# Electroencephalogram (EEG) Signal Processing

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**Abstract-**
To measure real-time electrodynamics of the human brain in neural networks, a key component of artificial intelligence, a wide range of electroencephalogram (EEG) signal processing techniques are being rapidly developed. This research paper's goal is to provide conceptual, mathematical, and implementation knowledge about EEG Signal Processing. and about Neurofeedback training.

**Keywords**-Electroencephalography (EEG), EEG signal processing, Techniques, Implementation, Neurofeedback.

## I. INTRODUCTION

Our brain weighs 1.133 kg, or about 2.5 pounds. it has a significant amount of oxygen and 40–60% glucose, allowing us to function productively all day. A combination of axonal and dendritic connections are employed to generate electricity in our brain through synchronized and collective actions of small and large groups of connected neurons. EEG is a painless and risk-free procedure.

Electroencephalography uses signal processing techniques to record electrical activity within the brain. Electrical impulses from the brain can be cap-tured by inserting two electrodes on the scalp and connecting them to a Cathode Ray Oscilloscope via an appropriate amplifier (CRO).

This procedure involves the placement of 16 or more electrodes on the scalp.These electrodes are placed on the **prefrontal**, **temporal**, **parietal**, and **occipital** regions of the brain.For grounding, one electrode can be placedon the earlobe.The patient is advised to lie immobile on the bed with his or her eyes closed dur-ing this procedure.A sleep EEG is performed after a sedative or hypnosis or orally administered. The EEG test takes approximately 45 minutes to 20 hours.

Different types of waves are generated by our brain like gamma waves, beta waves, alpha waves, theta waves, delta waves etc., and these waves are generated by the major nerve areas of our brain. Each generated wave has a different amplitude and frequency.

**i. Delta-wave:**

This wave has a frequency of **0hz – 4hz.** The wave's amplitude ranges from **20hz to 200hz** (too large). This wave is prominent in the brain's **occipital -temporal** region**.** This wave occurs during profound slumber. If it is generated while awake, then that will be brain dam-age ( i.e., any part of the brain is not working or damaged).

**ii. Theta-wave:**

This wave has a frequency of **4hz -8hz.** The wave's amplitude is greater than **200hz.** This wave is prominent in the brain's **parietal-temporal** region**.** This wave is generated in children during mild sleep and in adults during meditation or extreme depression. Theta wave is also known as **Memory Wave.**

**iii. Alpha-wave:**

This wave has a frequency of **8hz – 13hz.** The wave's amplitude ranges from **50hz -100hz**. This wave is prominent in the brain's**parietal -occipital**region**.**

When this wave is formed in the brain, the person is awake but relaxed, with their eyes closed or their minds wandering (like daydreaming).

**iv. Beta-wave:**

This wave has a frequency of **13hz – 30hz.** The wave's amplitude ranges from **5hz – 10hz**.This wave is prominent in the brain's **frontal**region**.**This wave is produced in the brain when the eyes are opened and the individual is awake and active.

**v. Gamma wave:**

Gamma waves are the fastest waves produced in the brain. The frequency of this wave is higher than **35 Hz.**And these waves can oscillate as fast as 100 Hz.Gamma waves are generated when a person is alert or concentrated.

Since the invention of the EEG method, it has become an essential method for monitoring brain activity. Electroencephalograms (EEGs) provide greater diagnostic capability for brain disorders (such as brain tumor) and abnormalities.There has been a rise in cases of mental health issues over the last decade. According to World Health Organization (WHO)“WHO estimates that the burden of mental health problems in India is 2443 disability-adjusted life years (DALYs) per 100 00

