Lecture 1: Intro to Cognitive Science

Basics of how neurons communicate

- What is an action potential
- What parts of a neuron are important
- What is the ultimate “work” being done

Parts of a neuron:

- cell body
- nucleus: where information is processed
- dendrites: full of synapses, this is where signals come in
- axon: the stem along which AP signals travel
- myelin sheath: insulates axons, lets AP signals travel faster
- node of ranvier: fast hopping points along myelin sheath
- axon terminals: ends in synapses, this is where signals go, and from there they hop to the synapse of another neuron’s dendrites

Action potential: the electrical membrane potential of a cell rapidly rising and falling. When a stimulus comes in, the neuron builds up a charge and releases it down the axon. This is how all messages are passed in the brain. It’s one signal at one intensity (voltage), but it can go at different frequencies, and the signal can travel at different speeds.

The signal travels faster on neurons that have an insulating myelin sheath, since not only does it travel faster inside it, but it can also hop along the nodes of ranvier, and even jump to other neurons. Reflex nerves, for example, it travels faster.

Higher frequency = stronger signal. The difference between “the thermostat is too high” and “oh god, I’m on fire”.

Main work being done: processing and transmitting information through electrical and chemical signals.

A key bottleneck with brain computational simulations

The brain has 100 billion neurons, but we can only gather data and monitor the activation of neurons about a dozen at a time.

What is the Big Brain Project and how the 3D rendering has been achieved

It’s a 3D map of the brain.

The atlas was created from the brain of an unidentified 65-year-old woman who died with no known brain pathology. Her brain was first scanned using an MRI machine in order to create an undistorted reference, then embedded in paraffin and sliced into 7,404 20 µm thick sections using a microtome. After each slice was removed, the uncut face was photographed in order to provide an additional reference for removing distortion. The brain sections were placed on large glass slides and then stained using the Nissl method, a process that causes the grey matter in the brain to be darkly stained while leaving the white matter uncolored. (More precisely, the Nissl process causes the nucleus of each brain cell to be stained as a dark dot.) The stained sections were scanned and digitized using a flatbed scanner, creating a one terabyte raw record.[2] The atlas took five years to complete.[3]

They tried to capture all the biological richness of the brain, recording everything, even if they had no idea what was relevant.

Why the brain is like a Rube Goldberg design

In both the brain and a Rube Goldberg machine, it's easy to see what the inputs (stimulus) and outputs (response) are, but what goes on in the middle is complex and messy, and almost impossible to understand.

What is the mind-body problem?

The question of how the mind interacts with the body, especially the brain.

What makes a "hard" problem hard?

Subjectivity. The problem of subjective experience will persist even when the performance of all the relevant functions have been explained. Though some philosophers who fall in the category of eliminative materialists such as Daniel Dennett would deny this; once we truly understand the brain, subjectivity will cease to be a mystery.

Ontology

- What is an ontological view and what are the main ones we discussed?

Ontology is the philosophical study of the nature of being, becoming, existence, or reality, as well as the basic categories of being and their relations. In other words, a theory about what categories of things exist.

Dualism: the mind and body are different.
Idealism: the mind is all that exists.
Reductionism/physicalism: everything can be explained at the physical level.
Functionalism: causal relationships between inputs, outputs, and mental states. Multiple realizability.

Multiple realizability says only the function is important, and it doesn't matter what hardware it's implemented on. So the human brain is conscious, but we could also have a computer be conscious, or a dog.

Inverse problems

- What are they?
- What difficulties do they impose?
- How can we circumvent them in cognitive science?

An inverse problem is when you try to calculate the causal factors given only the results. A forward problem is when you're given the model and the input and asked to calculate the output.

An inverse problem is more like you're given the output and asked to calculate the model. The difficulty is that many models may fit the data. We call this "non-uniqueness". For example, which two numbers were multiplied to give 12?

Using the treasure hunting example, the forward problem is: given the density of an object, you can easily predict its gravity reading. The inverse problem is given the gravity reading, predict the density of the object, compare that density to the known density of gold, and tell whether there's treasure there.

We circumvent the difficulties of the inverse problem in cognitive science by looking for a priori constraints and using converging evidence from multiple fields. Hence the multidisciplinary approach.

We get converging evidence by having multiple fields working together: philosophy, psychology, linguistics, computer science, neuroscience.

A a priori constraint here means knowing what the brain is capable of. For example, things you could find out from behavioural or experimental psychology: there's short term memory, there's long term memory, etc. Then we know what we're looking for when we ask how these are implemented.

Tri-level hypothesis

- What is the tri-level hypothesis and how does it help cogsci research?

The tri-level hypothesis says that to fully understand a cognitive process, we have to be able to describe it on three different levels: computational, algorithmic, and implementational.

Computational: the specific information-processing problem that must be solved, and any constraints on it.
Algorithmic: input and output, algorithm for transforming one into the other, and how the information is encoded.
Implementational: neural structures that represent the algorithm states, and the neural mechanisms that transform them.

In cognitive science, different fields are better at working at different levels. For example, neuroscience is really good at the implementational level, and philosophy and behavioural psychology are good at the computational level. Experimental psychology and computer science are good at the algorithmic level.

Major brain specializations

- Cerebrum vs cerebellum

- Wrinkles
  - What are they called?
  - What is lissencephaly and why is it problematic?
  - Did wrinkles definitely evolve so we could cram in all our complex processes?
    - What is the term for this sort of explanation
    - What is an alternative explanation, and what is the evolutionary biology term for these characteristics that are byproducts of some other characteristic?

Cerebrum: also called the neo-cortex, this is the newer part of the brain, as opposed to the older, more “primitive” part of the brain, the cerebellum. Cerebrum is divided into four lobes, and is responsible for higher-order cognition. Cerebellum is responsible for coordination, balance, reflex, and muscle tone, and damage to it may make you clumsy. Basically, it does motor control.

Wrinkles: sulci are the crevices, gyri are the ridges.

Lissencephaly: a brain disorder where someone is born without any wrinkles in their brain. They tend to die before 5 years of age due to respiratory failure.

Evolutionary psychologists call wrinkles a spandrel. They weren’t selected for, they don’t serve an adaptive purpose. It’s just a result of the thing the brain is made of when it expands.

Spandrel

A term in Roman architecture that evolutionary psychologists have borrowed. Originally referred to these sort of triangular things that show up in arches. What’s important for structural stability is the arch, but the triangles show up between two arches and what they’re holding up. The point is that the spandrels were never intended.

