Introduction to Cognitive Science



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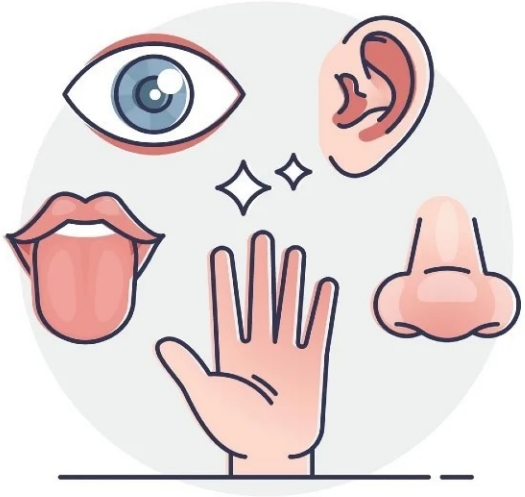




Memory is **essential to intelligence** - enables learning, problem-solving, and even advanced skills like natural language. For humans, memory allows experts to solve complex problems by drawing on past knowledge and experiences.

But what is memory?

TYPES OF MEMORY



SENSORY MEMORY



SHORT-TERM MEMORY



LONG-TERM MEMORY

The Working Memory Model
(Baddeley and Hitch, 1974, 2000)

Central Executive

Controls information flow, sets goals, and directs attention.



Episodic Buffer

Combines sounds, visuals, and long-term memories into short, temporary experiences with limited capacity.

In 1974, Alan Baddeley & Graham Hitch's influential model revolutionized working memory, replacing the single storehouse with a multi-component system. (Later revised in 2000).

Visuospatial Sketchpad

Holds and manipulates visual and spatial information, like a mental canvas.

Phonological Loop

Briefly stores and rehearses verbal content (e.g., speech sounds, words).

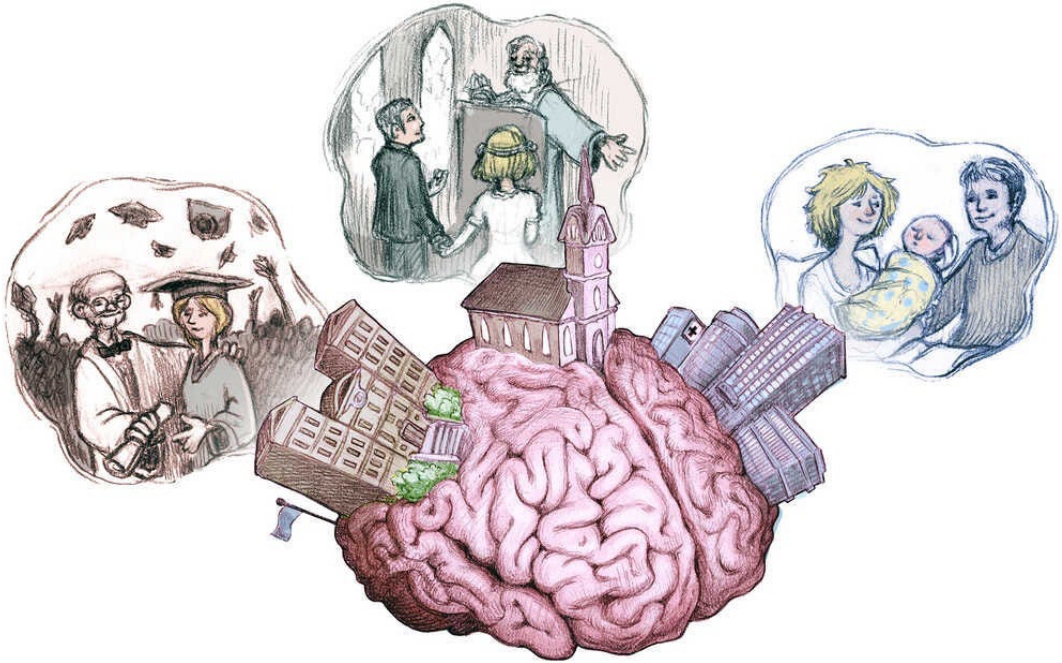
Phonological store:
Temporarily holds auditory information.

