WHY WE STUDY THE BRAIN:

- We want to study brains to understand for the sake of science

- For clinical purposes and to treat people with abnormal functioning in their brains.

- Simulating/building a brain for a machine that can behave like a human, humans can do.

- Neural networks are similar to neurons that have connections, which is related to the study of brains to build smart computers.

- To understand the mind and how the brain supports human intelligence and human cognition.

THE SEDUCTIVE ALLURE OF NEUROSCIENCE EXPLANATIONS:

- Researchers asked people to rate how good an explanation of a psychological phenomenon is.

- **Curse of Knowledge:** If people know something, everyone else will know even if it's not true. Causes other people to think everyone knows the same information as them.
- Once you integrate neuroscience research or reference to brains. People become worse at assessing a good scientific phenomenon vs a bad one.

- An appeal to brains makes people much less reliable from assessing good arguments from bad arguments.

  The Experiment:

  - **Good Explanation:** Researchers claim that the "curse" happens when a subject has trouble switching their point of view to consider what others may know.

  - **Bad Explanation:** Researchers claim that the "curse" happens when a subject makes more mistakes when they have to judge the knowledge of others. People are better at judging what they know.

  - Brain scans indicate that it happens because the frontal lobe brain circuitry is known to be involved in self-knowledge.

  - If anything with the brain is mentioned, people judge the bad explanations to be good.

NEURAL MECHANISM UNDERLYING COGNITION:

- Take a cognitive process (talking), which is a paramedic cognitive process because it's a facet of our minds.

- We ask how I talk, use words, and how our brain helps me talk and support that cognitive process.

- **The neural correlates of cognitive science:** The neural mechanisms that underlie the process of what parts of the brain support that cognitive process.

  Kinds of cognitive processes:
  - Talking
  - **Asking about the neural correlate of mental imagining:** being able to imagine things you have never seen (Ex: a shark with horse legs).
  - Anything the human mind can do must be supported by the brain and how the brain is able to support the cognitive process and how the neuron correlates

- You identify a cognitive process and do experiments then associate it with brain activity.

  What your brain does not tell you:
  - **Experiment:** People are listening to Gangnam style think they found the Gangnam style part of their brain:

    - It does not tell you that these brain regions are necessary. EX: Gangnam style does not cause the activation pattern. You could just think it's a correlation, but you can see a pattern of activation.

    - **Listening to music is not the only thing your brain does:**

      - Your body regulates body temperature
      - Breathing
      - Making you aware of your environment

  - You just see the patterns of activations because people are another commonality of these, which cause the elevated patterns of regions.

  - These neural correlations that are based on limited studies

  - They can't get you from correlation to causation and

  - It can't give you a reason to infer a causal explanation from what could just be a correlation.

  - Does not tell you about the cognitive process.

- It does not tell you how the brain supports the cognitive process

- It just shows what region of the brain is active

- Just having a map of a cognitive process of brain activity does not tell you how the brain is supporting the cognitive process.

FUNCTIONAL MAGNETIC RESONANCE IMAGING (fMRI):

- **fMRI** is a big bed that takes pictures of your brain over time.

- The big picture is non-invasive and is generally safe for children.

- **Positron Emission Tomography (PET)** involves people taking a radioactive drug called the Chaser tracer and being scanned.

- The tracer collects areas of the body with high levels of chemicals, which relates to diseases.

- **MRI** involves exposing the brain to multiple magnetic fields

- In **MRI**, it takes a picture one at a time, which takes 5 - 10 mins.

- **MRI** pictures are slightly higher resolution.

  fMRI:

  - Hydron protons respond by emitting an electromagnetic signal to the machine and it can create a high-resolution image of the brain.

  - Detects small changes in brain metabolism (oxygen use) in active brain areas.

  - Oxygenated blood has magnetic properties that influence radio-frequency waves emitted by hydrogen atoms in an MRI

  - **fMRI** by showing patients a stimulus who are interested in face perception that will cause brain activation.

  - The region that is responsible for processing a kind of stimulus you show them.

