Key Terms: Baseline | Cap | Electrodes | Frequency Bands | Artifact | Electroencephalogram (EEG)

ELECTROENCEPHALOGRAM (EEG)

The input that can be gathered from EEG has a lot of potential to give a direct and valid measure of global activity in the brain.

What is an electroencephalogram?

The brain can communicate a lot of information through the way it sends messages to other parts of the body. Information is passed through electrical activity in the brain via synapses. When billions of signals are passed in neural populations, the electric fields become strong enough to be measured outside the head (Ahmadian, Cagnoni, & Ascari, 2013). The synaptic waves can be recorded and analyzed in volts through a device known as an electroencephalogram, or an EEG for short. By placing electrodes on the scalp according to different brain regions or lobes, algorithms and imaging techniques are used to infer information from the brain (Kirschstein & Köhling, 2009). The number of sensors on an EEG can vary from as little as 4 to as many as 256 electrodes (Morey, 2018). The electrodes can notice electrical charges in the brain and amplify the charges to be depicted graphically (Biasiucci, Franceschiello, & Murray, 2019). The input that can be gathered from EEG has a lot of potential to give a direct and valid measure of global activity in the brain.

How is an EEG experiment administered?

EEG electrodes are usually assembled in a cap that has electrodes interspersed. The placement of the cap is very important, since that determines where the electrodes will be picking up signals. The signals are then amplified and recorded on a computer. The respondent is shown a stimulus like the image shown in Figure 1. The stimulus is time-locked and repeatedly presented. An EEG signal is obtained in the electrodes by measuring the electrical potential of the ground and active site electrodes. The continuous data collected is then averaged over several trials for each condition. This data is cleaned and interpreted through the EEG outputs that contain negative and positive peaks. The negative peaks are associated with activation and the positive peaks imply inhibition. The peaks help to give insight into the brain's electrical activity.

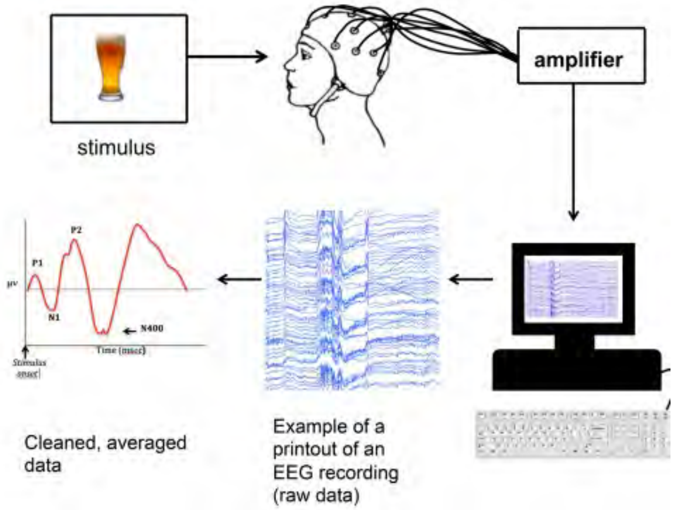


Figure 1

An example of the progression of a typical EEG experiment. The electrodes on the cap can measure the electrical brain activity during a manipulated stimulus (Beres, 2017).

EEG Units of Measurement

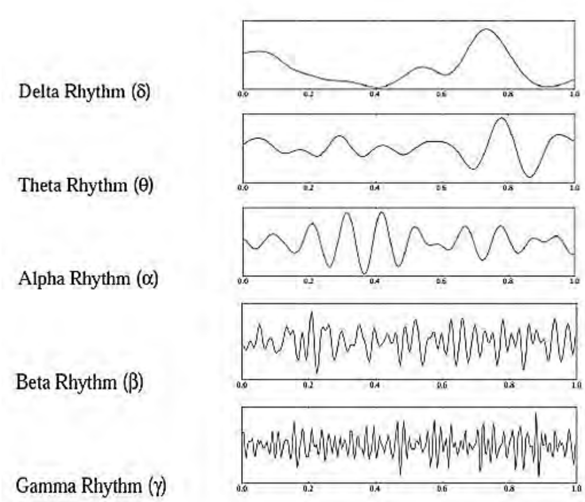
EEG voltage is determined by finding the difference between the currents on the active and ground site electrodes. The amplitude, or intensity, of an EEG signal averages in the 200 microvolts range, and the frequency, or speed of the wave, varies from around 0.01Hz-100Hz. EEG recordings are expressed through a measurement known as impedance. The unit for EEG output is presented in Ohms (Ω). By inducing an evoked potential with a respondent, the electrical activity in response to sight, sound and touch can be measured. An EEG has the advantage of being run for both long- and short-term projects. Short-term measurements tend to focus on specific stimuli, with a low amplitude of around 200nV-2uV. Longer-term EEG measurements evaluate the conscious state (Macy, 2015). The EEG scan has proven itself to be a valuable and versatile tool in fields including marketing, advertising, engineering, computer science, and medicine.