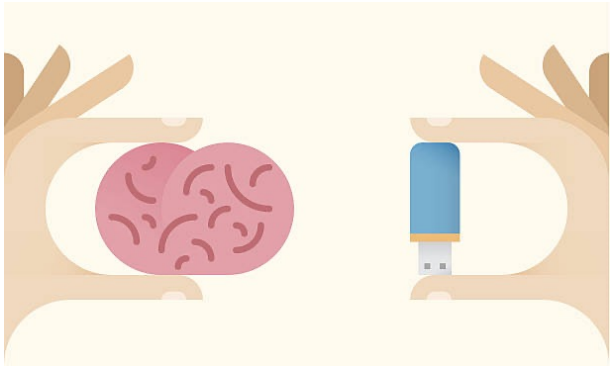
Articulatory rehearsal process:
Repeats sounds in mind to remember.

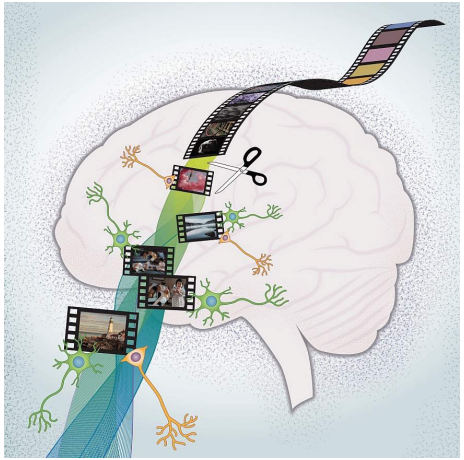
As research has progressed, even more types of memory have been identified:

Episodic Memory: Personal experiences, like your last vacation.
Semantic Memory: General knowledge, like knowing Paris is the capital of France.
Procedural Memory: Skills and "know-how," like riding a bike or typing.
Autobiographical Memory: Memories that shape your identity.
Flashbulb Memory: Vivid, emotionally charged events, like remembering where you were during a significant moment in history.
Prospective Memory: Remembering to do something in the future, like picking up groceries on the way home.

Many memory processes occur unconsciously: For instance, **implicit memory** studies show that people read previously encountered passages more quickly, even if they don't consciously recognize having read them before (Jacoby and Dallas, 1981). This highlights how past experiences shape behavior in subtle, automatic ways.







In a computer, data is stored in precise locations—files on a hard drive or memory chips—and retrieved exactly as it was saved. **But the brain operates very differently**.

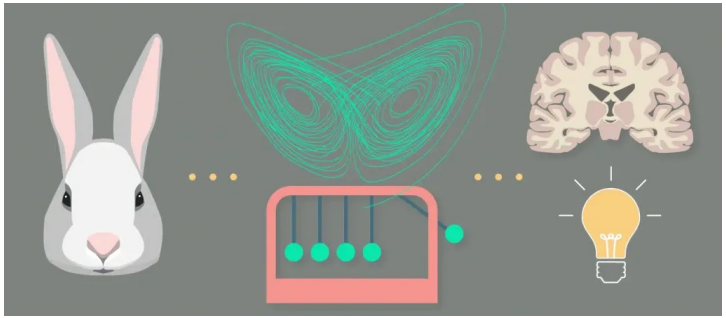


Imagine hearing a familiar song played in a different style - you still recognize it as the same song, **even though the sounds are completely new**

