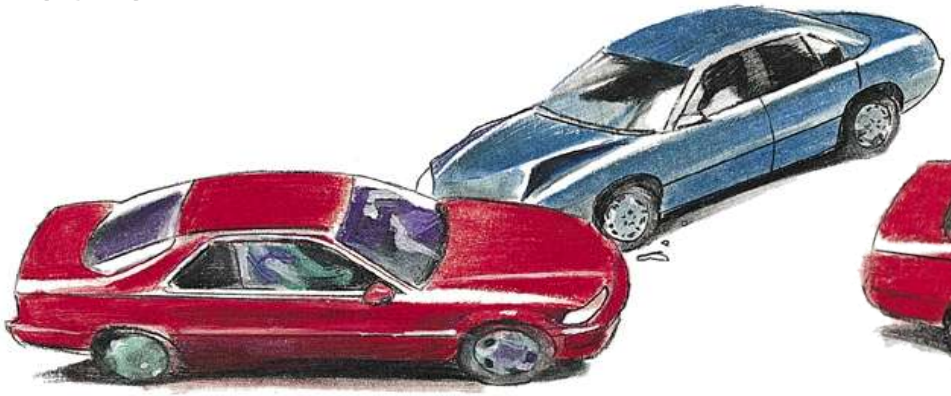
- the misinformation effect
- imagination inflation
- source amnesia
- déjà vu
- implanted memories

The Misinformation Effect:

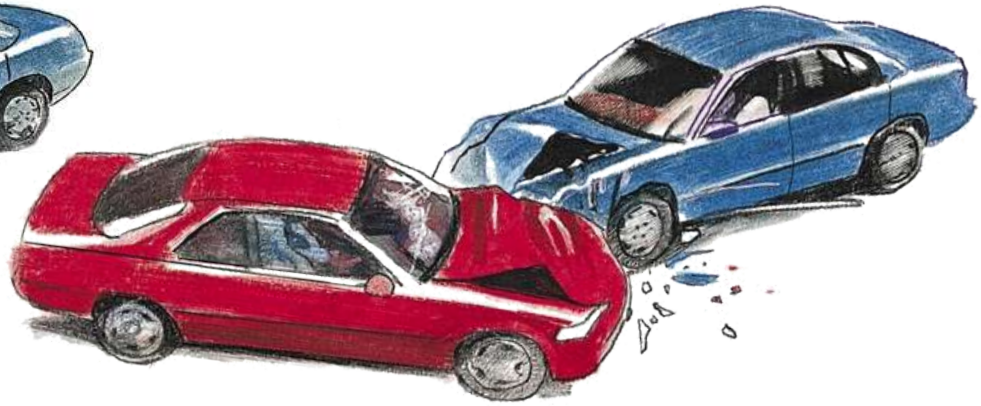
Incorporating misleading information into one's memory of an event.

In 1974, Elizabeth Loftus and John Palmer asked people to watch a video of a minor car accident. The participants were then asked, "How fast were cars going when they *hit* each other?"

Those who were asked, "...when the cars *smashed into* each other?" reported higher speeds and remembered broken glass that wasn't there.



Actual accident



Misremembered accident

Implanted Memories

In one study, students were told a false story that spoiled egg salad had made them ill in childhood. As a result, many students became [even] less likely to eat egg salad sandwiches in the future.

In a study by **Elizabeth Loftus,** people were asked to provide details of a incident in childhood when they had been lost in a shopping mall.

Even though there actually had been no such incident, by trying to picture details, most people came to believe that the incident had actually happened.

Lessons:

1. By trying to help someone recall a memory, you may implant a memory.
2. You can't tell how real a memory is by how real it feels.

Imagination Inflation

- Simply picturing an event can make it seem like a real memory.
- Once we have an inaccurate memory, we tend to add more imagined details, as perhaps we do for all memories.
- Why does this happen? Visualizing and actually seeing an event activate similar brain areas.

Source Amnesia/Misattribution

Have you ever discussed a childhood memory with a family member only to find that the memory was:

- from a movie you saw, or book you read?
- from a story someone told you about your childhood, but they were kidding?
- from a dream you used to have?
- from a sibling's experience?

If so, your memory for the event may have been accurate, but you experienced **source amnesia:** *forgetting where the story came from, and* ***attributing*** *the source to your own experience.*

Déjà vu ("Already seen")

- **Déjà vu** refers to the feeling that you're in a situation that you've seen or have been in before.
- In an experiment in the text, students got this feeling, because they actually were shown an image previously.
- However, we can feel very certain that we've seen a situation before even when we have not. This can be seen as source amnesia: a memory (from current sensory memory) that we misattribute as being from long term memory.
- Why does this happen? Sometimes our sense of familiarity and recognition kicks in too soon, and our brain explains this as being caused by prior experience.

Applying what we've learned about memory

Improving Memory to Improve Grades

Ways to save overall studying time, and build more reliable memory.

Learn the material in more than one way, not just by rote, but by creating many **retrieval cues**.

- Think of examples and connections (**meaningful depth**).
- Create **mnemonics:** songs, images, and lists.

Minimize interference with related material or fun activities; study right before sleep or other mindless activity.

Have **multiple study sessions, spaced further and further apart** after first learning the material.

Spend your study sessions **activating your retrieval cues** including context (recalling where you were when learning the material).

Test yourself in study sessions: 1) to practice doing retrieval as if taking a test, and 2) to overcome the overconfidence error: *the material seems familiar, but can you explain it in your own words?*