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# A Survey on Brainwaves and Its Analytics

Shankar Kantharaj, Saidutt Sharma
Information Science, BMSIT, Bangalore, Karnataka, India-560094

***Abstract*****—** *This paper describes the different types of brain waves, what triggers them and the points of origin of the different types of brain waves. It will be describing the various benefits of each type to our physical and mental health and how we can enhance brainwave activity. It will explain a few techniques to enhance the brainwave activity in a particular frequency range. The detection by using EEG and its working and some possible improvements which can be made are covered. These can helpful in various fields and their implementation to improve technology and also aid patients who are physically handicapped.*

***Keywords*****—** *EEG, Brainwave entrainment, Neuro-feedback, Bionic limbs, therapy, handicap, Machine learning.*

## I. INTRODUCTION

Brainwaves are complex electronic patterns in our brains, which are produced by synchronized electrical pulses from masses of neurons communicating with each other. They are detected using sensors placed on the scalp.

They are divided into bandwidths to describe their functions and are best thought as a continuous spectrum of consciousness. Brainwaves vary from very low frequency waves like a very deep drumbeat to higher frequency waves which are similar to a high pitch flute which can cohere with each other through harmonics. Brain waves change according to what we are doing when slower frequency brain waves are dominant we feel tired and sleepy and slow but when higher frequency waves are dominant we feel more active and energetic. Brain waves speeds are measured in hertz and according to their frequency are divided into various bands.

## II. CLASSIFICATION OF BRAINWAVES

There are many types of brainwaves depending on their own characteristics, each of which are listed and explained in brief in this section.

### *A. Delta Waves*

These are slowest brain waves, mostly found in young children but as we grow older our delta levels tend to decrease. They are associated with deep relaxation and regenerative sleep. They also arise in unconscious body function such as regulating heart beat and digestion. The adequate production of delta waves helps us feel completely rejuvenated after a good night's sleep, an individual that experiences abnormal delta activity may experience learning disability and may have difficulty in maintaining conscious awareness.

- Frequency range: 0Hz to 4Hz
- Excess Delta waves causes Brain injuries, learning problems, inability to think, severe ADHD
- Decrease in brain waves levels are also harmful as it causes Inability to rejuvenate body and brain and poor sleep
- Optimally levels brain wave levels are very useful
- Depressants and

### *B. Theta Waves*

This range of frequency occurs during day dreaming and sleep. Theta waves allow us to experience and feel deep emotions however excess of theta waves can cause depression. Theta waves can improve our intuition creativity and makes us feel more natural. It's also involved in restorative sleep and is very beneficial as long as it is not produced in excess.
Theta rhythms are usually observed around the hippo-campus in numerous species, including rodents, rabbits, dogs, cats, bats and marsupials. Increased theta wave production can be triggered through the consumption of depressants.

- Frequency range: 4Hz to 8Hz
- Excess theta waves cause ADHD, depression, hyperactivity and inattentiveness
- Lack of theta waves cause Anxiety, poor emotional awareness and stress
- An optimal amount results in Creativity, emotional connection, intuition and relaxation

### *C. Alpha Waves*

Alpha waves bridge the gap between our conscious and subconscious mind. It helps us calm down and can make us feel deeply relaxed. In a state of excess stress, a phenomenon called "alpha blocking" occurs which involves significant beta activity, which will block out the alpha activity and result in reduced alpha levels.

- The frequency range of alpha waves are 8Hz to 12Hz
- Excess alpha waves cause Daydreaming, loss of focus, excess relaxation
- Lack of alpha waves Anxiety, high stress, insomnia, OCD
- In case of optimal levels of alpha is beneficial and helps the body relax
- Alcohol, Marijuana, relaxants, some antidepressant increase levels of alpha waves in the brain

### *D. Beta Waves*

Beta waves are high frequency, low amplitude brain waves, which usually occur when we are awake. They are involved in conscious thought, logical thinking and tend to have a stimulating affect. These are very fast brain waves that most people exhibit throughout the day in order to complete conscious tasks such as critical thinking, reading, writing and socialization. Having an optimal amount allows us to complete daily tasks efficiently, but excess can cause stress, anxiety and unease. At still higher levels, it becomes difficult to think and



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focus clearly and we are likely to make bad decisions. This is because at higher frequencies the brain cells and neurons begin to fire wildly and chaotically, leading to a highly disorganized and unfocussed state of mind.