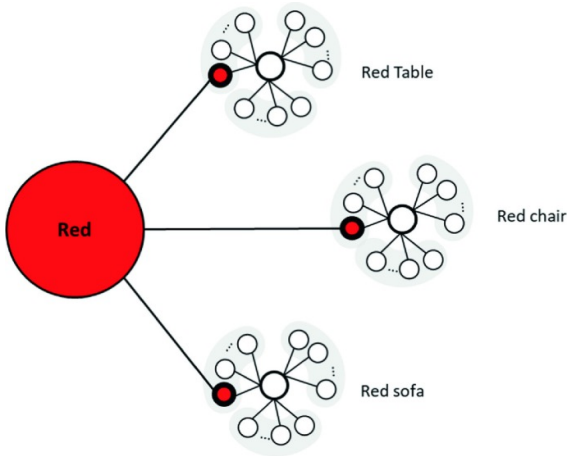
It doesn't explain: **certain memory phenomena** – e.g. why do we sometimes reconstruct memories inaccurately?

The complexity of memory types - the storehouse metaphor doesn't unify these types or explain how they interact.

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Confusion between **behavior and mechanism**. Memory is often described based on observable behaviors, like recalling a fact, but this doesn't necessarily explain the underlying processes.



The Symbol Grounding Problem - If memories are stored as discrete symbols in the brain, how are they connected to the real-world events they represent? Do we store one memory for each event, or multiple overlapping memories? How do these memories relate to one another?

Frame-of-Reference Problem

Memory is not an object within the system but a concept we use to explain behavior when we lack full information.



Ashby's Example: The Dog and the Car Accident

Imagine a dog cringing in fear at the sound of a passing car. **To an outsider, this behavior seems inexplicable** until the dog's owner explains that it was hit by a car six months ago. Suddenly, the behavior makes sense. We might say the dog **"has memory,"** but this is **just a convenient way of explaining** the connection between past events and present behavior.



Memory and Embodied Interaction

Memory **cannot be separated from the body** and its interaction with the **environment.**

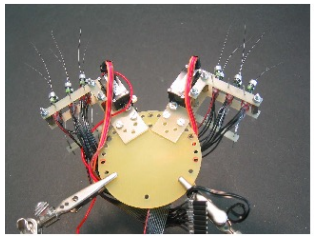
In memory experiments, participants don't exist in isolation. They are **whole agents** interacting with the **real world**. Consider a simple task like recalling a list of words. The subject reads or hears the words, processes them, and later writes or speaks them. These actions involve **sensory-motor coupling**—coordination between sensory inputs and motor outputs.

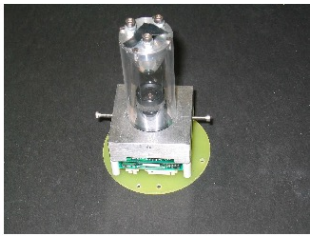
But that's not all that's happening. The participant might be **fidgeting in their chair**, **distracted by an uncomfortable environment**, **wondering** if they'll perform well, or even thinking about **needing a bathroom break**. All these factors influence their behavior.

The recall task isn't isolated; it's **embedded within the broader context** of their embodied experience.









(a) (b)

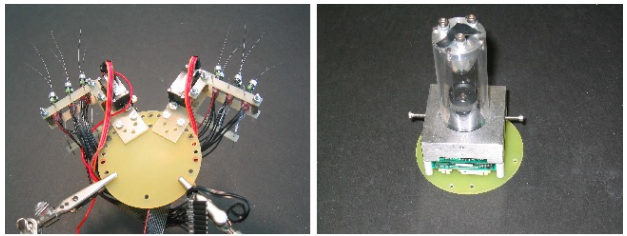
Bovet’s Artificial Mouse

The robot didn’t get immediate feedback on whether its decision to turn left or right was correct. Instead, it had to figure out which action led to the reward later—a problem known as **the "credit assignment problem."**

The robot was equipped with sensors for touch, vision, and detecting rewards. It didn’t know the rules of the task and started by making random turns

Hebbian learning: if the robot turned left, saw a red wall on its right, and received a reward, those events became linked in its neural network





(a) (b)

Bovet’s Artificial Mouse

This experiment redefines how we think about memory. Instead of being stored internally, memory can **emerge from interactions with the environment.** For example, humans use sticky notes or organize tools to remember tasks, offloading memory into the world around them. Similarly, the Artificial Mouse used its surroundings to "remember" its past actions.

