Media Engineering and Technology Faculty
German University in Cairo

Brain Computer Interface (BCI) - Emotional Reactions and Control

Bachelor Thesis

Author: Heba Alaa Ahmed Diaa Abdelrazek
Supervisors: Prof. Dr. Dirk Reichardt
Submission Date: 29 August, 2019

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This is to certify that:

(i) the thesis comprises only my original work toward the Bachelor Degree

(ii) due acknowledgment has been made in the text to all other material used

Heba Alaa Ahmed Diaa Abdelrazek
29 August, 2019

Acknowledgments

Write your acknowledgment here....

Abstract

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Introduction

1.1 Aim of the Thesis

1.2 Thesis Outline

Chapter 2

Background

2.1 Human States

The human brain is one of the most complex systems in the universe. We have several states whether emotional, mental, psychological, or physical. Each and every state affects the human activity in one way or another. Those states can vary from exhaustion and anger to meditation and relaxation.

Moreover, to perform as functionally as possible in one's daily life, one needs to acquire a relaxed at ease state. According to Jo Anne Herman [5], stress has been related to all kinds of sicknesses. Which in terms would mean that relaxation, the opposite of stress, would promote healthiness of the well being. Throughout all ages, humans always looked for different ways and method to self meditate.

Relaxation has a lot of ways to define it. The most general would be according to Oxford Dictionary [2]; the state of being free from any tension or anxiety. Relaxation is derived from the Latin word 'laxare' which means "to loosen up", and the prefix 're' is added to mean "again". Relaxation can be looked at as a decrease in tendancy of emotional arousal [5].

Forms of relaxation could include being physically at ease, where some muscles are ceasing to contract and others tend to unclench. Relaxation can also have an effect on skin conductance and other bodily functions such as heart rate, respiratory rate, and blood pressure. Not only does it affect the physical well being of the people, relaxation can as well affect their psychological and mental selves, evidently changing their emotional state. According to Hope Titlebaum [6], relaxation has a significantly good outcome on the physical and mental health of people, and consequently on their level of productivity. The lack of relaxation can cause multiple unpleasant results both physically and mentally or emotionally. Those could include insomnia, increased blood pressure, anxiety disorder, headaches, as well as chronic migraines induced from stress. In addition to this, its lack can encourage physical deterioration and joint dysfunction. Thus, being relaxed is a goal almost everyone is trying to attain.

Since all human states are controlled via the brain, and in order to have a further understanding of the relaxation state, we need to understand how it's interpreted in the brain itself. Consequently, we need to take a deeper look on the brain waves, and what their significance is.

2.2 Brain Waves

The brain waves are basically produced from numerous neurons in the brain, actively sending some sort of synchronized pulses to each other as their way of communication. According to (RESEARCH1-Desktop-bib), ions are pumped across the membrane transport ions in the brain which electrically charges the neurons. Neurons are simultaneously transferring ions with each other to transfer brain data. Consequently, ions with similar charges would repel each other, pushing other neighbouring ions. The combination of such electrical activity in the brain is what is called a brain wave pattern, for its wave-like nature.

Brain waves consist of different bandwidths who belong to the same spectrum. Brain waves speed is measured in Hertz (Cycles per second) denoting how fast they are. The beginning and end of the bandwidths varies among different authors. However, our approach will be following EmotivPRO's[1] set bandwidth ranges since this headset was the one utilized in our research and experiments. This states that Delta brain waves range from 1 to 4 Hz, t Theta brain waves range from 4 to 8 Hz, Alpha brain waves range from 8 to 12 Hz, Beta brain waves are divided to two parts; the Low Beta ranging from 12 to 16 and the High Beta ranging from 16 to 25, and finally, Gamma brain waves range from 25 to 45 Hz.

Researches have shown that each wave of the mentioned brain waves can have a corresponding significance to the emotional or mental state of the humans. In other words, we can translate the abundance of a certain brain wave production, into a certain level of consciousness or state of the person under test.

Delta brain waves are of the lowest frequencies and in accordance, they are considered to be the slowest of the brain waves. The production of the Delta brain waves is related mostly to the unconscious mind. In addition to them being observed as a source of empathy, they could be generated during a deep dreamless sleep, as well as in an extremely deep meditation state. (SURVEY1-Desktop-bib). In the deep dreamless sleep, most commonly healing from things people were subjected to occurs. Thus Delta brain waves are somewhat essential for the healing process of humans.[3]

Theta brain waves are more into what goes on in the subconscious mind, they could include activities as sleeping or dreaming(SURVEY1-Desktop-bib). Another study (FULLTEXT01-Desktop-bib) has related Theta brain waves to daydreaming and inefficiency. Moreover, theta waves could arise more from stress, specially if the person is disappointed or frustrated.

