A brief description of EEG

- Electroencephalography, often shortened to EEG, is an electrophysiological method used to measure fluctuations in voltage at specific sites of the brain.
- The fluctuations in voltage come from ions travelling into and out of neurons. The movement of these ions changes the voltage in regions of the brain, which is recorded using electrodes either applied to the scalp or to the surface of the brain, a technique called intracranial EEG
- EEG produces a recording of the fluctuating voltages over time, which can be used to study neural oscillations (brain waves), or fluctuations in voltage immediately surrounding an event, named event-related potentials

History

- Following the discovery of electric phenomena in the brains of rabbits in 1875 by Richard Caton, German physiologist and psychologist Hans Berger recorded the first human EEG in 1924
- EEG proved to be especially useful for studying epilepsy, and in 1935, Gibbs, Davis, and Lennox began the field of clinical electroencephalography by describing the spikes in neural oscillations of the altered state of consciousness following a seizure, as well as describing the pattern of absence seizures.

How/Why it works

- To truly appreciate EEG's capabilities, we must understand how and why the technology works.

Biology Background

What is a neuron?

- The neuron consists of a cell body, a long axon, and branching dendrites
- Neurons send "messages" to other neurons at the synapse, located at the end of the axon terminal.
- These messages are signalling molecules called neurotransmitters. When these neurotransmitters bind to another neuron's receptors, ions travel into the other neuron.
- If the difference in voltage between the inside and the outside of the neuron, known as the membrane potential, is -55 mV, the neuron is said to "fire", which means it will send signals to other neurons.
- The membrane potential when the neuron is not firing, known as the resting membrane potential, is -70 mV.
- To communicate from one neuron to another, an electric signal must first travel along the axon through pulses known as "action potentials"

What is an action potential?

- The resting membrane potential exists because of an imbalance of sodium and potassium ions inside and outside of the neuron. To change this voltage, there are channels and pumps to allow for the transfer of sodium and potassium ions. There are many different types of channels, but we are most interested in voltage-gated channels, which only open at a specific voltage.

- When an action potential starts at the cell body, sodium channels are opened, and sodium ions rush into the cell, increasing the membrane potential to approximately +30 mV. This is known as depolarization.
- The high voltage causes K^+ channels to open, allowing potassium in the cell to rush out, making the membrane potential more negative. This process is known as repolarization.
- Since potassium channels close slowly, the membrane potential has a refractory period where it is more negative than - 70mV, and slowly becomes less negative until it reaches the resting membrane potential of -70 mV. This process is known as hyperpolarization.
- When the action potential reaches the synapse, the membrane potential of the postsynaptic terminal can change through a postsynaptic potential. This postsynaptic potential is excitatory if the measured voltage is positive, which will increase the likelihood that the neuron fires or inhibitory otherwise
- EEG is said to record fluctuations in voltage arising from these postsynaptic potentials and not the action potentials.
- EEG cannot, however, measure the postsynaptic potential of a single neuron. It instead measures the summed electrical postsynaptic potentials of between 100 million to 1 billion neurons close to the site where it is attached

The engineering background

- The postsynaptic neuron can be thought of as a dipole, being more negative at the synapse and more positive away from the synapse
- There must then be a voltage gradient along dendrites. This causes a current flow in the conducting brain matter around it, called a “volume current”.
- This volume current can reach the scalp, and cause voltage differences on the scalp that can be detected by EEG electrodes
- The current flow in postsynaptic neurons aligned parallel to other neurons and perpendicular to an electrode produces the fluctuations in voltage seen in EEG.
- Neurons not aligned parallel to each other and perpendicular to the electrode produce voltage that cancels out with other neurons, which is why EEG requires the use of many electrodes
- The voltage fluctuations recorded by EEG are passed into a differential amplifier, which means that the voltages recorded are relative to another source.
- This source can be a reference voltage or other electrodes, depending on what the researcher is studying

How can EEG data be analyzed?

- Brain waves can be typically classified into beta, alpha, theta, and delta waves that correspond to wakefulness. You typically experience beta waves when you are awake and alert, and delta waves when you are in deep sleep
- Brain waves can be grouped by frequency bands, but it’s very hard to determine frequency just from the original wave
- There is an algorithm called the Fast Fourier Transform, or FFT, that transforms a function like the original EEG signal defined in terms of time, called the time domain, into a discrete function defined in terms of frequency, called the frequency domain according to the original function’s Fourier series

- The resulting frequency plot can be compared against a chart of beta, alpha, theta, and delta waves to determine the wakefulness of a patient

I'll now pass it over to my partner Elias, who will give more context to modern EEG.

Davies, H. (2013, September 14). An Introduction to EEG. Retrieved from https://www.ebme.co.uk/articles/clinical-engineering/introduction-to-eeg

MRC CBU Wiki. (n.d.). Retrieved May 29, 2020, from http://imaging.mrc-cbu.cam.ac.uk/meg/IntroEEGMEG

https://www.youtube.com/watch?v=oa6rvUJlg7o
https://www.youtube.com/watch?v=WhowH0kb7n0&vl=en
https://www.youtube.com/watch?v=aDKz3GUVAzg

Why do we use EEG? (Applications)

Why eeg over other tech:
Safe non intrusive
Low cost
Transportable
Can be used in more place than fMRI, MEG
High temporal resolution
Low spatial res

When

- Epilepsy
- Seizures
- Head injury
- Encephalitis
- Brain tumor
- Encephalopathy
- Memory problems
- Stroke
- Sleep disorders
- Brain surgery
- coma

How does it compare to other imaging technologies? (Current Limitations)

StoryBoard:

Explain advantage of high temporal res vs low spatial
Explain use cases for that
Explain cases can’t be used
Go into other technologies
Explain consequences of those
Explain other benefits of EEG