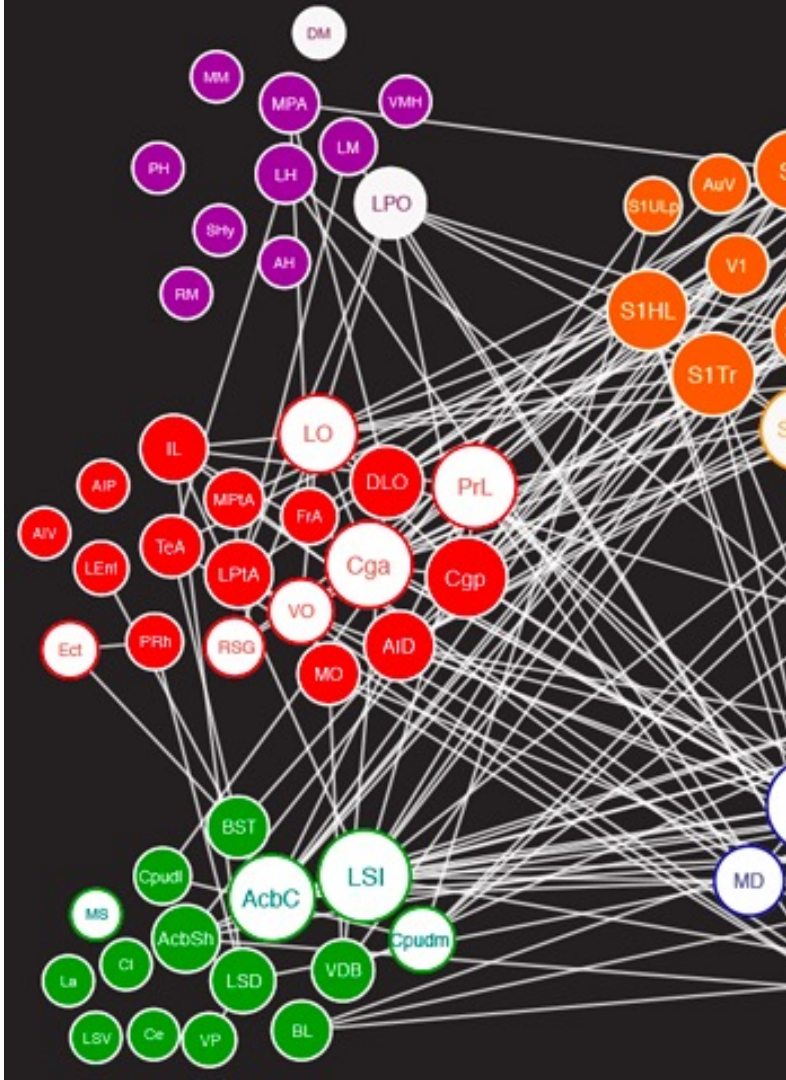
Bovet’s work shows that learning **isn’t always about what’s stored in the brain** or a machine’s memory. It can also come from **how we engage with the world**, offering a new perspective on both human and artificial intelligence.

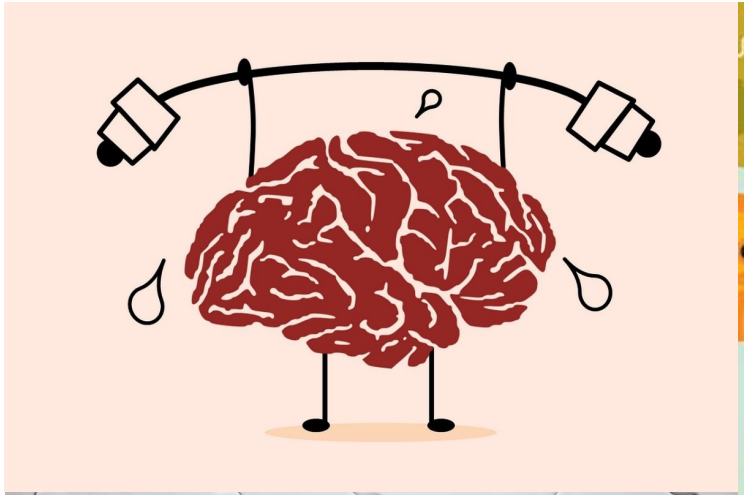
Distributed Models: The Role of Networks

