CHARECTERIZATION OF OCULARITY IN ELECTROENCEPHALOGRAM

A THESIS

submitted by

JOHN WILLIAM CAREY MEDITHE

for the award of the degree

of

DOCTOR OF PHILOSOPHY

DEPARTMENT OF ELECTRONICS AND COMMINICATION ENGINEERING

VIGNAN'S FOUNDATION FOR SCIENCE, TECHNOLOGY AND RESEARCH UNIVERSITY, VADLAMUDI
GUNTUR – 522 213 ANDHRA PRADESH, INDIA

May 2017

Dedicated

to

Carmel Prayer House, The church who constantly prays for me.
&
My parents, loving brother

DECLARATION

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b. I have followed the guidelines provided by the Institute in writing the thesis.
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(John William Carey Medithe)

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Dr. Usha Rani Nelakuditi
Research Guide,
Professor and Head,
Dept. of Electronics and Communication Engineering,
VFSTR University, Andhra Pradesh, India

Place: Guntur
Date:

ACKNOWLEDGEMENT

I would like to acknowledge my deep sense of gratitude to my supervisor **Dr. Usha Rani Nelakuditi**, Department of Electronics and Communication Engineering, Vignan's Foundation for Science, Technology and Research University, Vadlamudi, Guntur, for her constant valuable guidance and encouragement.

She gladly accepted all the pains in going through my work again and again, and giving me opportunity to learn essential research skills. Her ability to quickly understand the depth of the problem and suggesting a clear solution has always surprised me. This thesis would not have been possible without her insightful and critical suggestions, her active participation in constructing right models and a very supportive attitude. I will always remain grateful to her for giving direction to my life.

I express my sincere thanks to **Dr. C. Thangaraj,** Vice Chancellor, **Dr. B. Ramamoorthy,** Vice Chancellor for providing the necessary facilities for carrying out the research work. I would like to thank the doctoral committee panel, **Dr. Sk. Jakeer Hussain, Dr. B. Seeetharamanjaneyulu and Dr. Avireni Srinivasulu** for providing me with their suggestions.

I would like to thank teaching and non-teaching staff members of the Department of Electronics and Communication Engineering, who have been kind enough to advise and help in their respective roles.

I would like to acknowledge the support of my parents, **Ceaser Benjamin Babji Medithe** and **Esther Rani Medithe**, and my only loving brother **Enoch George Muller Medithe** for their continuing support and encouragement.

I also would like to thank all of my uncles, aunts, cousins for making me happy all the times during the course work.

I also would like to acknowledge my friends and collegues **V.Vijay**, **Dr.P. Chandra sakher, D. Luke Promod** for their continous encouragement and valuable suggestions

At last, my saviour **JESUS CHRIST**. I know, Am not worthy to utter his name. But, i want to thank him from bottom of my heart for all the love and compassion he shown on me, protected me, honourned me in many circumstances i pass through and make this thesis possible.

John William Carey Medithe

ABSTRACT

CHARECTERIZATION OF OCULARITY IN ELECTROENCEPHALOGRAM

KEYWORDS: Electroencephalogram, Electroculogram, Ocular Artifacts, Light, Optical Powered Glasses, Visually Evoked Potentials.

Brain is a control center for various sensory organs in human system. It consists of millions of neurons that coordinate emotion, movement and sensation. The electrical activity produced due to firing of neurons is accumulate over the scalp can be measured using electrodes, known as Electroencephalogram (EEG). EEG is a significant medical imaging tool to interpret the brain activity in form of Alpha, Beta, Theta, Delta and Gamma frequencies. Acquired EEG potentials are in an order of microvolt, which are very much prone to the contaminating with other bio signals and external parameters such as light etc. These undesired bio signals are originated from human organs like eye, muscle and heart etc. are overlapped over the true EEG and forms contaminated EEG. The contaminates present in the EEG are known as artifacts.

In the present research, impact of Electro-Oculo-Gram (EOG) from ocular sensor, light, powered glasses and Visually Evoked Potentials (VEP) on EEG is analyzed using experimental and subjective analysis. Further, the results also verified with the mathematical models and results are cross validated using MEDICAID system.