Alpha brain wave production is clearly noticeable if people are in a relaxed disengaged peaceful state, however, aware of themselves. It peaks when the brain is not very active and where there are quiet flowing thoughts.(SURVEY1-Desktop-bib). This kind of brain waves is mostly visible in the frontal lobe, as well as in the back of the head in the occipital region of the brain (O1 and O2). Alpha waves are the 'Power of now', they help coordinating the state of the body and the integration of the mind and body, in addition to the calmness and the alertness. (RESEARCH2-Desktop-bib)

Beta brain waves are basically a monitor for the brain activity and excitement. According to (FULLTEXT01-Desktop-bib), beta waves are linked to focused concentration, judgment, in addition to decision making. Beta brain waves can also increase with one's suppressing movement or maybe solving a maths question. This kind of brain waves is mostly visible in the frontal and central parts of the brain. The Beta/Alpha brain waves ratio could be an indicator for the person's level of arousal. In accordance to (RESEARCH6-Desktop-bib), Beta waves are produced when the user is feeling stressed, in fear, or in a state of agitation. Low Beta is thought of as being a fast idle state and emitted more in a musing state, while High Beta could be related to new experiences or excitement.

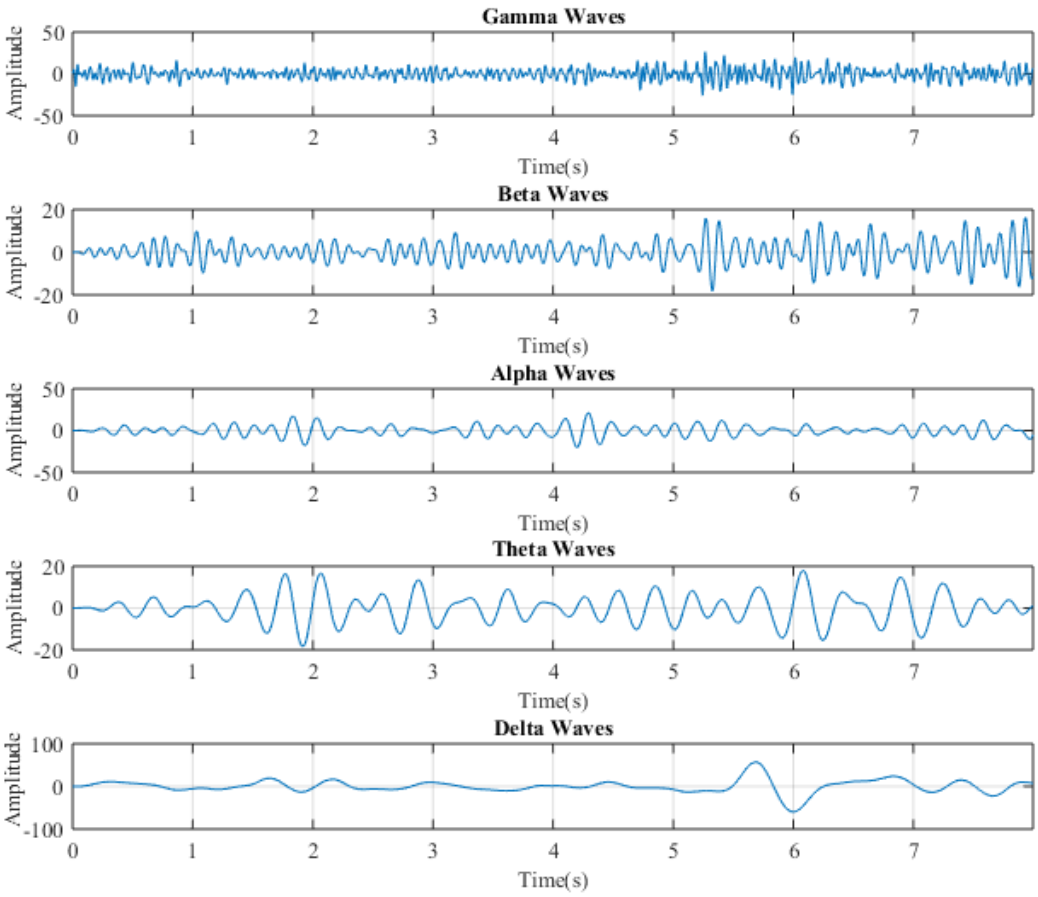

Figure 2.1: Brain Waves Pattern

Gamma brain waves are the fastest waves formed in the brain. They are best accessed when the person is at a quiet mind state. Gamma waves transfer information rapidly hence relating to the information processing in the brain. Its production is related to states of high level of consciousness, spirituality and higher virtues. Nevertheless, in order to have access to the brain and to actually retrieve the mentioned brain waves somehow, we need a connection between the human brain and devices, hence introducing the Brain-Computer Interfaces (BCI).