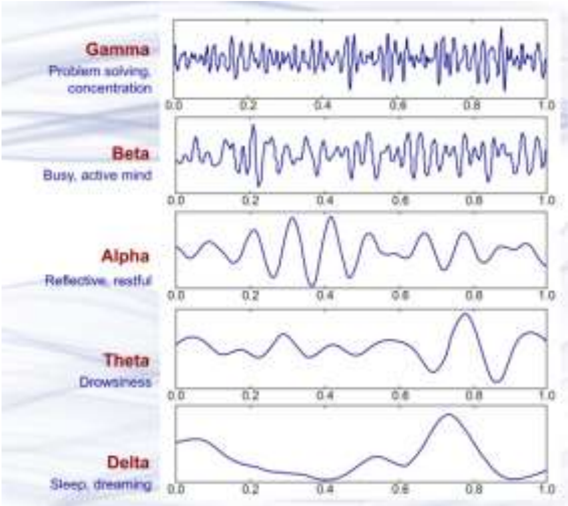


**Fig.1 Different types of waves generated by the major nerve areas of the brain.**

population; the age-adjusted suicide rate per 100 000 population is 21.1. The economic loss due to mental health conditions, between 2012-2030, is estimated at USD 1.03 trillion.” Cure of problems with psychological state is important. Neurofeedback is an EEG biofeedback training technique that is used to analyze patients' brainwaves and provide real-time feedback on how the brain is functioning. This training method is used to treat a wide range of psychiatric and neurological issues. Neurofeedback has shown great improvement in treatment of ADHD, anxiety, depression**,** epilepsy, autism spectrum disorder, insomnia, drug addiction, schizophrenia and learning disabilities. When a person suffers from a mental condition, the brain waves fluctuate, which may be recognized using Neurofeedback training. Any deterioration in brain functioning is mirrored in EEG signals. EEG signals are extremely complex, nonstationary and nonlinear

Brain waves or rhythms are divided into five groups and can provide information about a person's health and mental condition. The subsections that follow describe the categories.

**i. Gamma Waves :**

When this wave works actively, it becomes a major cause of anxiety, high arousal and stress; When this wave is suppressed, it causes **Attention Deficit Hyperactivity Disorder (ADHD)**, depression, and learning disorders.

**ii. Beta Waves :**

When this wave is active, it can cause anxiety, hyperarousal, insomnia, and stress, and when this wave is suppressed, it can cause ADHD, daydreaming, and sadness.

**iii. Alpha Waves :**

Alpha waves are predominant in daydreaming, difficulty to focus, and being extremely relaxed. They can induce anxiety, increased stress, and sleepless-ness if they are inhibited. When they are at their optimum, they provide a calm feeling.

**iv. Theta Waves :**

When theta waves are dominant, ADHD, sadness, hyperactivity, impulsivity, and inattentiveness are detected; when they are repressed, anxiety, low emotional awareness, and stress are observed.

**v. Delta Waves :**

Delta wave is commonly seen in brain injuries, learning disabilities, inability to think clearly, and extreme ADHD. Suppressing this wave results in an inability to restore the body and invigorate the brain, as well as poor sleep.

Neurofeedback is a potential ADHD therapy. According to current research, as few as 30 sessions of neurofeedback therapy can be as successful as common stimulants in lowering ADHD symptoms.

It is not uncommon for someone to no longer require ADHD medication following extensive neurofeedback treatment. Whether you're interested in neurofeedback as a therapy for ADHD, the first step is to contact your doctor to determine if it's a good fit for you.

Neurofeedback when combined with post-stroke hemiplegia has proven to be a successful long-term therapeutic therapy for motor dysfunction induced by neurological damage in the human brain when paired with BCI. On the other hand, individual neurological differences have resulted in variations in single sessions of rehabilitation therapy. The effect of brief training sessions on human brain functioning patterns can be evaluated and standardized using research on the effect of short training sessions on brain functioning patterns. In this research paper, we investigate changes in brain patterns following programmed short-term rehabilitation using electroencephalogram (EEG) signals.

BCI systems translate control signals to monitors or external devices by detecting variations in brain impulses that indicate human intents or actions. Typically, BCIs track the electrical impulses generated by brain activity. It includes sophisticated pattern recognition and the use of classification algorithms to convert brain activity into the required control signals. Robust signal processing and machine learning methods are employed to accurately categorize brain events, and brain development has been the primary focus of BCI research.

BCI operation is also referred to as a type of neurofeedback application, and understanding and studying fundamental neurofeedback principles allows BCI researchers to understand the training process as well as adapt it to operant learning principles. Although empirical data on the "optimal" training setting for this procedure do not actually exist, BCI researchers may benefit from neurofeedback training experiences in the future.