As ocular sensor is very much nearer to the brain, and also due to involuntary movement of eye, there is lot of possibility in creating artifacts in EEG by EOG. In this connection, existing artifact removal techniques such as ICA, PCA and Wavelet methods are analyzed. But, existing techniques are post processing, doubles the examination time. Hence, a hardware system using NI myRIO processor to detect the ocular artifact in EEG is developed and patented. It can be used with to any bio-potential amplifier with on board LEDs to detect EOG artifacts (blinks), which can be interfaced to any existing standard medical systems. This blink detector is validated on 80subjects with 96.2% accuracy. The blink detector can be used as Driver safety system and Blink controlled home appliance system.

As external parameters light also influences physiological parameters through ocular sensor. The effect of light on EEG is analysed, and it is observed that is observed that the amplitude of the Ocular artifact increases with increase of light intensity falling on eye, which is proved by developing mathematical model. This is due to, with the increase of light intensity falling on eye, cornea charges more positively with respect to negatively charged retina. This seems to be a seizure, leads to wrong diagnosis. As per the previous research, the lightening conditions (low luminance >2500lux) affects only occipital region synchronised with alpha activity. But, from the current research performed on 25 subjects, it is observed that low luminance conditions increases beta activity in the frontal region. This is due to more mental stress experienced by the awaken subject in the recording room which makes physician to misinterpret as EEG abnormality.

Optical powered glasses used to correct the refractive error (Myopia and Hypermetropia) of an eye cause variation in the light intensity experiencing by the subject. This variation affects the alpha activity in occipital region. Usage of improper prescription optical powered glasses increases the subject mental activity to focus the vision. This makes increment in beta activity in the frontal frequency. This is confirmed from the experimental and subjective analysis performed on 80 subjects.

In this work, to analyse abnormalities associated with the visual pathway and optical nerve. VEP test was performed on 42 subjects. An experiment is performed using 1 Hz checker board pattern reversal as a stimulus with 100 samples on each subject. It is observed that, positive powered optical glasses increases the light intensity falling on eye and increases in amplitude of P100 wave and reduces its latency. Whereas, negative powered optical glasses cause reduces amplitude and increases the latency of P100 wave. The variations in amplitude and latency can be misinterpreted as lesion or abnormality in visual pathway and optical nerve by the physician.

In present research work, ocularity due to EOG and light on EEG is characterized using mathematical models, subjective and experimental approaches using NI LabVIEW and Neuromax MEDICAID EEG acquisition system acquires signals using 32 channel 10-20 standard electrode placement system recommended by international EEG societies.

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LIST OF SYMBOLS AND ABBREVIATIONS

µV	Microvolts
ECG	Electrocardiogram
EEG	Electroencephalogram
EMG	Electromyogram
EOG	Electroculogram
Hz	Hertz
LDR	Light Dependent Resistor
lux	Illumination/Light intensity
ms	Milliseconds
mV	Millivolts
OA	Ocular Artifacts
Ω	Resistance
cd	candela

CHAPTER 1

INTRODUCTION

1.1 Introduction to Electroencephalogram

The Electroencephalogram (EEG) is a non-invasive test that represents the electrical activity of the brain. This reading helps the physician to detect any abnormality in the psyche. It is primarily used to estimate the cerebral lesions, to study the level of the epilepsy, sleep patterns and to have an inspection and analysis of brain responses to various sensory stimuli like auditory and visually evoked potentials. EEG is composed of electrical rhythms and transient discharges which are identified by the amplitude, frequency, placement on the scalp and other working attributes. EEG can determine the relative strength and position of electrical activity in different brain regions. As for the R. Bickford's research, EEG can be useful to:

Monitor subjects alertness and brain destruction.

Locate injury in brain, tumour, stroke, etc.

Test diffrent pathways (by evoked potentials).

Monitor perceptive engagement (alpha rhythm).

Observe the depth of anesthesia.h.

Examine origin of epilepsy seizure.

Test drug effects on epilepsy.

Monitor brain growth.

Test convulsive effects of drugs.

Explore s physiology and sleep disorders.

1.2 EEG Acquisition

EEG is an indication of the potentials originated from various nerve cells called as neurons in the cerebral cortex and capture cerebral function. Electrical impulses originated due to firings of neurons in the brain diffuse through the head and can be measured by electrodes placed on the scalp. Subdural electrodes are used as an invasive method while performing any surgery.