A further increase could lead to the risk of a nervous breakdown. The only way to relax is to lower down the frequency of our brainwaves to alpha state.

- Frequency range of beta waves 12Hz to 40Hz
- Excess amount of beta waves cause Adrenaline, anxiety, high arousal, inability to relax, stress
- Lack of beta waves cause ADHD, daydreaming, depression, poor cognition
- Benefits of having optimal beat wave levels are Conscious focus, memory, problem solving

### *E. Gamma Waves*

These waves are involved in higher processing tasks and higher cognitive functions. They are an essential part in learning, memory and information processing and it is believed that the gamma waves are important in the binding of our senses in regard to perception and are involved in learning new material. It has been shown that individuals who are mentally challenged and have learning disabilities tend to have lower gamma levels on average.

- The frequency range of gamma is 40Hz to 100Hz
- Excess gamma waves causes Anxiety, high arousal, stress
- Lack of gamma results in ADHD, depression, learning disabilities
- Optimal level of gamma helps in binding senses, cognition, information processing, learning perception, REM sleep

## III. BRAINWAVE ENTRAINMENT

People experience a soothing and relaxing feeling listening to natural sounds such as a waterfall, beach, forest, river, ocean waves etc. This occurs because all the sounds have a relaxing effect on the brain. This is the basic idea behind brainwave entrainment which has been taken a step further that goes beyond the soothing effect of the normal music. The relaxing natural sounds are embedded with special sub-audio frequencies. These beats or tones are not directly perceived by your ears by have a direct impact on your brainwaves. This is the basis of brainwave entrainment.

While listening to entrainment music our brainwaves tend to resonate at the frequency of the beats. If we change the frequency of the beats, the brainwaves frequencies synchronize with it. This allows us to control our brainwaves, thus giving us control over our mental state.

For instance, a 10Hz beat will shift the brainwaves to the alpha wave region (8-12 Hz).

Entrainment is when one vibrating object induces vibrations of the same frequency into a nearby object which may be vibrating at another frequency or not vibrating at all. This is a very common phenomenon in nature. Whenever the brain receives stimulus through eyes, ears or any other senses, it responds by emitting an electrical charge. Entrainment can be achieved by any form of rhythmic stimulus, such as drumbeats, clicks, light flickers, physical vibrations or electrical pulses. Here we try to achieve entrainment by sending audio signals to the brain from outside.

There are three common modes of brainwave entrainment.

### *A. Binaural Beats*

This is the most well-known form of brainwave entrainment, where two slightly different frequencies are presented to opposite ears. The brain perceives them as a warbling sound at the difference frequency. These cyclic pulsations are called binaural beats. The two input frequencies should be lower than 1000 Hz and the frequency difference below 30 Hz. Headphones are required for this technology to work since the input to each ear is different.

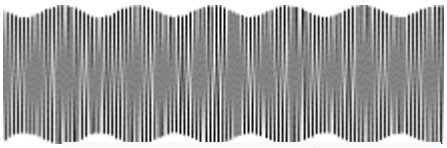

Fig. 1. Binaural beats in the brain after processing.

### *B. Monaural Beats*

Monaural beats work similar to binaural beats and combine two sound frequencies to form pulsating beats. However, they are formed by combining the frequencies digitally before the sound reaches the ears. They are considerably more effective than binaural beats due to greater amplitude variations compared to binaural beats.

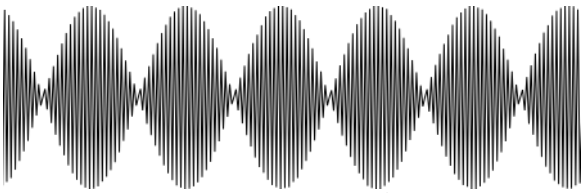

Fig. 2. Monaural beats in the brain after processing.