Similarly, the red colour of blood is a “spandrel” in the evolutionary psychology sense of the word. Nothing ever selected for red blood.

Hemispheres

- Right-brained vs left-brained
- Dominance
- Lateralization

Both sides: prefrontal cortex, auditory cortex, visual cortex
Left side: speech center, writing (if right handed), general interpretive center (language and mathematics)
Right side: analysis by touch, spatial visualization and analysis

Chicks. They showed light to only one of their eyes (except the control group). Laterized light to one side of the brain, so they could check for food with part of the brain while the other they check for predators. Lateralization might help make some tasks more automatic, helping multitasking. But more, it can help the brain process tasks more efficiently, without requiring the whole brain.

Corpus callosum

Where messages are passed between the left and right parts of the brain. People who have epilepsy often need this cut. Or at least, that used to be the treatment.

Lobes

- Major functions
- Deficits due to lesions

Note that visual attention and face recognition is in the parietal lobe, not the occipital lobe. The temporal lobe is responsible for categorization and ordering of objects. Speech is the parietal lobe, but understanding spoken language and rhythm is the temporal lobe, and expressive language and meaning is the frontal lobe.

Parietal lobe

Located at the back of the head directly under the skull bone, it assists in the processing of visual images and other sensory input, mainly visual attention and facial recognition. When you touch a hot stove, it is this part of the brain that perceives the danger and sends an urgent message to your muscles to move your hand. If damage is sustained to the parietal lobe, a person would most likely have difficulty reading, recognizing people and objects, and having a comprehensive awareness of his or her own body and limbs and their positioning in space. For those with traumatic brain injuries to this area, the ability to multi-task is reduced or eliminated, as is mathematical ability and recognition of the difference between right and left.

Temporal lobe

Located on the bottom and at the side of each of the two brain hemispheres, the temporal lobes are responsible for the primary organization of sensory input. When damage occurs to these areas of the brain, patients may experience disturbance of auditory sensation and perception, an inability to pay attention to what they see or hear, impaired ability to comprehend language, impaired factual and long term memory, emotional disturbance, and altered sexual behaviors. They may also have seizures, lose their sense of humor, and become obsessive.

Damage can lead to

- Agnosia (the man who mistook his wife for a hat). The inability to process sensory information, or recognizing objects. Object recognition pathway is cut off.
- Acquired savant syndrome. They're able to recognize the object, but it they have to look at all the different pieces. Object recognition goes through a different pathway with them, but it still gets there eventually.

Frontal lobe

When traumatic brain injury occurs to the frontal area, it is impacting the brain's largest lobe. Located at the front of each cerebral hemisphere, this lobe is responsible for conscious thought, voluntary movement, and individual personality characteristics. When you are searching for just the right word to say, it is this section of the brain upon which you rely.

Damage to this vital lobe can cause impairments in judgment, attention span and organizational ability, as well as a loss of motivation. In addition, the frontal lobes are charged with the task of regulating mood and emotions. Consequently, when they are compromised, a patient may become impulsive, act rashly, and adopt risky behaviors such as substance abuse.

Damage here could lead to disexecutive syndrome: difficulty in abstract thought, planning, and behavioural control.

Occipital lobe

When you look at a clear sky and are able to discern its blue color, you are using the occipital lobe. Located at the back of the brain, the occipital lobes are responsible for visual perception, depth perception, and color recognition. Damage to them results in loss of visual capability, an inability to identify colors, and hallucinations. At times, patients experience severe vision loss or total blindness, called cortical blindness.

Acquired Savant Syndrome Theory

Just like agnosia, this occurs due to damage in the temporal lobe, where object recognition and categorization happens. However, these people demonstrate greater brain plasticity, and they're able to find a way to understand the world, and sometimes these weird pathways gets activated, leading them to have some special cognitive abilities.

Instead of seeing an object all as one thing (e.g. the forest), they would see it as a collection of a hundred little things (the trees).

Lecture 2: Sense and Perception

Basics

- What is sensation?
- What is perception?

A sensation is the process by which a stimulated receptor creates a pattern of neural messages that represent the stimulus to the brain (transduction), giving rise to our initial experience of the stimulus.

A perception is the sensory experience of the world around us, the mental process that elaborates and assigns meaning to incoming sensory patterns. In other words, <u>our interpretation of sensation</u>.

Perceptual senses

- Main perceptual senses
- How are they similar?
- What other perceptual senses exist that humans do not have? What are the implications of this?

Similar: they all transduce some stimulus into electrical signals in the brain.

External:
- Touch
- Sight
- Smell
- Taste
- Hearing

Internal:
- Pain
- Position

Non-human:
- Magnetism (bees)
- Polarization (octopus)
- Ultraviolet (bees)
- Infrared (snake)
- Echolocation (bat)
- Electricity (platypus)

Implication is that we're not seeing all of reality, there are other ways of understanding the world.

The example she likes is the horse. Its eyes are further apart, so it has better depth perception. We call this parallax--having two different views from eyes that are in different positions. It can better estimate how far away predators are. On the other hand, it has trouble seeing things that are right in front of it.

Sensory receptors

- What kinds of sensory receptors are there

Photoreceptors (retina)
Chemoreceptors (tongue, nose)
Mechanoreceptors (cochlea, skin)
Nociceptors (skin)
Thermoreceptors (skin)

Vision

- What is transduced?
- Differences between cones and rods
- Inversion of image
- Trichromatic vs opponent process theory

Photoreceptors in the retina transduce electromagnetic energy into neural signals.

Rods: 120 million of them, peripheral vision, motion detection. Can't see colour, responds little to red light. Takes up to 30 minutes to adapt to optimal low-light vision. Much more sensitive, and in optimal conditions can respond to as little as a single photon.

Cones: 6-7 million of them, mostly in the center of the visual area (fovea centralis). Can see colour. Very quick adaptation to changing light levels (e.g. going indoors from daylight). Less sensitive, but offers much greater resolution. Three different types: red, green, and blue.

The light falling onto the retina is actually an upside-down (inverted) image, just like a pinhole camera. There's some processing going on to flip it back. There's also crossing over: the left visual field of both eyes is handled in the right visual cortex, and the right visual field of both eyes is handled by the left visual cortex. The visual cortex is in the occipital lobe.