To obtain an EEG in the safe and secure manner and to have better exploration and understanding, International Federation of Clinical Neurophysiology (IFCN) suggested a standard to acquire EEG for clinical practices. Society of American Clinical Neurophysiology has recommended using a minimum of 21 electrode acquisition system called International 10-20. EEG signals are acquired from electrodes positioned on the scalp in a 10-20 arrangement, an electrode position scheme practiced by the International Federation of Societies of EEG. The 10-20 system was developed to standardize the collection of EEG and facilitate the comparison of studies performed at different laboratories. The positioning of the electrodes over the scalp at the midline between nasion and inion is used to place front polar electrodes (10%), frontal (30%), central (50%), parietal (70%) and occipital (90%) electrodes. Additional locations and more closely spaced electrodes can be appended if necessary.

All the attributes of the EEG are entirely dependent on the placement of the electrodes over the scalp. American electroencephalography society recommends International 10-20 standard, which is a popular strategy for the electrode placement system. Here, "10" and "20" referred as the space between the adjacent electrodes are either 10% or 20% of the total right–left or front–back distance of the skull. This electrode location placement is symbolized as front polar (FP), frontal (F), occipital (O), Parietal (P), Central (C) and temporal (T). Electrodes placed in the midline are represented with suffix 'z'. This arrangement can be of unipolar or bipolar. A unipolar arrangement is composed of electrode leads connected to a common reference electrode such as earlobe electrode. While, bipolar arrangement is realized by the interconnection of scalp electrodes. The international 10-20 electrode placement over the scalp is shown in Fig 1.1.

There are other methods like fMRI & PET also available for recording brain activity. EEG is more powerful compared to other modalities. EEGs can sense changes over milliseconds, which is exceptional in view of an action potential takes approximately 0.5-130 milliseconds to propagate across a single neuron. While, other techniques which sense brain activity, such as fMRI and PET have time resolution between seconds and minutes. EEG directly measures the brain electrical activity, while other techniques record the variations in blood flow, which are indirect recorders of brain electrical activity. Positioning of electrodes in 32 channel EEG acquisition system is shown in Fig 1.2. its 3D representation is given in Fig 1.3.