### *C. Isochronic Tones*

Isochronic tones are evenly spaced well-defined pulses of sound waves. They are created manually by switching on and off the sound source. This is by far most effective of the three methods. The spacing between the pulses decides the frequency of the tone. Here you have complete control over the amplitude (intensity) as well as spacing of pulses.

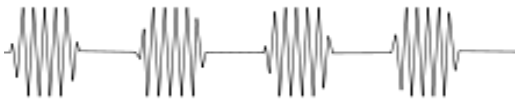

Fig. 3. Isochronic beats in the brain after processing.

People following a healthy living style will find the use of brainwave entrainment audios to be both practical and beneficial. The brainwave audios can be used to offer a drug free way to relax fast and effectively. Regular listening builds up physical and emotional resilience and boosts the overall sense of wellbeing.



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Stress and anxiety relief: The mental states of anxiety and stress prompt high levels of beta activity. By entraining an individual into an alpha frequency region, stress can be easily relieved.

*Relaxation:* Alpha brainwaves are dominant during the periods of relaxation and rest. Entraining brainwaves into the alpha frequency puts the individual into states of relaxation. Lower alpha frequencies give better relaxation.

*Inducing sleep*: The state of deep sleep is characterized by the frequencies of delta brainwaves, 1-4 Hz. Feeding stimulating frequencies in this range induces sleep when synchronization is achieved.

*Meditation:* Theta and alpha waves contribute towards deep meditative states. These are also the frequencies observed during states of deep relaxation and sleep.

## IV. Neurofeedback of Brainwaves

Neurofeedback is direct training of brain function, by which the brain learns to function more efficiently. We observe the brain in action from moment to moment. We show that information back to the person. And we reward the brain for changing its own activity to more appropriate patterns. This is a gradual learning process. It applies to any aspect of brain function that we can measure. Neurofeedback is also called EEG Biofeedback, because it is based on electrical brain activity, the electroencephalogram, or EEG. Neurofeedback is training in self-regulation. It is simply biofeedback applied to the brain directly. Self-regulation is a necessary part of good brain function. Self-regulation training allows the system (the central nervous system) to function better.

Neurofeedback addresses problems of brain dysregulation. These happen to be numerous. They include the anxiety-depression spectrum, attention deficits, behaviour disorders, various sleep disorders, headaches and migraines, PMS and emotional disturbances. It is also useful for organic brain conditions such as seizures, the autism spectrum, and cerebral palsy.

In this section we will discuss working of neurofeedback, the conditions where it can be helped and its usage.

### *How Does Neurofeedback Work?*

We apply electrodes to the scalp to listen in on brainwave activity. We process the signal by computer, and we extract information about certain key brainwave frequencies. (All brainwave frequencies are equal, but some are more equal than others...) We show the ebb and flow of this activity back to the person, who attempts to change the activity level. Some frequencies we wish to promote. Others we wish to diminish. We present this information to the person in the form of a video game. The person is effectively playing the video game with his or her brain. Eventually the brainwave activity is "shaped" toward more desirable, more regulated performance. The frequencies we target, and the specific locations on the scalp where we listen in on the brain, are specific to the conditions we are trying to address, and specific to the individual.

### *What Conditions Can It Help?*

We are especially concerned with the more "intractable" brain-based problems of childhood whose needs are not currently being met. This includes, Seizures and sub-clinical seizure activity, severely disruptive behaviour disorders such as Conduct Disorder and Bipolar Disorder, Autistic spectrum and pervasive developmental delay, Cerebral palsy, Acquired brain injury, Birth trauma.

Many children have sleep problems that can be helped such as Bed wetting, Sleep walking, sleep talking, Teeth grinding, Nightmares, Night terrors. We can also be helpful with many of the problems of adolescence including Drug abuse, Suicidal behaviour, Anxiety and depression.