2.3 Brain-Computer Interfaces

As literally as it could sound, the Brain-Computer interface is a real-time path of communication between the user who uses the computer system and accessing the neural activity of the brain as defined by (FULLTEXT01-Desktop-bib). It's a channel of output for the brain controlled by the user. Its aim is to convey people's intentions to the outside world just by reading their thoughts. Brain-Computer Interfaces should learn to develop a distinction between various patterns of the brain activity, and to reach that distinction with a level of accuracy. But the Brain-Computer Interfaces will not manage to form such a distinction without the user actually performing different mental tasks which in accordance would produce distinct brain signals(RESEARCH3-Desktop-bib). Some may argue that the brain's normal neuromuscular channels could affect the input to the brain activity detected by the Brain-Computer Interfaces, however, the brain signals are the ones that get inputed to the Brain-Computer Interfaces not the peripheral nerves and muscles.

The Brain-Computer Interfaces have grown a popularity as they are invested in many fields and have several applications including Human-Machine Interaction, and neuroscience research. Most commonly, Brain-Computer Interface applications would be focusing on researching and trying to find solutions for disabled people for improving their quality of life by allowing them to work independently from their bodies' support like in bioengineering applications. Another focus could be aimed for detecting diseases and disorders like in human subject monitoring applications. Some researches may delve into finding ways to bring balance to the body which needs adjustment. For instance, (RESEARCH2-Desktop-bib) is using Brain-Computer Interfaces to detect stress that disrupts the body and mind, and tries to treat it. The detection of the brain waves using the Brain-Computer Interfaces requires a system that could translate the brain wave signals into something readable, hence the use of a system called Electroencephalography (EEG) which is a common method to develop a Brain-Computer Interface.

2.4 Electroencephalography

According to (SURVEY1-Desktop-bib), there is an imaging technique which can manage to read brain activity by measuring some voltage fluctuations of the brain waves. This

technique is called an Electroencephalogram (EEG). Commonly, the EEG signal measured is 10-100 V. The EEG data can be analyzed using a lot of programs such as Matlab which has a lot of toolboxes designed for it.

Moreover, some other research [4] described EEG as a collection or an embodiment of some signals that occur from the brain cells, formed from their synchronous actions. The origin of the word itself is from two Greek words; "Enkephalo" which is the brain, and "Graphein" which is the act of writing.

We measure the EEG using electrodes in contact with the scalp. However, there is an another way to use them, which is directly on the cortex. This way is called Electrocorticogram (ECoG). There are two kinds of electroencephalograms, one of which is recorded when there is an internal stimuli like skipping an expected stimulus, or maybe an external kind of stimulus like a tone or a light flash which is the Event-Related Potential (ERP) and the other is without any stimulus occurring which is the spontaneous type.

Electroencephalography is mainly describing how the electroencephalogram, the EEG, is recorded and translated. EEG-based Algorithms appear to be the most valid and reliable emotion and mental state recognition system algorithms according to (RESEARCH4-Desktop-bib). Brain activity reactions to events can not be altered by the candidates intentionally, unlike their facial expressions or their words and feedback. So one may call the EEG signals the truest measure of emotion of the user. The spacial resolution of EEG is not adequate but in spite of that, its temporal resolution is great (less than 1 millisecond), which makes it the most spread Non-Invasive brain imaging technique. (RESEARCH5-Desktop-bib).

A distinction between the EEG and Brain Computer Interfaces is that EEG is mainly about the brain waves themselves while the Brain-Computer Interfaces are more of the system with interprets those brain waves in a computerized aspect. Mental activities would lead to some changes of the electrophysiological brain signals like the EEG. The Brain-Computer Interface system would detect such changes and then it would be able to transform it into some sort of a control signal. This control signal generated could be used in multiple applications such as motion of wheelchair, or giving commands using your thinking process, even commands to your own brain (RESEARCH3-Desktop-bib).

As brain waves and signals are easily acquired and translated with the current level of human knowledge and technology, this indeed triggers the question of whether or not we can manipulate these waves since they are related to different mental states. If yes, one might even wonder about the methods to accomplish this.