Trichromatic theory: there are three types of cones, red, green, and blue, and colour vision comes from the proportion of red, green, and blue that are activated.

Opponent process theory: there's another level of processing beyond the photoreceptors. In the ganglion, there are red-green and blue-yellow opponent processes, and a dark-light opponent process.

Audition

- What are the three parts of the ear?
- What causes the cilia to vibrate?
- What is transduced?
- Main pathway of sound through the ear
- Major transformations that occur
- Tonotopic preservation in cortex

Three parts of the ear: outer ear (what you can see, and the auditory canal), middle ear (basically the eardrum), inner ear (cochlea).

Hair cells (a type of mechanoreceptor) transduce mechanical energy from sound waves to electrical energy.

1. Sound waves in air travel through ear to cochlea
2. Pressure from sound waves at oval window (still air) send vibrations through fluid-filled cochlea
3. Fluid wave spreads through cochlea and vibrates the basilar membrane
4. Basilar membrane converts vibrations to neural messages
5. Neural messages travel to auditory cortex

The cochlea is filled with a watery liquid, the perilymph, which moves in response to the vibrations coming from the middle ear via the oval window. As the fluid moves, the cochlear partition (basilar membrane and organ of Corti) moves; thousands of hair cells sense the motion via their stereocilia, and convert that motion to electrical signals that are communicated via neurotransmitters to many thousands of nerve cells. These primary auditory neurons transform the signals into electrochemical impulses known as action potentials, which travel along the auditory nerve to structures in the brainstem for further processing.

Transduced sound information travels to the thalamus and then to the primary auditory cortex in the temporal lobe.

Olfaction

- What is transduced?
- Link with memory

Transduction

Olfactory sensory neurons (chemoreceptors) transduce chemical energy to electrical energy.

Olfactory receptors expressed in the cell membranes of olfactory receptor neurons are responsible for the detection of odor molecules. Activated olfactory receptors are the initial player in a signal transduction cascade which ultimately produces a nerve impulse which is transmitted to the brain.

Link with memory

Because the olfactory bulb is part of the brain's **limbic system**, an area so closely associated with memory and feeling it's sometimes called the "emotional brain," smell can call up memories and powerful responses almost instantaneously.

The **olfactory bulb** has intimate access to the **amygdala**, which processes emotion, and the **hippocampus**, which is responsible for associative learning. Despite the tight wiring, however, smells would not trigger memories if it weren't for conditioned responses. When you first smell a new scent, you link it to an event, a person, a thing or even a moment. Your brain forges a link between the smell and a memory -- associating the smell of chlorine with summers at the pool or lilies with a funeral. When you encounter the smell again, the link is already there, ready to elicit a memory or a mood. Chlorine might call up a specific pool-related memory or simply make you feel content. Lilies might agitate you without your knowing why. This is part of the reason why not everyone likes the same smells.

Haptics

- What is transduced?
- Types of touch receptors
- Somatic sensory map

Tactile receptors transduce mechanical energy into electrical energy. Sensations include pressure, skin stretch, vibration, temperature. The relevant types of receptors include mechanoreceptors (touch and pressure), thermoreceptors (temperature), and pain and itch (nocioceptors).

Somatic sensory map: this is the homunculus.

Gustation

- What is transduced?
- Myth of the tongue map

Taste receptors transduce chemical energy into electrical energy.

The tongue map theory is baseless because every part of the tongue has all of the taste receptors.

Perceptual illusions

- Examples and implications
- Difference between sensory illusions and perceptual illusions

Necker cubes, the Herman grid, ambiguous figures, the dress colour, is the cat going up or down the stairs. Many problems in perception can be posed as a process of estimating physical parameters. We have a lot of information coming in, and we need to make rapid judgements about them. We need to apply heuristics, but there's bias. Our brains choose the most likely interpretation given past experience, but when faced with illusions, this fails.

The implication is that our visual experience may not be as objective as it seems.

Extremes

- Examples and implications

Ben Underwood, the boy who sees using echolocation. His eyes were removed at 3 years old because of cancer, but he makes this clicking noise and interprets that sound to "see" in his environment. This demonstrates the <u>plasticity of the brain</u>, its ability to make new connections to compensate for damage to the body.

Case study of Jonathan I. He received some brain damage and lost not only the ability to see colour, but all of his memories of colour. He ended up becoming a great artist who focused on form. It's like he became super good at seeing shape and shading. This demonstrates the <u>plasticity of the brain</u>: when one part is damaged, it makes new and stronger connections in other related areas to make up for it.

There is an artist with tetrachromacy; she was born with an extra colour receptor, and she can discern about a million hues that other humans can't. She became an artist, and her work hints at a different way of seeing the world. Whereas we may think water is colourless, she sees all sorts of different hues in there. This implies that our perception and experience of the world is based on our bodies, that we're not seeing all of reality, and what we are seeing is always filtered and limited by our senses.

Synesthesia

- Examples and implications

Chromesthesia: sound to colour
Grapheme synesthesia: letters or numbers to colour (most common)
Lexical-gustatory synesthesia: words have taste

The fact that different people can have such widely different perceptions of the same things is yet another point of evidence for how we're not seeing absolute, objective reality. Everything is filtered through our senses. It also shows that our brains can be wired in very different ways.

Some argue that grapheme synesthesia may be a result of early childhood association, not a true case of synesthesia.

Lecture 3: Memory

Definitions of memory

- Why are some definitions of memory unsatisfactory?

Some definitions are that memory is the capacity to think about things that happened before. A way of holding onto an experience without having it right in front of you. First, it misses the difference between remembering a fact and remembering how to do something. Remembering your friend's birthday is very different from remembering how to ride a bike. Second, it doesn't explain unconscious associations. Why when one person hears to song they laugh while another cries. Basically, they're too simple.

Tri-level approach

- When studying memory using the tri-level approach, what is the major question at each level and which methodologies are appropriate?

Computational

Major question: what is memory designed to do / what does it actually do.

- Represents stimuli that are not physically present
- Evolved to supply useful, timely information to the organism's decision-making systems
- Inextricably linked to learning

Methods:

- Behavioural psychology: you can't begin to understand the lower levels until you know what people are actually capable of doing
- Philosophy: Philosophy cleans up the concepts behind memory, and shows us how we're biased by the way we think or speak about memory. If you study a holepunch thinking it's a paperweight, you'll miss some insights. Philosophy helps with experimental design and reasoning process.