We can also help to maintain good brain function as people get older. The good news is that almost any brain, regardless of its level of function, can be trained to function better.

## V. Detection of Brainwaves Using EEG

A device called Electroencephalograph (EEG), which is an Electro physiological method used to monitor the brain state of a person, can detect brain waves. This device is the most common method of measuring brain waves and it involves no invasive procedures for extracting brain signals of test patients under study. Electrodes placed on the scalp can sense fluctuations in the ionic currents produced by communication of neurons or firing of signals between neurons.

*Working:* Billions of neurons maintain the brain's electrical charge. Neurons are electrically charged (or "polarized") by membrane transport proteins that pump ions across their membranes. Ions of similar charge repel each other, and when many ions are pushed out of many neurons at the same time, they can push their neighbours, who push their neighbours, and so on, in a wave. This process is known as volume conduction. When the wave of ions reaches the electrodes on the scalp, they can push or pull electrons on the metal in the electrodes. Since metal conducts the push and pull of electrons easily, the difference in push or pull voltages between any two electrodes can be measured by a voltmeter. Recording these voltages over time gives us the EEG.

*Research use:* EEG are mainly use in neuroscience, cognitive science, cognitive psychology, neurology and also psychophysiological research. But treatment on mental disabilities, such as Auditory Processing Disorder (ADP), ADD, or ADHD can be diagnosed by using EEG

*Advantages:* Many other methods to study brain function exist but there are various advantages of using EEG over them such as:

- Hardware costs are significantly lower.
- EEG sensors can be used in more places than fMRI, SPECT, PET, MRS, or MEG, as these techniques require bulky and immobile equipment.
- EEG has very high temporal resolution, on the order of milliseconds rather than seconds. EEG is commonly recorded at sampling rates between 250 and 2000Hz in clinical and research settings, but modern EEG data



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collection systems are capable of recording at sampling rates above 20,000Hz if desired.

- EEG does not involve exposure to high-intensity (>1 tesla) magnetic fields, as in some of the other techniques, especially MRI and MRS. These can cause a variety of undesirable issues with the data.
- Extremely un-invasive as it doesn't require to put devices physically inside our body, it is just a device we can put like a cap.

*Disadvantages:* Many disadvantages are listed below.

- Low spatial resolution on the scalp. FMRI, for example, can directly display areas of the brain that are active, while EEG requires intense interpretation just to hypothesize what areas are activated by a particular response.
- EEG poorly measures neural activity that occurs below the upper layers of the brain (the cortex).
- Signal-to-noise ratio is poor, so sophisticated data analysis and relatively large numbers of subjects are needed to extract useful information from EEG

## VI. Applications of Brainwaves

Brainwaves can be made use of in various technological applications and also in studying and aiding patients suffering from various physical disorders. Here are a few examples.

### A. Compose and Play Music

The composition of music always takes place in the brain. But through brainwaves musicians can now directly play music from the brain without the need of using sheets of notes or even using any instruments at all. Electroencephalography (EEG) headwear devices can be used to send signals to the computer in which their wearer would recognize the signals they are sending by associating certain signals to a particular task, wherein the computer would these tasks with the same signals. Thus to create music, such thoughts would be associated to musical notes and sounds to create musical thought directly from the brain. This has been implemented by the University of Michigan in the MIND ensemble (Music in Neural Dimensions) program.

### B. Screen Mobile Phone Calls

Brainwaves can be used in deciding which calls can be allowed to pass through by monitoring to the state of the brainwaves of the receiver. Thus if the receiver is in a tense or busy state the call would get rerouted to voicemail, and if the receiver is in a receptive state it lets the call go through.

### C. Create 3D Objects

A Chilean company has announced the first object to be created by thought alone-paired with the growing power of the latest 3d printing machines. They called the system the Thinker Thing. The Thinker Thing system employs an Emotiv EPOC EEG headset to map its wearer's brainwaves. This paired with the company's own software the Emotional Evolutionary Design, display "building block" shapes on the computer screen.