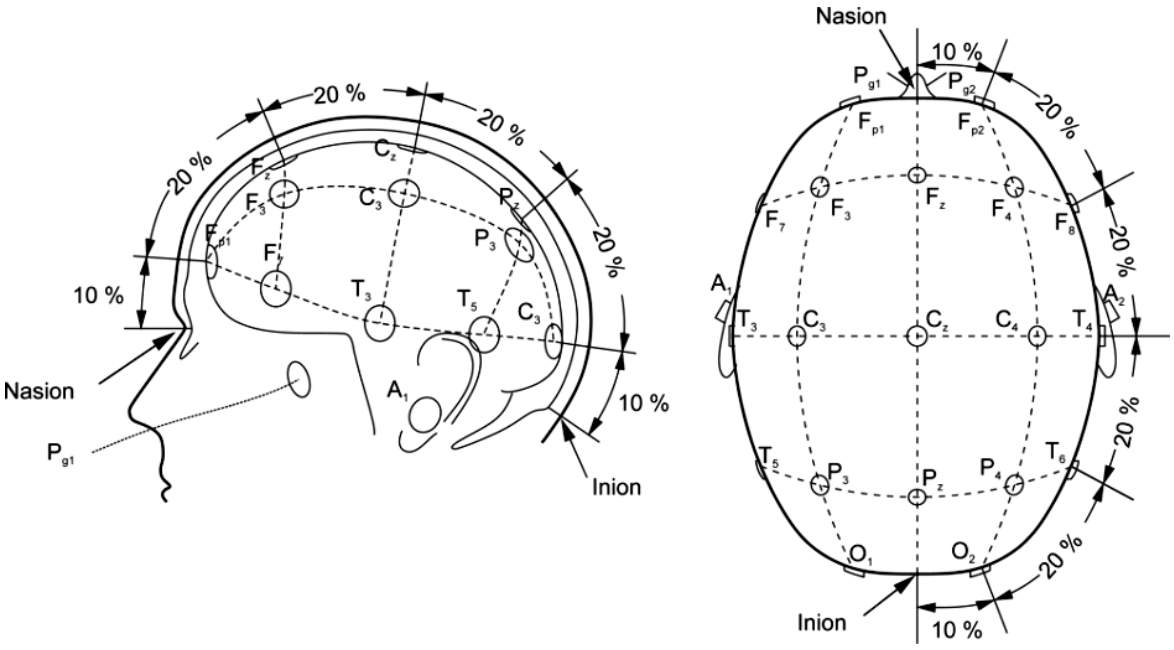


Fig 1.1: The 10-20 international system for the acquisition of EEG

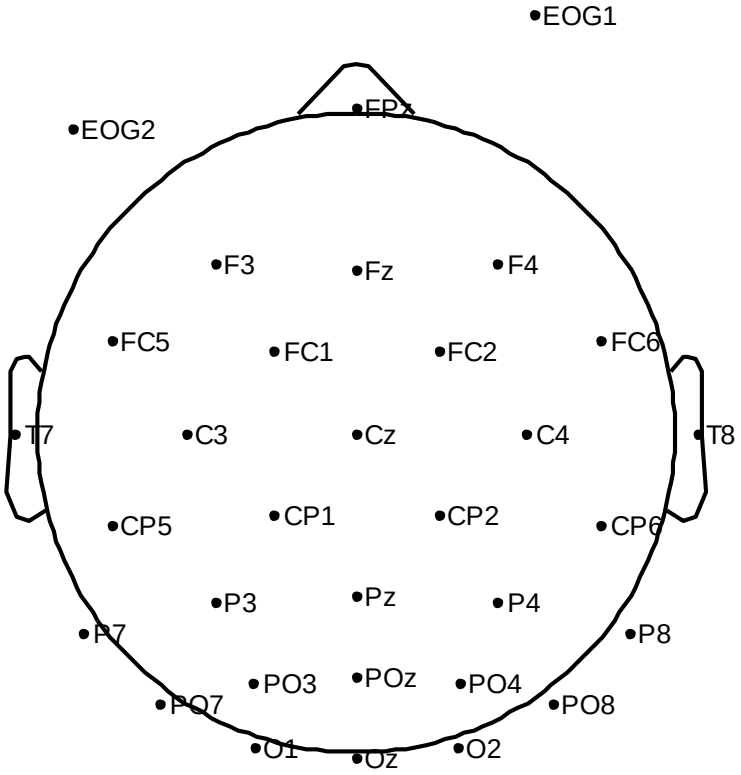


Fig 1.2: Channel location of the 32 channel EEG

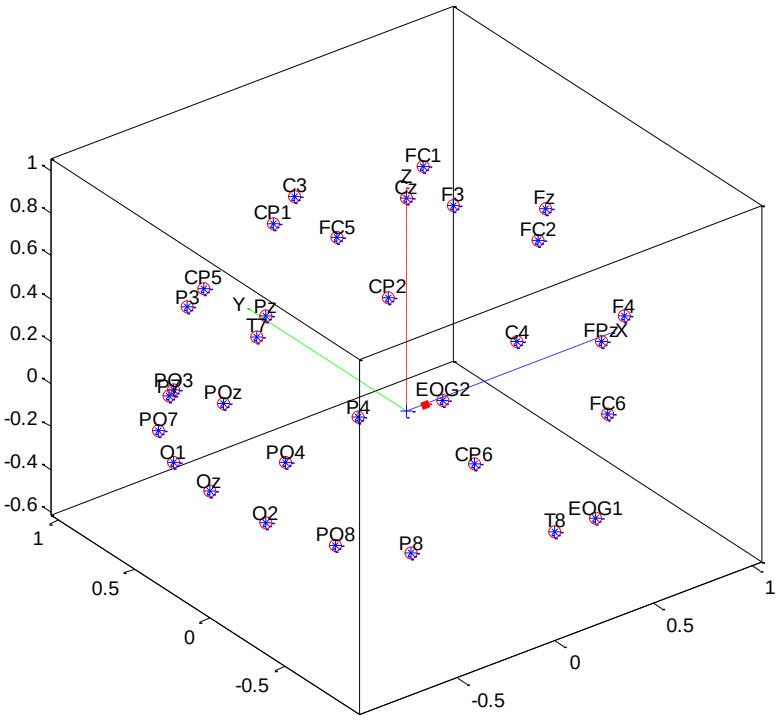


Fig 1.3: Dimensional representation of the 32 channel Dataset locations.

To have better interpretation, EEG acquisition system is required to have high gain differential type preamplifiers and also equipped with internal and external noise rejection filters.

1.3 EEG Representation

Although EEG signal range varies widely, based on the clinical interest the complex EEG waveform can be considered in the range between 0.3 to 30Hz. This clinically considered frequency range of EEG signal is divided into different frequency bands such as delta, theta, alpha, beta and gamma frequencies. These frequencies are generated due to different action done by the neural system. These are purely dependent on the subject's age, state of alertness, and other factors.