LET'S DIVE INTO THE WAVES

It is no surprise that there is constant brain activity, regardless the type of stimuli in the environment. Analyzing the different frequencies occurring within the brain helps to gain a better understanding of what the respondent is experiencing. There are multiple different types of wave frequencies that can be extrapolated from an EEG recording via the Fast Fourier Transform (FFT). The most common frequency bands are as follows:

- Delta waves (0.5-4 Hz): The delta wave is recognized as a slow rhythm and usually has the highest amplitude. It is associated with non-rapid eye movement (REM) sleep. A deeper sleep equates to a stronger delta rhythm (Macy, 2015). Increased concentration on working memory tasks, or focusing on difficult activities, have also been noted in increased amounts of delta waves.
- Theta waves (4-8 Hz): Theta waves are slow rhythms that are typically found in children under 13 years of age. Theta waves can be seen during sleep in adults or if a person is feeling fatigued (Macy, 2015). They are associated with memory and emotional regulation. If undergoing a frustrating event, it is likely that theta waves will become more prominent. Theta waves are also associated with drowsiness or idling.
- Alpha waves (8-13 Hz): As a moderate rhythm, the alpha wave is typically reflected in the occipital region of the head. Alpha waves are found when a person is relaxing or closing their eyes. This type of wave diminishes when eyes are opening or a person is alert. Alpha waves are most commonly seen in states of relaxed wakefulness within people after the age of

Figure 2



An example of the progression of a typical EEG experiment. The electrodes on the cap can measure the electrical brain activity during a manipulated stimulus (Beres, 2017).

thirteen (Macy, 2015). Alpha rhythms correlate with inhibition and attention in the brain.

- Beta waves (13-30 Hz): The beta wave is a fast rhythm. As we move our body or watch other people move, beta frequencies increase. A person who has his/her eyes open will have beta waves; however, beta rhythms also are found in REM sleep (Macy, 2015). Beta waves are represented with focused attention, arousal and memory retrieval. Motor functions and higher mental activity involve gamma waves.
- Gamma waves (30-100 Hz): Gamma waves are also fast rhythms that are noted during mixed sensory processing and associative learning (Macy, 2015). Think about watching a music video. It is an auditory and visual experience, thus combining hearing and seeing. Short-term memory matching also has been reported to show gamma waves.

It should be noted that although these are the general conditions that frequencies are associated with, there are many additional features that link to each type of wave. The frequencies provide a better idea of what is happening on an implicit level. These channels should be analyzed carefully to provide the strongest interpretation of the data possible.

Seeing Isn't Always Believing

Due to the popularity and availability of EEG, there has been some questionable research conducted with downright sketchy claims. No EEG study can predict exact emotional profiles or read your brain. Figure 3 displays the complexity of the brain by showing how synaptic connections from the nerves make up the brain. It is easy to recognize the magnitude of how the consistent firing of neural networks is incredibly intricate. Scientists are challenging themselves to develop technology to identify minuscule interactions on the neural level; however, the body does not work in isolation. For activity to occur, multiple different components from a micro level work together to respond. Although improving constantly, EEG is not currently capable of recording such detailed mechanisms within the brain.

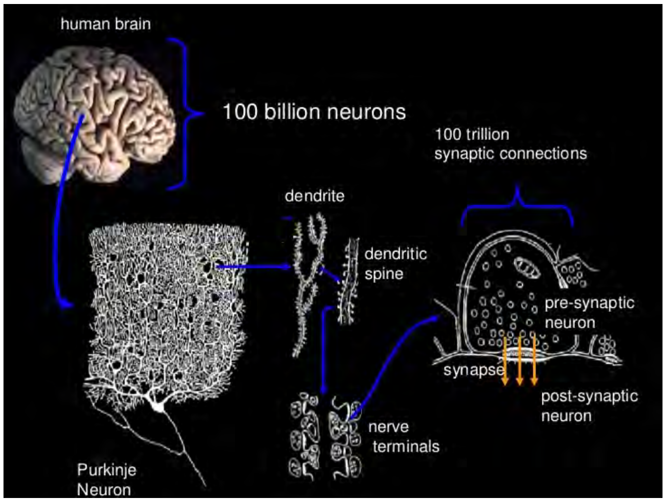


Figure 3

Although the estimations vary, roughly 100 billion neurons (with 100 trillion synaptic connections) are in the human brain. This image breaks down how neural connections occur in the brain.