Algorithmic

Major question: How does memory work. Is there one memory system?

It's an inverse problem. We can't see how it's implemented; all we can do is look at the outputs.

Methods:

- Experimental psychology: tests on limits of short term memory, turned up chunking. What affects how likely something is to make it into short term memory.
- Neuroscience: Brain scanners see which brain regions are activated given some input
- Computational models: allows us to simulate
- Linguistics: all our memories and concepts are biased by the language we have to think about it. How does your memory and concept of turquoise change if your language doesn't have a word for it?

Implementational

Major question: How is memory achieved in the brain?

- Is there a "locus" of memory (systems problem)
- What is the molecular basis of memory? (molecular problem)
- What are the similarities/differences across different "kinds" of memory?

Methods:

- Neuroscience: looks at neurons
- Computational: AI, simulations, Big Brain Project

Representations

- What is a big assumption about representations we have to keep in mind?

We don't store the event itself in our mind, we store a representation of it. You sense something, then you perceive it, then you form a representation of it in your mind, then it is stored in memory.

We're skipping over representations in this course, and she wants us to be aware that there's a lot there that we're skipping.

Engrams

- What is an engram

An implementation-level idea. Basically, the engram is the neural correlate of a memory; the discrete representation in the nervous system of specific ideas, concepts, or behaviours; the trace left behind when you learn something. No one disputes that it exists, but we still haven't found where it is. One explanation is that memories are distributed throughout the brain.

Engrams (in short-term memory) tend to degrade in 10-30 seconds unless rehearsed.

Phases of memory

- What is encoding, storage, and retrieval?

Encoding: laying down a memory trace. Processing information so it can be entered into memory.
Storage: maintaining a memory trace. This may involve consolidation, where the trace is crystallized for long-term storage and moved from the hippocampus to the neocortex. This doesn't happen for sensory perceptions; those only last a fraction of a second. It could also involve long-term potentiation.
Retrieval: Reactivating a memory trace for current use. Accessing or recalling stored memories.

Basic pipeline of standard model

- Sensory > Short Term > Long Term
- Where is a memory when it is conscious?

Sensory input that you pay attention to enter short-term memory. Items in short term memory that you rehearse are stored in long-term memory.

When you are conscious of something, it is in short-term memory.

This is only one of many ways of framing memory. Some AI theorists say that it actually goes Sensory > Long Term > Short Term, and they have evidence to support this claim.

Kinds of memory

- Basic descriptions
- Major differences in encoding/storage/retrieval
- Main evidence supporting existence of particular memory systems (e.g. Sperling Experiment)
- Chunking

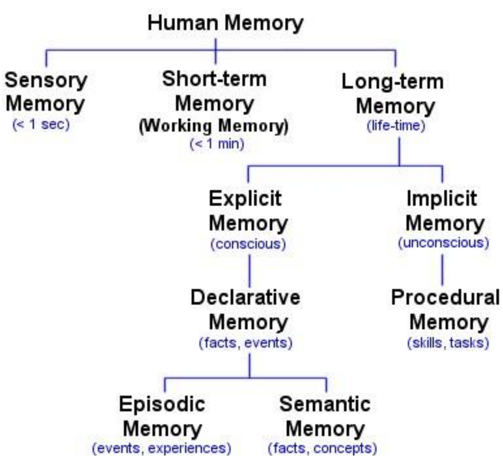
Experiments

George Sperling	Sensory	When primed with the right tone, people can remember the right row. They have access to all the rows, but their sensory memory of it degrades quickly.
Robert Sternberg	Short-term	Exhaustive serial search: Sternberg, 1960s. He'd give a sequence of numbers and ask if it contained, say, the number 7. The longer the list they'd been given, the longer it took for them to check, *even when* 7 occurred early on. That's why we say it's both exhaustive and serial.

Ebbinghaus; Murdock	Short- vs long-term	The Serial-Position curve (Ebbinghaus, 1913; Murdock, 1962). People were given about 100 words and asked to remember them. They were most likely to remember those at the beginning (reached long-term memory) and those at the end (still in short-term memory).

Sensory memory

The ability to retain impressions of sensory information after the original stimuli is no longer present. Lasts less than 500ms.



Automatic response, independent of attention. Modality specific (we have iconic, echoic, and haptic sensory memory). Immense amount of detail, high resolution.

Encoding: “engram” resulting in highly realistic precept (the sparkler’s circle)

Storage: Coded version of “snapshot” stored automatically in a sensory form (in primary sensory cortices), degrades within 500ms

Retrieval: Can’t access percept after engram has decayed. Not accessible to conscious recollection. If it is, then it’s actually in short-term memory.

Evidence that this is a real kind of memory in George Sperling’s experiment. When primed with the right tone, people can remember the right row. They have access to all the rows, but their sensory memory of it degrades quickly.

Short-term memory

The capacity for holding a small amount of information in mind in an active, readily available state for a short period of time.

Attentional control is required to actively maintain information.

Encoding: *some* information from sensory memory makes it to short-term memory. This may be mediated by neurotransmitters (NMDA, AMPA). Attention and emotion affect what makes it into short term memory and what gets remembered from there.

Storage: Passively maintained for a brief period (15-30 seconds)

Retrieval: Exhaustive serial search.

Evidence for exhaustive serial search: Robert Sternberg, 1960s. He'd give a sequence of numbers and ask if it contained, say, the number 7. The longer the list they'd been given, the longer it took for them to check, *even when* 7 occurred early on. That's why we say it's both exhaustive and serial.

Long-term memory

Maintains a seemingly unlimited amount of information in mind for anything from minutes to years.

Broken down into

- Explicit
  - Declarative
    - Episodic
    - Semantic
- Implicit
  - Procedural

Characteristics:

- Some memories easier to access than others because of retrieval cues or how it was encoded. Easier to retrieve a memory if you're in the same environment where it was encoded.
- State-dependent recall: what you learn while drunk easier to remember while drunk
- Outside of conscious awareness, but can be transferred to short-term store

Encoding: elaborative encoding, more levels of processing makes it easier to store and recall. Attention also makes it easier to encode.

Storage:

- Long-term potentiation: a persistent strengthening of synapses based on recent patterns of activity.
- Systems consolidation: A reorganization process in which memories from the hippocampal region, where memories are first encoded, are moved to the neo-cortex in a more permanent form of storage

Retrieval:

- Cues
- Familiarity vs recollection. Sometimes you can't recall a fact or event consciously (recollection), but you know you've seen it before (familiarity). It turns out that people usually underestimate the accuracy of their sense of familiarity. If you think you've seen something before, you probably have.