1.3.1. Delta frequency

Delta waves are with the characteristics of the low frequency range 3Hz or less and seem to be as Large in amplitude shown in Fig 1.4. This frequency usually occurs during the subjects Deep and dreamless sleep, non-REM sleep, unconscious. The occurrence of this frequency in EEG recording is said to be abnormal when if seen in awake adults. This frequency can be treated as a symptom or result of a lesion or tumor.

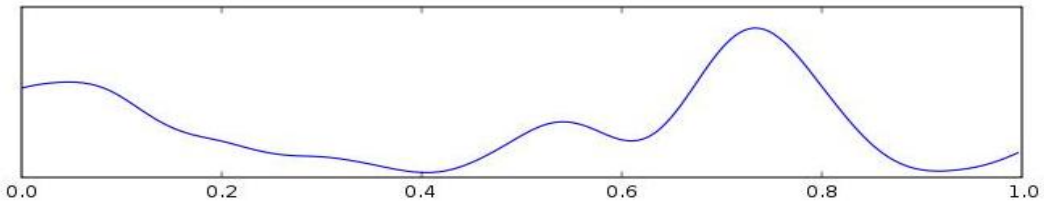


Fig 1.4: Delta Frequency

1.3.2. Theta frequency

Theta waves can be identified in the EEG recording which exhibits frequency range of 4-8Hz and Larger amplitude than beta frequency shown in Fig 1.7. This frequency usually occurs in early stage of drowsiness and day dreaming. Occurrence of this frequency is said to be abnormal when this frequency is seen in awaken adults. This frequency may occur as a symptom or as a result of Head injuries and brain lesions.

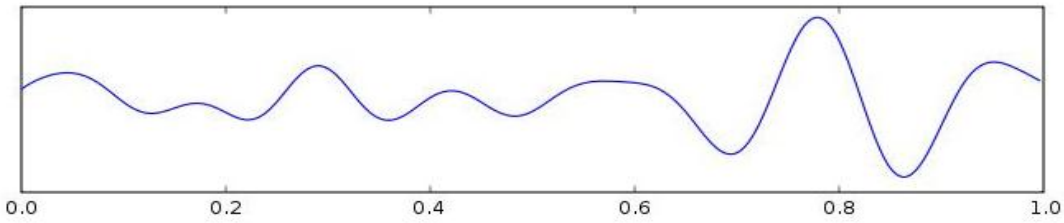


Fig 1.5: Theta Frequency

1.3.3. Alpha frequency

Alpha frequency wave usually occur when subject is Awaken but relaxed with closed eyes. This frequency usually originated in occipital region with frequency range of 8-13Hz and amplitude is found to be mostly less than 50µV, shown in Fig 1.5. The state of occurrence of this frequency is said to be abnormal when it is found in frontal regions which may suspect subject with any depression and attention problems. Head injuries are also major cause for usual occurrence of Alpha frequency in regions other than occipital region.

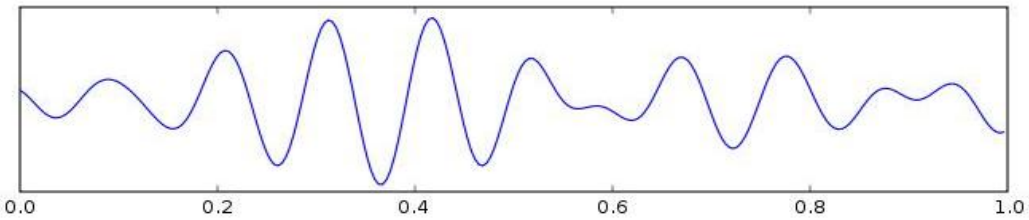


Fig 1.6: Alpha Frequency

1.3.4. Beta frequency

Beta wave exhibits high clinical frequency range of 13-30Hz and with Small in amplitude shown in Fig 1.6. This frequency usually occurs when the subject gives more Alertness or more mental effort to perform any task. Deficient beta may rise to lack of concentration and problem solving. While, Excessive beta may rise to sleep disorders, hyper activeness.