In the 1980s, a shift in thinking about memory emerged with the rise of **connectionist models**, which proposed that **memory is distributed across networks of neurons** rather than being stored in specific "locations."

How Distributed Models Work:

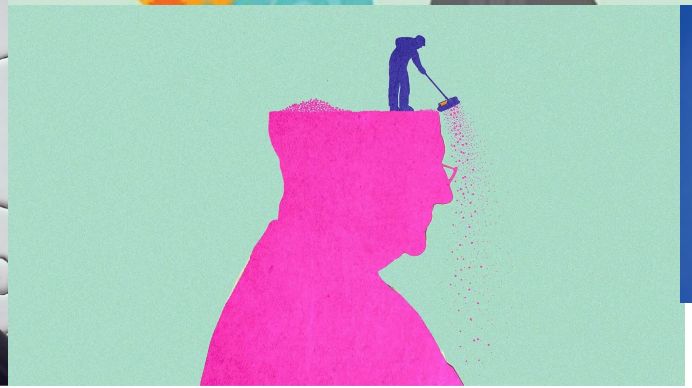
In a connectionist model, memories are not stored as isolated files but as patterns of connections between nodes. Each "node" represents a small piece of information, and together these nodes form a web of associations. When a memory is recalled, it is not retrieved as a whole but **reconstructed from the pattern of activity across the network**.








Generalization





Embodiment: Sensory-Motor Coordination and Memory

The **complete agent principle** highlights that when agents act, they generate sensory feedback, creating correlations between their actions and sensory input. These correlations can help recall.

For instance, if you hear a snippet of a song but can't remember the rest, you might **hum the part you know**. The act of humming creates sound waves, which your ears detect, **generating sensory feedback** that can trigger the memory of the rest of the tune.

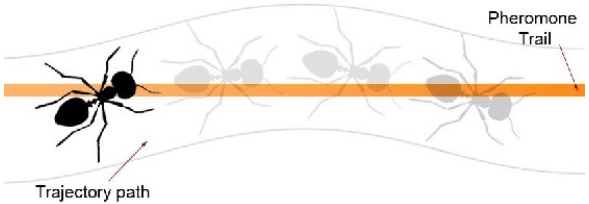
This feedback loop **reduces the need to store everything in the brain** because part of the memory process is outsourced to the interaction between the agent and the environment.



Scaffolding: Memory in Interaction with the Environment

Scaffolding refers to how we structure and manipulate our environments to support memory and cognitive functions. Instead of relying solely on internal memory, humans often use external aids to simplify tasks and ensure better outcomes. This idea is pervasive in our daily lives. People **take notes**, **keep diaries**, **leave sticky notes**, or use **digital tools like reminders** and **calendars** to offload cognitive effort.

As Andy Clark humorously put it, "Our brains make the world smart so that we can be dumb in peace."





As Rodney Brooks famously said, **"The world is its own best model."**


ANY
QUESTIONS?





Classical Computational frameworks provide a powerful start for understanding the mind, but they potentially falls short when we consider **real-world fluency** and **the intricacies of embodied thought.**

Cognitive science is moving toward viewing the mind as ***fine-grained, multipurpose, and embodied*** – not a centralized, abstract system, but a fluid, distributed one, constantly shaped by interactions with the world.

As we integrate insights from **connectionism** and embodied cognition, we edge closer to understanding human cognition as *fine-grained, multipurpose, and deeply embodied*.





THE EXTENDED MIND

Thanks!



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