Evidence for short term and long term memories existing. The Serial-Position curve (Ebbinghaus, 1913; Murdock, 1962). People were given about 100 words and asked to remember them. They were most likely to remember those at the beginning (reached long-term memory) and those at the end (still in short-term memory).

Declarative memory

Explicit long-term memories that can be consciously recalled. Two types: episodic and semantic.

Episodic memory

Episodic memories relate to specific moments in time that we can usually visualize very well. These make up our self story. Very subjective. Autobiographical, narrative structure.

Semantic memory

Memory for facts and general world knowledge, like knowing when your friend's birthday is. Not tied to any particular instance of experience. More abstract. Often studied with computational models because it's easier to simulate.

Procedural memory

Implicit long-term memory responsible for knowing how to do things. Often requires practice. Learning comes in three stages:

- Cognitive phase: you have to consciously think about what you're doing.
- Associative phase: repetitive practice, but you're getting better.
- Autonomous phase: you've mastered it and can perform without thinking.

Retrieval means to perform the skill again.

More evidence came in the form of double dissociation in brain injured patients, for example Henry Molaison (H.M.), who had part of his hippocampus removed to cure his epilepsy. Long-term memory storage involves transmission from the hippocampus to the neocortex. With it removed, he could not form new memories, but he could still pick up new procedural skills. So there must be a difference in storing episodic memories vs procedural ones. He could also function normally besides that, so he must have still had a separate short-term memory in good condition.

Memory abilities

- Hyperthymestic Syndrome: the condition of possessing an extremely detailed autobiographical memory (episodic). Hyperthymesiacs remember an abnormally vast number of their life experiences.
- Savant syndrome (Treffert, 2009)

Memory disorders

- False memories and why they occur
- What agnosia is, generally
- Difference between anterograde and retrograde amnesia
    - Which do H.M. and the Memento guy have?

False memories: some kind of confabulation goes on when consolidated memories are retrieved from long-term storage.

Elaborative encoding

- What it is, how the memory palace is useful

Elaborative encoding: the more ways in which you work with something, the more associations there are, the more likely it is to be encoded in long term memory, and the easier it is to recall. So you hear the name Baker, and you'll probably forget it, because it's this arbitrary thing encoded one way. But if you hear the word baker, you're thinking about a baker you know, the smell of fresh bread, the taste, flour on fingers, the warmth of the oven.

Most people have a very good visuo-spatial memory, much better than any other system. The memory palace is a metaphorical place you imagine, where in each room you put one something that represents what you wanted to remember. And you try to make each one as elaborately encoded as possible, and as funny, surprising, and unforgettable as possible.

Bottom-up / Top-down effects

Bottom-up: lower perceptual pathways affect memory.

- Colour: can affect how well something can be recalled
- Body position: for infants, this impacts learning

Top-down: conscious and frontal lobe stuff affects memory

- Depression impairs learning
- Chronic stress can impact how well you remember something
- Acute stress has a different effect

Storytelling

- What does it mean to say that each of us is a storyteller?
- What are the implications of this?

We experience thousands and thousands of moments every month, but we only remember a few of them. And the story of who we are is made up of what memories we keep.

Lecture 4: Emotion

Why is emotion a “hard” problem?

Subjectivity, and it’s in inverse problem. You can see the facial expressions, body language, what came before, and whether they seek/avoid more of it, but you can’t know objectively what’s going on in their heads.

Reasons for different descriptions

- In class, we reviewed various ways of describing emotion (including philosophical definitions, physiological descriptions and evolutionary explanations). Why do we have so many ways of describing emotion?

Because it’s a subjective, inverse problem that’s so hard to understand, and no one can look inside somebody and see objectively what they’re feeling. All we can do is study it empirically from the outside and attempt to describe it.

Philosophical descriptions

- Be able to describe the different philosophical descriptions of Emotion mentioned in class:
  - As feelings: Emotions are just physiological responses. Problem with this though is you can have the same physiological response to different emotions.
  - As intentional objects: as emotion is an attitude *about* something. So disgust is an emotion because you’re disgusted by something, but depression is not, since you’re just generally depressed.
  - As evoking Action: First comes emotion, then you interpret whether it’s good or bad.
  - As Judgements: First comes the judgement of whether the stimulus was good or bad, then comes the emotion.

The Limbic System

- Is it a true “system”?
- Know the following parts and be able to describe generally what they are responsible for: Amygdala, Hippocampus
- What symptoms occur as a result of amygdala damage?
- Know that there are major tracts ascending to the frontal lobes and what this implies about the influence of perception on emotion

Not really a true system, since it’s so far apart.

Amygdala: responsible for associating emotion with stimulus, or emotion-based learning. Also memory consolidation and fear conditioning. This is called valence response.

Damage to the amygdala, you may not be able to associate fear with the stimulus that caused it.

Hippocampus: Responsible for moving memory from short to long term memory. Especially responsible for forming long term episodic memory. Spatial memory and navigation. In systems consolidation, memories move from the hippocampus to the neocortex. This is what was cut in H.M., giving him anterograde amnesia. Also one of the first places to take damage in Alzheimer's patients.

Neuro Chemicals

- Know the 4 major neuro chemicals associated with emotion (you can think of noradrenaline and adrenaline as the same for the purposes of this class)
- Know the major functions of each
- Know which combinations (or lack therefore) result in: anxiety, happiness, depression, love, flight/flight

They are:

- Dopamine
  - Movement
  - Pleasure/reward (generally, motivation)
- Seratonin
  - General happiness / well being
  - Lots of seratonin receptors in the gut, which is why it's called the gut brain. This is why you crave comfort foods when you're depressed.
- Oxytocin
  - Bonding, intimacy
  - Child rearing, lactation
- Adrenaline/noradrenaline
  - Flight/fight respectively

Anxiety: low dopamine
Depression: low dopamine and seratonin
Schizophrenia: high dopamine
Love: seratonin, dopamine, oxytocin
Fight/flight: Noradrenaline/adrenaline

Tetrodotoxin is <u>not</u> one of the four main neurochemicals :P

The Vagus Nerve:

- The video shown in class (of a young child surprised by the return of his military dad) is a typical example of a "vagus nerve" activator. What feelings are associated with this kind of activation?
- Know what the vagus nerve is and the general characteristics mentioned in class

General warm fuzzy feeling throughout the body

- Originates in brainstem, activates various organs (heart, lungs, liver, digestive organs)
- Involved in parasympathetic response (calming)

- Closely linked with oxytocin
- Top down and bottom up effects
    - If you sever the ties from the body to the brain, it breaks things like fear conditioning. What's in the body affects the mind.