It works by changing how to shapes change and evolve according to the users positive and negative emotional response each change monitored by the headset. As the software processes brain feedback, the well-received shapes and changes are kept and expanded, while the disliked ones fade away. This procedure goes on till we finally get an object that is according to the user's preferences. The company's Monster Dreamer project was applied on schoolkids to create a monster they would imagine in minutes.

### D. Drive A Wheelchair, Car

For many years, scientists have been working on a way to allow people who have lost control of their bodies but still have a sharp mind to have the ability to move around and this problem can be solved by using a person's brainwaves to move a vehicle directly. In 2009, Japanese scientists at Toyota and research lab RIKEN announced a thought-controlled wheelchair that used an EEG sensor cap to capture brainwaves and turn them into directional commands in just 125 thousandth of a second with a 95 percent accuracy.

At Lausanne, Switzerland's Federal Institute of Technology, scientists have added "shared control" to the concept. Their chair's software analyses the surrounding area's cluttered environment and blends that information with the driver's brain commands to avoid problems like collisions with objects.

The system also eases the strain of command because users needn't continually instruct the chair—the software processes a single directional command and automatically repeats it as often as needed to navigate the space.

German engineers at the Free University of Berlin have attempted to take this concept on the open road with a car that can be partially controlled by the driver's thoughts. The team took an autonomous Volkswagen Passat, one of the emerging breed of driverless vehicles, and outfitted it with a computer system and software designed to work with Emotiv's commercially available EEG brain-scanning headset.

Drivers were trained to produce recognizable thought commands, like "turn left," by manipulating a virtual cube on a screen. The on-board computer then analysed and converted those thoughts to commands recognized by the car itself each time they were thought by the driver.

The "BrainDriver" application is not roadworthy yet. But on the long run, human machine interfaces like this could bear huge potential in combination with autonomous driving--for example, when it comes to decide which way you want to take on a crossroad, while the autonomous cab drives you home.

### E. Bionic Limbs

In some instances, human machine interfaces are becoming part of the human body. One new prosthetic even provides a sense of "touch" like that of a natural arm, because it interfaces with the wearer's neural system by splicing to residual nerves in the partial limb.

The prosthetic sends sensory signals to the wearer's brain that produce a lifelike "feel", allowing users to operate it by touch rather than by sight alone. This ability enables tasks many take for granted, like removing something from inside a grocery bag, and knowing how hard to grip items with the prosthetic hand.



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Researchers at Case Western Reserve University, now working with the Defence Advanced Research Projects Agency (DARPA), developed the prosthetic DARPA is a leader in the development of advanced prosthetics.

## VII. EEG Applications

Few applications of EEG are listed below.

### *A. Therapy*

Real-time EEG has a role in the monitoring of the state of mind of patients undergoing a variety of therapies.
EEG is a useful tool for practitioners in the treatment of Addiction, Migraine, Depression, Sleep Disorders, Eating Disorders, Anxiety, Learning Disabilities, Chronic Pain, Epilepsy, Insomnia, Attention deficit hyperactivity disorder (ADHD/ADD), Tourette's Syndrome, etc.

### *B. Neuroscience Research*

Many universities and institutions carry out research in the field of neuroscience using EEG. The advantage of using EEG is that the brain activity can be monitored even while the person is engaging in his day to day activities. In the field of neuro science research this device can be used to treat wide range of neuro behavioural disorders including head injury, epilepsy, pain syndromes, movement disorders, cerebrovascular disorders, metabolic and neurodegenerative disorders (including age-related), thought disorders, mood disorders, anxiety disorders, personality and substance dependence disorders, chronic stress, Alzheimer's, schizophrenia, and many other problems and illnesses.

## VIII. Conclusion

There have been many prospects in the field of brainwaves in recent years and there are many useful applications few of which this paper illustrates. The scope of brain waves is vast and there is still a lot of work to be done in this field. With this paper we hope to incite more people to do research in this field and provide a better understanding of the importance of brainwave studies.

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