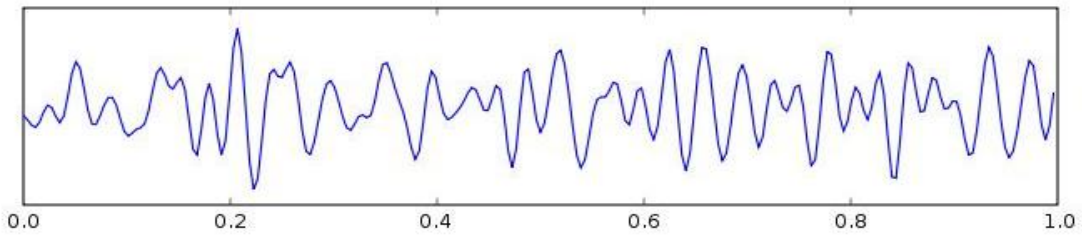


Fig 1.7: Beta Frequency

1.3.5. Gamma frequency

This frequency range usually occurs when subject any motor functions and higher mental activity. This wave can be recognized with frequency range which is Greater than 30Hz and small in amplitude. Occurrence of this frequency seems to be abnormal when it occurs for long time.

The above classification of the normal EEG waveform is based on the frequencies and its state of occurrence when subject undergoes EEG recordings. The characteristics of these waveform are compared in below Table 1.1. The EEG waveform is said to be abnormal in the following comparison when one frequency band exhibits properties of other may be higher or lower frequency band properties. The properties of each frequency band have its own unique nature like shape, amplitude etc.

Table 1.1. Classification of EEG frequencies

Type of Waveform	Characteristics	State of occurrence	Abnormality
Delta waves	• **Frequency range 3hz or less** • Large amplitude	• Deep, dreamless sleep, non-REM sleep • unconscious	• If seen in awake adults • result of a lesion or tumor • may indicate damage from a stroke
Theta waves	• **Frequency range 4-8hz**	• Early stages of drowsiness. • Day dreaming	• If seen in awake adults • Head injuries and brain lesions

	• Larger amplitude		
Alpha waves	• **Frequency range 8-13hz** • Amplitude is mostly less than 50μV	• When subject is Awaken but relaxed with closed eyes	• If present in frontal regions may suspect as depression and attention problems. • Head injuries
Beta waves	• **Frequency range 13-30hz** • Small in amplitude symmetric	• When the subject gives Alertness, mental effort • When taken drugs	• Deficient beta may rise to lack of concentration and problem solving. • Excessive beta may rise to sleep disorders, hyper activeness
Gamma waves	• **Frequency range is Greater than 30Hz** • Small in amplitude	• Motor Functions • higher mental activity	• Abnormal when for continuous for a longer time

1.4 Artifacts

EEG acquires potential of brain electrical activity using electrodes which are placed over the scalp. These acquired EEG signals are in very low order of microvolt as low amplitude, which are prone to contamination of undesired bio-electrical activities originated from heart, muscle, eye, etc. into true EEG readings. These other electrical activities are superimposed on EEG signal and forms a cocktailed signal, the other electrical activity which overlay on true EEG is called as Artifact with respect to the brain electrical activity. Mainly EEG readings are affected with contamination of artifacts which is near or around the brain like EMG, ECG, EOG, etc. creates their impact as a artifact on the EEG, contamination of these artifacts makes the physician to have wrong interpretation of EEG and direct the subject to have unwanted diagnosis which causes the severe issue. Artifacts that overlay on true EEG can be caused from the side of patient, machinery used for acquisition and other environmental issues. Among this all sources of the artifacts the Ocular artifact triggered from the subject's ocular organ takes a principal component because the eye is very much nearer to the psyche.

Originally, EEG is proposed to acquire brain electrical activity only. But, in this case it also adds electrical activities arising from sites other than the brain. The recorded activity that is not of cerebral origin is termed as an artifact. Artifacts are waves or

group of waves that are produced by technical or other disturbances, which are not due to brain activity (Selim Benbadis et al., 2002). The EEG recordings are aimed to acquire only brain electrical activity, but contamination of other bioelectric potential in to the true EEG rise as an artifact. In the present study all the participants are allowed to sit on the good base with head rest to eliminate Muscular artifact. Similarly, the preliminary precautions have to be taken for individual artifact that contaminating in to the EEG. There are various kinds of artifacts which can be divided into physiologic artifacts and extra physiologic artifacts. Physiologic artifacts are generated from the patient and arise from sources other than the brain. Extra physiologic artifacts arise from outside the body like equipment, environment, etc (Selim Benbadis et al., 2002).