Why we have emotions

- What are the two main "why" explanations? Be able to describe these generally.

Cultural: emotions are the products of societies and cultures, and are acquired or learned by individuals through experience. Embarassment, guilt, shame, jealousy, envy, empathy, pride, etc.

Evolutionary psychology: emotions help us learn, they help us act appropriately, they make us seek things that help us survive and reproduce and avoid things that hurt our chances.

Phases of emotion

- What are the typical phases of emotion? Be able to identify and describe each phase.

Elicitor--some stimulus arrives or some perception occurs
Appraisal--attaching significance to the stimulus/perception
Feelings/motivaional states--your internal experience of the emotion
Expression--gestures, body language
Actions--conscious response

Physical correlates of emotion

- What are the physical correlates of emotion mentioned in class that are typically used to categorize emotion? Be able to generally describe each.

Facial expressions, physiological changes, molecular changes. Appraisals (seeking/avoid more of the stimulus), antecedents (what stimulus caused it).

Ekman and Panksepp

- What is similar about the way these two scientists conduct their research?
- Each scientist's criteria for identifying "universal" emotions is different. Be able to generally describe why.

Both searched for universals in emotion.

Ekman

- What are the 6 basic emotions Ekman identified?
- How did he classify these emotions?
- What application comes out of Ekman's research?

Anger, fear, disgust, surprise, happiness, sadness

Classification method: basically facial expressions and gestures. Or in a more complex wording: universal signals, distinctive physiology, automatic appraisal, commonalities in antecedent events which call forth the emotions.

What came out of it was he became the world's best lie detector.

Panksepp:

- What 7 emotion pathways does Panksepp study, and what are the affective correlates of each pathway?
- How does Panksepp (methodologically) study these pathways in animals?
- Panksepp's research has been extremely beneficial for depression research.

See his presentation

Primal emotion	**Affective feelings**	
Seeking	Enthusiasm	Diminished in depression
Rage	Pissed off	
Fear	Anxiety	
Lust	Horny	
Care	Tender and loving	
Panic	Lonely and sad	Psychological pain, panic attacks. Gateway to depression
Play	Joyous	

Opiates mediate motherly love. Oxytocin is like a brain opioid. It reduces psychological pain and diminishes depression.

Interesting note: testosterone counteracts crying, and that's why men cry less than women.

Three new treatments for depression:

1. The use of safe opioids to reduce psychological pain that leads to depression and suicidal ideation (Buprenorphine)
2. The use of Deep Brain Stimulation (DBS) of the SEEKING system to elevate capacity for **enthusiasm**
3. The genetic analysis of PLAY--elevated social joy in the brain--to identify new neuro-chemistries to promote positive social feelings (GLYX-13)

He studied these emotions in animals by activating the related parts of their brain and seeing if they opted to turn the stimulators off. If they did, then that meant is was a negative emotion. He classified the seven behaviours as things the animals either wanted or avoided. It's easy to see which ones are which.

Baby chicks

- When a baby chick is looking for its mother, what system is activated?
- When a mother puts its chick under her wing, what class of neurochemicals are released?
- What research, being conducted in Israel, has come out of these types of studies?
- When the panic system is in overdrive, how does this affect the seeking system?

Looking for its mother: the panic system
When a mother puts it under her wing: oxytocin
Research conducted in Israel: opiate-based anti-depressents
When the panic system is in overdrive, the seeking system is depressed (lower levels of activation)

Love

- Why is it considered a "complex emotion"
- What are the three main pathways thought to contribute to feelings of love? Be able to describe each and cite the major hormones associated with each.
- What was the "love competition" and what did it reveal about the complexities of love?

Love is considered a complex emotion and because it's made up of a bunch of other emotions (lust, attraction, attachment), and there are so many different kinds of love. Love for your baby sister, love for your crush, love for someone you've been married to for 50 years. Love includes happiness, joy, lust, grief.

Three main pathways:

- Lust
  - Testosterone (sex hormone)
  - Estrogen (sex hormone)
- Attraction
  - Dopamine (reward/pleasure, motivation)
  - Norepenephrine
  - Serotonin (general happiness)
- Attachment
  - Oxytocin (bonding, intimacy)
  - Vasopressin

Bottom up, Top down

- What is the "baby schema"? How is it adaptive?

If it looks like a baby, we'll be drawn to it and want to nurture it (oxytocin?), even if it's not ours. Even if it's not human. So we say a bear is cute because of its rounded face and chubby cheeks. A kitten is cute because of its small nose and mouth.

Being perceived as cute or cuddly motivates caretaking behaviour in other individuals. In species whose young depend on long-term parental care, such bias could be adaptive and enhance offspring survival.

Examples of bottom-up vs top-down

Moral reasoning is high effect. A fake example would be like seeing the colour blue all day might make you more cynical with your moral reasoning. A bottom-up effect.

Top down effect. Language higher level than colour detection. But based on what words you have in the language you speak, you can see colours that other people can't see. Like languages that don't have a word for turquoise.

Bottom-up: perception affects how we feel. Like the Facebook study about altering people's feeds.
Top-down: people who are depressed see colour less vividly than other people.

LECTURE 6: UNCONCIOUS MIND

Dreaming and Learning

TEDxRiverCity - Robert Stickgold - Sleep, Memory and Dreams: Fitting the Pieces Together
https://www.youtube.com/watch?v=WmRGNunPj3c

A bunch of words shown, related to doctor, but doctor not actually in there. Later, people were asked if they saw "doctor" in there, and they responded yes. This is false remembering. You forget what actual words you saw over the day and the night, and eventually you just remember the gist of it. Note that there's less forgetting over the night than over the day, *but* while sleeping, more false memories of "gist words" are created.

If you take a nap and dream of performing the task, you show substantial improvement over those who didn't take a nap or who took a nap but didn't dream of it. Just thinking about the task didn't help! Just napping barely helped! Only by napping and dreaming of the task was there a substantial improvement. It's like when you sleep and dream about something, your brain is processing information on multiple levels. Your dream can be vaguely related to the task, and that's fine. For example, a maze task, and your dream was about searching for something.