## II.HISTORY OF EEG BASED NEUROFEEDBACK

Neurofeedback has remarkable beginnings, and experts have been investigating its effects for decades.

The German psychiatrist Hans Berger used a ballistic galvanometer in 1924 to detect a little amount of electricity in a patient after applying two electrodes—small, round metal discs—to the patient's scalp. Between 1929 and 1938, he produced 14 publications detailing his EEG studies. His research is largely responsible for our current understanding of the subject, especially in the middle frequencies. Berger conducted subjective research on EEGs [1], but G. Dietsch was the first to conduct what is now known as quantitative EEG (QEEG) in 1932 by using Fourier analysis to seven EEG recordings [2].

Dr. Kamiya discovered that people could regulate their brain waves using a simple incentive system. He induced an alpha state in people by rewarding them with the ring of a bell. This was the first-time humans received real-time feedback based on EEG monitoring – the first instance of neurofeedback training. Dr. Kamiya presented his results in Psychology Today in 1968.

Dr. Sterman discovered that cats in his lab could be instructed to raise brain waves at a specific frequency when rewarded with food at the same time period. This frequency, termed as Sensorimotor Rhythm (SMR) by Dr. Sterman, was between 12 and 15 Hz, which is also known as Lo-Beta.Dr. Sterman conducted an experiment for NASA a few years later to see if rocket fuel induced seizures, and he used the same cats as test subjects. During this investigation, he discovered (to his surprise) that cats that had received SMR training were substantially less likely to have seizures than other cats. Dr. Sterman subsequently used this procedure on patients with epilepsy, discovering that 60% of the participants were capable of reducing their epileptic episodes by 20–100%, with long-lasting improvements.

Dr. Joel Lubar was the first to conduct controlled research using neurofeedback training on children, adolescents, and adults to cure attention deficit hyperactivity disorder (ADHD) in the 1970s. Since then, there has been a considerable amount of research on the efficacy of neurofeedback therapy for ADHD, with several trials demonstrating significant and long-term benefits following neurofeedback training.

Neurofeedback took a fresh tack in the 2000s when it came to researching deep states. Test subjects for alpha-theta training included those with anxiety, alcoholism, and other addictions. This low frequency training is similar to Elmer Green and Joe Kamiya's early alpha training and differs significantly from the high frequency beta and SMR training that has been conducted for more than thirty years [3]. Since beta and SMR training increase brain's sensory inhibition while blocking alpha patterns, which lower metabolism, they have a more directly physiological effect. On the other hand, alpha-theta training involves using the alpha-theta state to uncover repressed or painful memories and is based on the psychotherapy method [4]. The EEG depiction is where the term "alpha-theta state" originates.

A recent development in the field is the Coordinated Allocation of Resource Model (CAR) of brain functioning, which postulates that diverse electrophysiological properties that can overlap across different cognitive processes are responsible for different cognitive skills [5]. In order to apply the activation database guided EEG biofeedback approach, the patient is first assessed on a range of cognitive tasks that are relevant to academics. The QEEG readings are then compared to a normative database, with an emphasis on task achievement criteria [6].

## III. METHODOLOGY

EEG is a type of test that uses small metal discs (called electrodes) attached to the human skull to record electrical impulses originating from the human brain. Electrical impulses are used by human brain cells to communicate with each other. Even when humans are sleeping, they are always doing their work continuously. Wavy lines represent brain activity on EEG recordings. It is a snapshot in time of the electrical activity of the human brain.

We used an EEG-BCI system to examine changes in short-term (approximately 1-hour) MI training data with and without visual feedback. We initially investigated the attenuation of the EEG signal's Mu band power induced by Event-Related Desynchronization (ERD). Then, we utilize the Event-Related Potentials (ERP) properties of the EEG to build brain networks and evaluate the training from three perspectives: small-scale utilizing single nodes, medium-scale centered on hemispheres, and large-scale based on the entire brain.

By transmitting neural orders to external devices, BCI effectively translates human brain activity into external action.Although BCI is most frequently used to assist handicapped people with motor system diseases, it may also be a highly beneficial tool for enhancing the quality of life of healthy individuals, particularly the elderly.