  - Once the brain activates, lots of neural firing is going to cause oxygen consumption in the region.

  - You will get an inflow of oxygen native blood to the region to replenish the O2 that was consumed with the activation

- It allows us to measure the **BOLD** signal **(Blood Oxygen Level Dependent)** dependent activity.

- A hemodynamic measure that tracks the ratio of oxygenated blood to deoxygenated blood to the flow of the blood in the brain.

- Deoxygenated hemoglobin is relative to the oxygenated hemoglobin ratio.

- **fMRI** does not measure direct neural activity.

- **fMRI** measures activity across a lot of different neurons, which is evident by blood flow.

- O2 consumption and then inflow of oxygenated blood, so the flow of the blood is measured when doing **fMRI** scanning.

  What does this technique tell us:
    - This process is very slow

    - Must wait for the area for the O2 to be consumed and then for an inflow of oxygenated blood.

    - Takes 10 - 12 seconds to see this inflow of oxygen to the region

    - This technique has a bad **temporal resolution**

    - **fMRI** is not a good technique to tell you when these regions are activated.

    - **The benefits:**
        - **fMRI** has a very good spatial resolution
        - It tells us where things happened
        - You're able to see where the blood is going with a high degree of specificity

- **fMRI** is tracking changes in the movement of oxygenated blood

- The brain is always active, so **BOLD** signals are a relative unit of measurement and not absolute like centimeters.

- **fMRI** compares one set of **BOLD** signals activation patterns to another, which requires a baseline (EX: Show someone a blank screen and then show them a picture to see the spike in their brain activity).

    - **fMRI** and **BOLD** measures require contrasts because the brain is always doing something.

    - **fMRI** is always correlational, not causal

TRANSCRANIAL MAGNETIC STIMULATION (TMS):
- A non-invasive method

- A big coil that is held above someone's head creates an electromagnetic field that causes neurons to fire.

- It stimulates the motor cortex and makes muscles twitch.

- Can possibly induce seizures and is uncomfortable.

- It can be very precise about where we stimulate the brain.

- However, you can stimulate very far into anyone's brain below the surface.

FUNCTIONAL SPECIALIZATION:
- **FFA** does not only respond to faces, it is not dead silent with other stimuli.

- It responds to other visual objects besides faces such as cups, letters, and bodies.

- **FFA** is the best area to demonstrate functional specialization of the brain and is the most functional specialized region.

- **FFA** is responding to face stimuli and face processing

- There is also increased **FFA** activation when people are doing things they have expertise in.

- People have much expertise in identifying faces.

- **FFA** is just specific to expertise, but we do not have the same expertise for faces, unlike other stimuli.

- **We are also able to isolate different kinds of processing such as:**
    - Color
    - Motion
    - Faces
    - Places
    - Bodies
    - Visual words

    - Other objects

- **Domain-Specificity:**
    - We are just one giant lump of meat that is able to compute things

- **Consistency across people:**
    - Some brain regions are dedicated to doing particular things such as face perception and social cognition, which is mainly consistent with people.

- Brains naturally know how to walk, talk, think. Just like a computer, it comes with essential programs and actions.

- Brain areas are connected to fibers, which restrict the information flow from other areas.

- **Theory of Mind:**
    - The belief story **(in the lecture)** and the physical story **(in the lecture)** have the same structural commonalities.

    - One is in terms of belief and theories of mind.

    - The other is doing in terms of physical relationships.

    - The patterns of activation in **fMRI**, a region called the right temporal bridle junction.

    - This region favors the arising of the theory of mind.

    - Participants are able to give answers faster in the belief story instead of the physical story.

    - You can see more activation in the belief story rather than the physical story.

- **Visual word form area:**
    - Responds to more words than any other sort of visual object.
    - It's close to the fusiform face area
    - The visual word form area is very consistent across different people.
    - **VWFA (Word area)** responds when a person is reading a word.