Lucid Dreaming

Tim Post at TEDxTwenteU
https://www.youtube.com/watch?v=OK3SfNxbK3Y

What's important here is that lucid dreaming is a hybrid system between system 1 and system 2 being in control. It happens almost exclusively in REM sleep, the most immersive state of sleep/dreams. Lucid dreams have flexibility. Lucid dreaming is learnable

LECTURE 9: ARTIFICIAL INTELLIGENCE

Why?

Why is AI different? Because it's a forward problem. We're making the algorithm to generate the output rather than looking at the output and guessing the algorithm.

Also, we need the entire thing to have the system work. That's why it's like a Rube Goldberg machine. If you take out any of the parts, it won't work.

Cellular Automata

For the pictures: the white square is the cell, the gray squares around it are the neighborhood.

Other slide: some things are stable, some disappear, some patterns eat other patterns. One person noted that things generally become symmetrical over time.

Glider gun example

Glider gun: it's like something is firing across the screen

Conway's game of life

It looks like it's really complicated rules, perhaps each pattern following different ones, but really there's only four simple rules.

She may ask us to memorize the four rules for the test. Hint hint.

Beacon, blinker and toad are simple oscillators based on two states. Pulsar is a slightly more complicated oscillator based on three states. Spaceships and gliders are oscillators that move across the grid over time.

Originally Conway thought there would be no pattern that would generate a finite state over time, and there was a big prize for discovering one.

Gemini spaceship. Mimics replication.

Basically the idea that simple patterns and rules can be used to explain complex underlying behaviour.

Biological examples

Shells and mollusks(?) and cephalopods can be modelled using seed states and cellular automata. For example, rules about which cells produce pigment.

Microtubules

Neuron microtubules
Protein tracks for axon transport
Protein qubit

So this goes back to the physical theories of consciousness from a while ago. This is one of them. Microtubules: long, rope-like proteins that exist all over the body, but mostly in axons in neurons. They act like little railroad tracks that other proteins can shuffle along. These proteins can be used for cell growth, maintenance, etc.

Examples in Cognition

We usually think of neurons communicating through action potential. But that doesn't explain a number of things. One problem is that if we model a neural network the size of the brain, we only get about 37 bits of information, which is ridiculous. In response to that, the microtubules were proposed as a way for the other information to be carried. And microtubules can be in any one of several different states. (Different from the binary set of states available to cellular automata or the simple on/off of an action potential in a neuron).

Some of the pictures show a glider-like pattern in microtubules.

There's also the idea that microtubules may be important for consciousness.

Example for alzheimer's: it's strongly linked to what's going on with your microtubules. The tau proteins degrade, so the microtubules destabilize. We know that alzheimer's results in impaired consciousness, not knowing who you are.

Another example is from anesthetics. When you're knocked out, people aren't sure how that works, since the normal synaptics (neurons) are still firing. But we know anesthetics destabilize microtubules, so maybe that's how they work. There are reasons to think microtubules could underlie consciousness.

Roger Penrose had the idea that quantum mechanics must underlie consciousness, but he didn't know how. He got together with a microtubule expert, and they figured out what quantum mechanics might be doing in the microtubules to give rise to consciousness. (Implementational and algorithmic level working together).

Language

Eliza (Weizenbaum, 1966). Named after the character Eliza Doolittle from <u>My Fair Lady</u> (1964). It's a chatterbot.

Robotics

Al-Jazari, the book of knowledge… (1206 BCE)
Some sophisticated robotics going on. The book was full of drawings of complicated mechanical automata. Picture of a hydro-powered perpetual flute.

Writer Automaton 1721-1790

It looks like a small boy, and it can write. It's 240 years old at the time of the video. Built in Switzerland. By Pierre Jaquet-Droz, one of Switzerland's greatest clockmaker. Inside the boy are almost 6,000 parts. And every one of these crafted components was refined and miniaturized to fit inside the body of the boy. He used the technology of homeostasis, miniaturization to make the robot. Even the eyes move! It "reverse engineered the act of writing". The center stack that controlled the robot was composed of pieces that could be rearranged to program the boy to write something else.

Early robotics: SHAKEY

SHAKEY was one of the first robots that could plan and manipulate around its environment on its own (one definition of intelligence). It navigates around obstacles to get to the doorway. Sort of like an ancient ancestor of the roomba.

It was one of the first robots to be able to "reason." Observe its environment, update its model, change its behaviour. This is progress from the programmable boy who can't use information from his environment.

Complex movement

Spot (Boston Mechanics). A smart robot dog that can go around, even handle being kicked. Movement isn't true cognition, it's a lower level system. But it's still a really complex system that's useful to us on an everyday basis.

Strandbeest (Theo Jensen). It's really complex stuff.

Artificial Agents

Artificial agents need a way to take in information and a way of carrying out their decisions.

3 types of artificial agents

Reflex agent: responds very simply to its environment
Goal based agent: be able to pick from a few possible end states and pick which one is most desirable
Learning agent: can take feedback from its environment and alter its decision pathways

LECTURE 10: METHODS 3(DEVELOPMENTAL PSYCH) AND SPECIAL TOPICS (SEX DIFFERENCES)

Developmental psychology

We've already seen some examples of this. And we've seen how this can give us insight into how the mind is organized. E.g. how language is acquired in infants.

Historical viewpoints

Children used to be viewed as irrational, illogical, and egocentric. They came into the world as a blank slate (tabula rasa) and were conditioned by the environment. This goes against what we found about innateness, e.g. the language acquisition device. Romantic writers refer to them having "celestial openness", which is a fancy way of referring to the tabula rasa idea.

It turns out there are quantitative and qualitative differences between adult and child thinking. They're not just little mini adults, they think differently. E.g. children younger than 2 don't have theory of mind.

Origin of childhood (1)

The conceptualization of childhood has changed over time.

1600s: Used to say they're just mini adults or a blank slate
Enlightenment: we started to see childhood as an age of innocence, and they have yet to receive experience of the world and be taught. They depend on us to give them the cognitive skills they need to succeed in life.
Industrialization: the age of child exploitation. Chimney sweeps, Charles Dickens.

19th Century: sanctity of the child, they have to be protected from exploitation.