In the past ten years, a wide variety of BCI applications have been created to aid older people in maintaining a healthy, positive quality of life and sense of wellbeing.
Depending on the electrodes used to measure human brain activity, BCIs can be divided into two different types: Non-invasive BCIs, where electrodes are placed on the human scalp (for example, EEG-based BCIs), and invasive brain computer interfaces, where electrodes are directly connected to the human brain [for example, BCIs based on electrocorticography (ECoG) or intracranial electroencephalography (iEEG).
BCI technology has already demonstrated promising outcomes in terms of aiding in physical and cognitive support and rehabilitation, and we anticipate more advancement in this crucial field of study that will eventually have an impact on all of us.

**Procedure during EEG :-**
**1.**You lie down on an examination table or bed, and a technician places around 20 little sensors on your scalp. These electrodes take up electrical activity from neurons within your brain and transfer it to a machine, where it appears as a sequence of lines recorded on paper or shown on a computer screen.
**2**. You will be requested to remain motionless once the recording begins.
**3**. You will relax with your eyes wide open first, then closed. Because both of these might alter your brainwave patterns, the technician may request you to breathe heavily and fast or to gaze at a flashing light. The equipment just records brain activity and does not stimulate it.
**4**. A seizure during the exam is unusual.
**5**. You can conduct an EEG while you're sleeping. When additional physiological processes, including as your respiration and pulse, are monitored, the test is referred to as polysomnography.
**6.**In rare situations, you may be offered an EEG equipment to go home and either send the data straight to your physician's surgery or save it for later study.

**EEG Applications :-**
EEGs are used to identify seizures caused by:
**1.**Tumors of the brain
**2.**A head injury leads to brain damage.
**3.**Brain dysfunction caused by a variety of factors (encephalopathy)
**4.**The brain is inflamed (encephalitis)
**5**. Epilepsy and seizure disorders
**6.**Sleep problems
**7.**Stroke
An EEG may also be used to detect whether seizures produced a coma, if brain activity has stopped, or to establish the appropriate amount of anesthetic for someone in a coma.

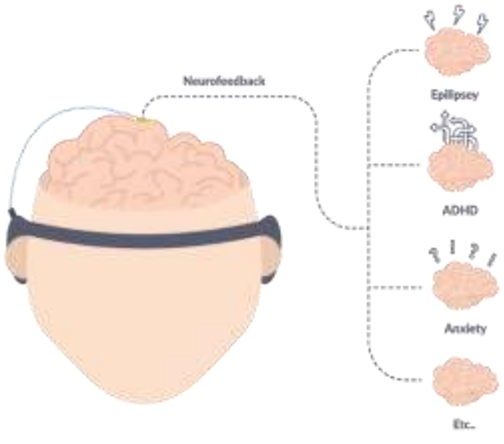


**Fig. 2 Neurofeedback holding therapeutic benefits for a range of neurological and psychiatric problems.**

**IV. Conclusion**
In general, it has been found that neurofeedback holds therapeutic benefits for a range of neurological and psychiatric problems, including EEG neurofeedback, anxiety, ADHD, and epilepsy. When providing neurofeedback, the patient receives separate EEG recordings from which various brain activity segments have been extracted. With this method, participants can monitor their progress and become conscious of the changes that occur during training, enabling them to perform at their best. Certain brain processes and symptoms influence the decision to implant electrodes. The entire therapy process is considerably easier when information regarding these skull sites is considered. The most often used protocols in neurofeedback training are alpha, beta, theta, and alpha/theta. However, there are other protocols as well.

Many research has been undertaken to far on neuro-feedback treatment and its usefulness in the treatment of a variety of disorders. However, significant methodological constraints and clinical ambiguities exist.
Similar to other therapies, neurofeedback has benefits and drawbacks. The validity of neurofeedback has been questioned due to the lack of conclusive scientific evidence, despite the fact that it is a safe and non-invasive procedure that has shown improvement in the treatment of many disorders and problems, including ADHD, nervousness, unhappiness, epilepsy, insomnia, drug and alcohol habit, schizophrenia, dyslexia, and dyscalculia. Furthermore, many insurance companies do not pay the high cost of neurofeedback procedures. The benefits of this technique are likewise only temporary, and it also takes time. In the end, it can take a few months to get the desired results.

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