Certain parts of the brain have multiple, sometimes contradicting, abilities. For example, the amygdala is known as a benchmark for fear and arousal. Yet, if both of those reactions light up the same area, how do we know which experience is being 'felt' by the subject? We can't infer that someone is scared just because there is a spike in activity in one scan. When affect and cognition are generalized, it can reach a place where outlandish claims begin to be fabricated. (It was disappointing when everyone's IQ didn't skyrocket by doing crosswords to Mozart every day.) The reasoning behind these hesitations is due to the lack of spatial resolution in EEG. Electricity spreads among the scalp, hence, the current doesn't flow from a neuron to a single electrode (Biasiucci et al., 2019). Knowing this, it is possible that activity from one neuron can be picked up by various electrode sites. If someone claims to know exactly where in the brain the activity is occurring, that should be a red flag to be cautious of the findings. Similarly, it is near impossible to know exactly what specific emotion a stimulus elicits based on a singular biometric.

EEG Artifact

It is important when considering EEG results to note the type of methodology that is being implemented during the study. If the respondent is in a situation with high level movement or talking, a lot of noise can be created to disrupt the data collection. Due to the weak signal of EEG, it is very easy for it to be contaminated. When we say EEG "artifact," we are not referring to some prehistoric object one would find in a museum. Artifacts can be anything that is reflected on the EEG signal that is not originating from the brain (Britton et al., 2016). Artifacts can be either physiological or non-physiological. Electric fields within the body from the heart, eyes, or muscles can create an artifact. Blinking, chewing or sneezing are also common ways that artifacts can be produced (Beres, 2017). Sweat also can alter the electrode-scalp connection creating an artifact. Non-physiological artifacts can be caused by movement or electric equipment. Electrode quality is an important factor to check before any research session. Over time, electrodes can deteriorate which leads to unwanted noise (Britton et al., 2016). Noise can also come from something non-constant, such as an elevator moving from floor to floor. The researchers running the study should be aware of these potential artifacts to assure that the lab environment is conducive for strong data collection.

BENEFITS OF EEG

There are multiple advantages to using EEG for brain imaging. Firstly, EEG is a direct measure of neural activity. Cognition, brain function, and dysfunction have all utilized EEG to assist in making new discoveries. This is a safe, noninvasive procedure that does not cause discomfort or create any sensation. EEG has a time resolution in milliseconds, which basically creates no meaningful delay (Beres, 2017). EEG is a great option if you are trying to answer questions related to the timing of what is happening with behavioral coding. It provides a global idea of what is occurring on an electrical level during the presentation of stimuli in real-time.

EEG data can be a lot more influential when combined with behavioral results and other biometrics. While EEG has a lot of advantages, such as the excellent time resolution discussed earlier, if paired with an additional biometric, it can really provide a better overall picture about human behavior. HCD Research works hard to pair the right tools with the right message.

CITATIONS

Ahmadian, P., Cagnoni, S., & Ascari, L. (2013). How capable is non-invasive EEG data of predicting the next movement? A mini review. Frontiers in human neuroscience, 7, 124.

Beres, A. M. (2017). Time is of the essence: A review of electroencephalography (EEG) and event-related brain potentials (ERPs) in language research. Applied psychophysiology and biofeedback, 42(4), 247-255.

Biasiucci, A., Franceschiello, B., & Murray, M. M. (2019). Electroencephalography. Current Biology, 29(3), R80-R85.

Britton, J. W., Frey, L. C., Hopp, J. L., Korb, P., Koubeissi, M. Z., Lievens, W. E., ... & St, E. L. (2016). Electroencephalography (EEG): An introductory text and atlas of normal and abnormal findings in adults, children, and infants. American Epilepsy Society, Chicago.

Kirschstein, T., & Köhling, R. (2009). What is the Source of the EEG?. Clinical EEG and neuroscience, 40(3), 146-149.

Macy, A. (2015, July 15). Electroencephalography (EEG) Pt. 1. Retrieved February 22, 2019, from https://blog.biopac.com/electroencephalography-eeg/

Morey, A. C. (2018). Electroencephalography in communication research: a review of the past and a glimpse of future possibilities. Annals of the International Communication Association, 42(4), 243-269.