- You are able to see computational and representational commonalities in behavior

PLASTICITY:

- The brain seems to be plastic and that processing is being influenced by the kind of stimuli people are getting

- **Example:**
    - a blind individual has activation in their visual cortex when they hear the language, but not activation when seeing someone.
    - Blind people are using parts of the visual cortex to process language
    .

- Brains are very efficient and if you don't use an area of the brain for a while, it gets repurposed to help you.

- The brain can repurpose neurons to do other things.

SUMMARY FOR fMRI COGNITIVE NEUROSCIENCE:

- **Cognitive neuroscience** is the study of the neural mechanism underlying cognition.

- **fMRI (neuroimaging)** and TMS **(non-invasive stimulation)** are two of their main tools.

- A lot of cog neurons are concerned with studying **functional specialization** in the brain.

- The brain has some specialized regions (e.g., faces, language, and theory of mind).

- A lot of this specialization emerges early. Some of it is developed through experience (e.g., **FFA vs VWFA**).

- Some parts of the brain (mainly, in the **PFC**) are not specialized (i.e., are domain-general).

ELECTROPHYSIOLOGY (EEG):

- Measures the electrical activity of the neurons themselves.

- Every time neurons fire, they fire signals to each other.

- We can measure it by putting electrodes onto a persons' head.

- We are measuring the work the brain is doing as it is being done.

- Has great temporal resolution because it's taking a sample of our brain's electrical activity thousands of times a second.

- Has very bad spatial resolution because we don't know where the brain's activity originates from.

- Useful to tell what kind of process is going on in the brain and what steps the brain takes to do certain computations.

- **EEG** measures electrical potentials.

- **Why EEG:**
    - It allows us to see cognitive processes unfold in real-time
    - It's great for asking questions that have to do with time since it has a great temporal resolution.
    - It is great at telling us about covert processes
    - EEG tells us if someone is having a brain response that they are not aware of.
    - Allows us to test hypotheses about completing algorithms.

- **Steps for EEG:**
    - Measure a person's head to get a good fit of the net

    - The net is then placed on a person's scalp where electrodes come into contact with our skin.

    - The brain activity is measured with the neurons firing inside the brain.

    - After the neurons are fired, they send electrical activity across the synapse to other neurons they are connected to.

    - It filters up all the way outside our brain, to the hair, to the electrodes.

    - The signal is amplified heavily, so we can see it due to it being a weak signal.

    - This process is part of reducing the amount of electrical resistance between the electrodes and the brain itself.

    - You can watch the brain waves come in real-time, unlike **fMRI.**

- **Neurons fire 2 different kinds of electrical signals:**
    - **Action Potential:** Happens within a neuron and is able to go very fast (1 msec).

    - **Postsynaptic Potential:** Happens between neurons and is slower (10s / 100s msec).
        - They generate a dipole in a magnetic field.
        - If enough of them are summed together, then it is possible to measure them.

  - This requires a lot of neurons at the same time.

- **EEG** only measures postsynaptic potential at a depth of only 5mm in the brain.

- Most of the functionally we are interested in is happening in the very thin outer layer of the cortex.

- In that layer, we have vertically oriented pyramidal neurons.

- If enough of those pyramidal neurons at the same time, it creates a signal with a strength we can measure and observe.

- We want to measure something called an event-related potential and measure the specific brain response to a specific process.

- The average brain response looks like a waveform.

- We can identify brain responses based on how the waveforms look.

- We can use amplitude to see how low the waves are.

- We have latency to look at the timing of a peak and how long it goes for.

- We have polarity, is it a positive peak or a negative peak?

- We have scalp location and we can still measure it at the scalp even though we don't have a precise location.

- Top-down processing requires predicting on what the next thing we are going to experience

  Brain Predicting sound:
  - **Prediction error:** When you fail to interpret what happens next.

  - When we think of something similar that happens in the human brain, it is a process we can measure using **EEG.**

  - We can measure an ERP called the **Mismatch Negativity (MMN).**

  - It does not require any attention and is very automatic.

  - It is a test that can be performed on comatose patients to find out if their brain is still working
  - If a brain hears the same sound over and over, it will predict it will hear it again

- The brain only cares about categories.