2.5 Brain Entertainment

https://brainworksneurotherapy.com/what-are-brainwaves last part

https://brainworksneurotherapy.com/what-brainwave-entrainment warnings

https://brainworksneurotherapy.com/types-brainwave-entrainment

Modultion, Habitulation, types of music.

2.6 Binaural Beats

Theory behind it. Kinds. Aims. Uses.

2.7 Related Work

Previous Experiments +literature of theta and gamma success

Chapter 3

Methodology

3.1 Equipments Used

3.1.1 Emotiv EPOC+ EEG Headset

Emotiv: Their motto is You think, therefore you can (Emotiv, n.d.). Emo- tiv claims that you can use thoughts, feelings and emotions to control your computer. The accompanying software comes with a machine learning al- gorithm that learns how your brain visualizes, for example push and pull of objects, from the EEG measurements. This can be mapped to computer con- trols. Their neuroheadset consists of 14 sensors, includes a gyroscope and is priced 299 US dollars. The headset is high-tech and a comparison with a traditional EEG hair net is shown in figure 4.2

It is common that brain signals appear with certain undesired artifacts such as heart beating, breathing, and blinking [1-2] and removing these signals cannot be done efficiently with active filters.

The electrode positions are labeled by combinations of letters and numbers. The F, T, C, P and O letters refer to the lobes, such as F for frontal and T for temporal, with the exception of C (central) which is present for positioning purposes. The numbers indicate electrodes at either the right (even) or the left (odd) hemisphere.

3.1.2 EmotivPRO

3.1.3 Sustained Attention To Response - SART

3.1.4 Gnaural Java

3.2 Binaural Beats Settings

Binaural Beats were generated what freq????

3.2.1 Pink Noise

3.2.2 Duration of Exposure

Chapter 4

Experiments and Results

4.1 Preliminary Experiments

4.1.1 SART Experiment

Talk about sart

4.1.2 Binaural Beats Experiment

Speak of Binaural exp

4.2 Results of Preliminary Experiments

4.2.1 SART Results

results of sart

4.2.2 Binaural Beats Results

results of bin

4.3 Experiment Design and Analysis

talk about 2 experiments??? how?????

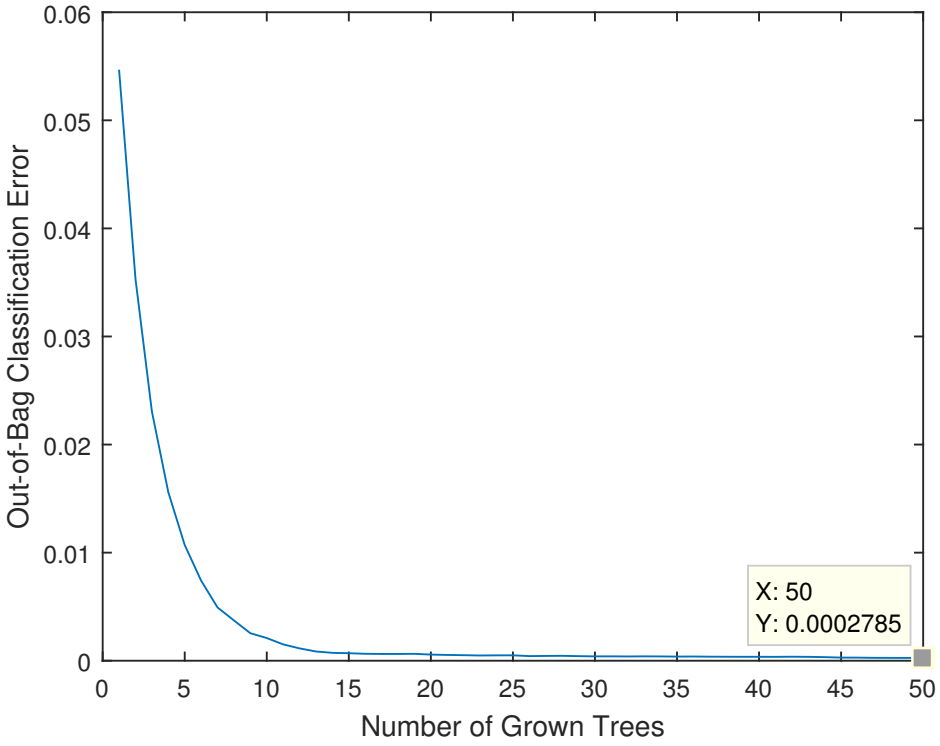

Figure 4.1: Graph showing the relation between number of trees in a forest and out-of-bag error

Chapter 5

Conclusion and Future Work

Insert Conclusion Here

Appendix

Appendix A

Code

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