Origin of childhood (2)

Gradient of precociality. An altricial is like the baby bird in the nest. They are completely dependent on their parents for nurturing and protection. They need their mothers to regurgitate into their mouths, the epitome of helplessness. A precocial animal, like in the wildebeest video, it's just born and it can already get up and walk. A lot more able to take care of itself.

So why should humans be altricial? Human babies are pretty exposed and helpless. Why?

When you rely on learning through culture and nurturing, you need to have less information hard-coded in the brain (instincts). That means space can be saved in the brain for abstract thought.

We're the only surviving upright walkers, and we're also the only surviving ones with such an extended childhood. Upright walking means narrower hips. Our brains became so big that an upright walker like us wouldn't be able to birth the baby if its brain was fully formed. So we gave birth to them earlier. Their brains continue to develop outside of utero, and we became more altricial.

What's key about this is that instead of cognitive development happening in utero, it can happen in the environment. A lot more stimulus, a lot more learning based on the environment while the brain is still plastic. In utero, you don't have the ability to interact with the environment.

Powerful computing machines

Graph shows a correlation between increasing brain size and length of childhood.

Period of learning

Powerful statistical computers. A child's brain is in a state where they can do an amazing job of computing conditional probabilities, revising their understanding of the world. Children are better at this than adults are, even though they're less intelligent than adults in other ways.

Powerful learners

Obvious thing to adult is that you have to put the piece on top of the block. But most effective thing is to wave the block above it. Four year olds are better at this task than adults, more likely to detect the correct (unlikely) hypothesis.

When children do this, we call it "getting into everything" or "playing around". They process novel information much better, they're exploring, trying all sorts of different hypotheses. Unlike adults, who have years of experience narrowing their focus and knowing what to pay attention to. An adult brain is streamlined for processing certain types of stimuli, but children don't know what's important, so they have an area of focus that's much broader. Everything is novel and requires processing.

Children aren't bad at paying attention; they're really bad at *not* paying attention (to everything). They're like little ADD machines.

Adults have all sorts of different biases that children don't.

On an implementational level, there's all sorts of neurotransmitters and stuff that's responsible for plasticity.

Processing new information is very linked to time perception. When we're processing information, it feels like things are slower. But when we're on autopilot, it feels like time is going faster. So maybe this is why it feels like time goes faster when we get older; less information is novel.

Visceral learning (1)

Learning begins in utero.
Sound of mother's voice. Everything sounds like "wah wah", the adults in Charlie Brown, but the baby can still recognize it later.

- Cat in the Hat. They can recognize the story.
- Soap opera theme songs. Children can still recognize it after.
- Crying accents. They have accents of their native language. French babies cry on a rising accent and german babies cry on a falling accent.

Tastes

- Carrot juice during 3rd trimester. They have memories for tastes if the mother drinks carrot juice, for example.
- Anise

Visceral learning (2)

Two stories. During the second world war, when the germans blockaded West Holland, and there was no food available. Lots of people died of starvation. People survived on 500 calories a day, ate tulip bulbs. So all sorts of health problems and cognitive deficits. And also it turns out that babies born during that time had, as adults, higher incidence of diabetes, obesity, heart disease.

Babies in utero get signals from the mother's body that they can expect not many calories in the world when they're born, so they are born smaller and with a metabolism that makes them more able to hold on to calories. (Low energy and fat?)

9/11 example she won't talk about.

But the point is when we're born, our bodies and minds are streamlined for what we're going to encounter.

Piaget's stages

He was part of this idea that children are irrational, illogical, and egocentric. Breaks up childhood into phases.

Object permanence: the idea that if you hide an object, it still exists.

Pre-operational phase won't be on exam. Centration means the tendency to only focus on one part of the situation or problem. Leads to flaws in reasoning. Example of the beaker picture. Children will predict that the one on the right has more than the one on the left. They only focus on the height dimension, and forget that it came from the same original volume.

Powerful learning mechanisms

Sensory perception
Language
Theory of mind

Sensory perception

Some developments based on sensory capabilities
Some based on experience and learning

Children come into the world more sensitive to the yellow part of the spectrum, and not being able to see in three dimensions (happens after 4-5 months). These sorts of learning depend on input for the environment to develop. Then there's size constancy (an object further away makes a smaller impression on the retina, but we understand that it stays the same size), and that requires interaction with the environment. Facial recognition also takes some time to develop. A one month old will look at your hairline (boundaries) rather than your face (inner structure and features).

Language

Don't worry about all the stuff in these slide pictures. But here are some interesting speech errors that occur. No matter who the child is, they make the same types of errors. Tells us something about our language acquisition device.

Language (verbal)

Two-word stage, children start by omitting function words. “Daddy eat”.

More-word stage. Children learn to apply plurals. They learn the irregular plurals first. “Men”, “geese”. Then later they understand the rule of applying the -s morpheme. Then they start applying it backwards and go to saying “mans”. And if you try to correct them, it won’t do anything. They’ll argue with you, they won’t get it. They just have to go through these checkpoints.

Children also won’t apply -s to words that end in a sibilant. “Horse”, “nose”. But once they learn this, they’ll backtrack again and start saying “manses”.

Meaning stage: complexive concepts. A child is learning the important thing a word refers to. When they hear “dog”, they’re testing out hypotheses about that “dog” means. Does it mean the furriness, all things with four legs, things that move around? They’re doing some bayesian statistics to see what might be the case.

And they make some really cute errors. Children mixing up “blanket” and “team” because they were told earlier in the day to sit on a blanket with their team.

Theory of mind

Saw from morality lecture the false belief task. Between ages of 3-5 they start to understand that what they have in their mind may be different from what other people know.

Teenage brain

We start to lose some gray matter. This is where all the cell bodies are. Not where the communication happens but where information processing happens. Because once we learn what’s important over time, our neural pathways become more streamlined. We can prune the neural pathways we don’t really need anymore. Because adults aren’t doing as much learning as children.

Sex differences

Diffusion tensor imaging shows connections between different areas of the brain. Males, at the top, have more intrahemispheric connection. The front and back, for example. Females, on the bottom, have more interhemispheric connections. She says women are way better than men at multitasking, but men are better at sensorimotor processing. Women are better able to integrate different types of information on the fly, and men are better streamlined to one task. Think of women with a baby on their hip and doing a bunch of other stuff at the same time.

Carl Sagan

We eventually learn how we’re supposed to act and what’s important. Curiosity is beaten out of us. A scientist is someone who holds onto that childlike curiosity and interest in experimenting.