- The brain represents the sound it is hearing

- It is only using the category information to make predictions.

EEG STUDIES IN ACTION:

- Speech sounds exist on a continuum and are perceived as distinct categories.

- There has to be some part of mapping between the continuous physical spectrum and the discrete categories we recognize in our minds.

- **Question:** Do we encode the sounds in a continuous way or do we encode them as categories?

- Giotto Scannow found that there is a correlation between the amplitude of the brain response measured with EEG and the physical description of the sound that a person is hearing.

- There is a perfect linear correlation between where a sound is on the spectrum and what the amplitude of the brain response is.

- It tells us that the brain is encoding the analog or continuous nature of those sounds.

- It is encoding the physical description of those sounds before it converts them into discrete categories.

- Our auditory system encodes continuous sounds. They are encoded in a continuous way then they are mapped to those discrete categories.

- It tells us how we form mental representation and how we encode sensory information.

MAGNETIC AND CEPHALIC GRAPHIC (MEG):

- When you measure the magnetic fields generated by brain activity but don't have the issue of resistance.

- Magnetic fields permeate through the human skull just fine.

IMPLICIT VS EXPLICIT LEARNING:

- When you learn something, there is a physical change in your brain.

- **The phonological rule for Chumash:** A word can have an S or it can have an SH or an SHA, but it can't have both.

- **LPC:** a much later brain response that has peaks that are 600 milliseconds after the stimulus and it's positive. It is generally associated with linguistic processing.

- **P300:** A positive wave that peaks 300 milliseconds after the stimulus.

- It is a sibilant harmony pattern that Chumash and Navajo both have.

- **Implicit Learning:**
    - Cue-based
    - Effortless
    - Unconscious
    - Gradual
    - No feedback
    - Only positive examples

- **Explicit Learning:**
    - Rule-based
    - Effortless
    - Conscious
    - Abrupt
    - Feedback
    - Positive and negative examples
    - Not the best way to engage neural plasticity

- **An experiment where it tested implicit learners vs explicit learners:**
    - **Implicit Learners:**
        - They get the LPC brain response that is associated with native language processing.

        - Even if their accuracy was low on their test, they still internalized this rule and they are treating it in the same way they treat the rules in their native language.

    - **Explicit Learners:**
        - When people are doing tasks where they have to categorize something good or bad, or grammatical or ungrammatical, there is usually a P300 brain response.

        - No LPC, so they are not processing the same rules in their native language. They were not told the rule explicitly so it makes sense.

        - When people internalize rules even though they learned them for the first time, they get the same brain response to violations in their native language.

        - People process rules the same way they process their native language.
        - There is no brain response.

        - They don’t have the brain categorization response.

KEY CONCEPTS:

- **Electroencephalography (EEG):**
    - Measures postsynaptic potentials.

    - Measures a specific kind of electrical activity in the brain.

    - Measures the activity between neurons.

    - A good way of measuring covert processes.

    - Good at measuring stages of processing related to time.

    - A great way of accessing algorithms and mental representations.

- Post-synaptic potentials

- Covert processes

  Neural encoding of speech sounds

- Implicit vs Explicit learning

- The anterior cingulate cortex(ACC) is thought to participate in conflict detection.

DO WE PROCESS MATH WORD PROBLEMS DIFFERENTLY DEPENDING ON RELATIONS BETWEEN OBJECTS?:

- **Ex:** “3 tulips + 4 vases”

- Tulips and vases are related because one contains either

- The semantic relationship is conceptually meaning sets that are bound to the mathematical roles.

- **Addition:**
  - **Aligned**
    - 3 tulips + 4 daisies
  - **Misaligned**
    - 3 tulips + 4 vases
- **Division:**
  - **Aligned**
    - 12 tulips / 4 daisies
  - **Misaligned**
    - 12 tulips / 4 vases

- **N400:** Related to semantic aspects of language processing

- Negative deflection in response to semantic incongruity

- Peak amplitude 400ms following word onset.