The following are the types of physiologic artifacts:

Muscle artifacts

Glossokinetic artifacts

Eye artifacts

ECG artifacts

Pulse artifacts

Respiration artifacts

Skin artifacts

The following are the types of extra physiologic artifacts:

Electrode popping artifacts

Alternating current artifacts

Artifacts due to movements in the environment

Eye movement and blink related artifacts are principal artifacts over other contaminating bio-electric signals (Vigon et al 2000; Tatjana Zikov et al2002).

1.5 Ocular Artifacts

Ocular artifacts arise on the incident when the ocular potential is overlaid on the true brain electrical activity. This can be enlightened by the type of the movement done by the subject's eye and even by the blink of an eye. The Frontal (F) and Front Polar (Fp) electrodes which are positioned near or above the ocular region mainly affected with the Ocular Artifacts. This is because eye consists of cornea and retina, which cornea is more positively charged than the retina and having the potential difference of 100mV. This combination of cornea and retina can be treated as dipole.

Blinking or moving of an eye during EEG recording produces high electrical potential compared to EEG potential around the eyes known as Electrooculogram (EOG), which is a undesired brain electrical activity that induces over the scalp and contaminates the EEG with ocular artifact (Croft and Barry 2000a). The characteristics of the EOG waveform depend on factors such as origin and eye movements. Horizontal, Vertical, and round eye movements creates square shaped artifact in EEG, while eye blinks produce spike-like waves, this can be misinterpreted as a seizure by the physician (Vigon et al 2000; Tatjana Zikov et al 2002). Ocular Artifacts (OA) is a collective term used to describe a number of contaminating voltage potentials caused by eye movements and blinks (Jervis et al 1988).

1.6 Motivation of The Work

On encouragement of saying "We see in the electroencephalogram a concomitant phenomenon of the continuous nerve processes which take place in the brain, exactly as the electrocardiogram represents a concomitant phenomenon of the contractions of the individual segments of the heart"—Hans Berger. It is to be known that proper interpretation of true brain potential of a subject leads to better diagnosis by the physician as ECG for heart. Research is still carrying out on ECG interpretation to have better heart diagnosis, EEG is also an emerging research scope to study the true brain response for the diagnosis of brain disorders for the present and future societies. Hence, highly motivated to provide better instrumentation and to suggest important factors to be consider by the physician while acquiring EEG.

1.7 Thesis Objective

From the last decades, continuous research is carrying out in various research laboratories for various case studies associated with the neural response to different

external stimuli. Here, in this present study, on intend to find ocular impact on electroencephalographic readings which make true EEG signal to mask its abnormality or to show up in excess of abnormality than encompassed in the subject. The objectives of the present work are to

Devise a system to detect the ocular artifacts in EEG

Analyse the impact of light on EEG

Experiment the consequences of optical powered glasses on EEG

Evaluate the variations in Visually Evoked Potential parameters due to light

1.8 Organization of Thesis

Chapter (2) reviews the existing literature. It presents the interpretation of EEG and various standards for acquiring EEG and its applications. It also elevates the problem identified in the existing literature.

Chapter (3) elaborates Contaminations of EOG artifacts in brain potential. Central weighting up on ocular artifacts, reasons for contamination and methods for the removal of ocular artifacts and merits and demerits of each method are verified. Automatic eye blink detector is developed using NI myRIO which can be interfaced to the existing EEG acquisition system to detect the EOG artifact in the EEG.

Chapter (4) gives the study on the impact of light on EEG. Various physiological parameters that alter due to change in light intensity are correlated to the variations in electroencephalographic readings. Effects of light on EEG frequencies are also studied. It is found that, light also effects the frontal frequency in poor luminance condition along with the alpha frequency in the occipital region.

Chapter (5) presents the variation in the light through optical powered glasses. This variation is proved using Light Dependent Resistor(LDR) test. And this variation is correlated to the physiological factors that effects EEG recordings. It is also found that; improper focused lens used by the subject also leads to variation in EEG readings.

Chapter (6) gives the effect of luminance on the Visually Evoked Potentials(VEPs). Moreover, this effect is also varied when subject uses optical powered glasses. It is found that, there is a variation in the parameters of VEPs when

subject uses high powered glasses (> ± 3 D). The VEPs between normal and abnormal ocular refractions are compared.

Chapter (7) concludes with important recommendations to the EEG practitioner or physician from the study and experiments performed in previous chapters. Future Scope to carry out the further research as an extension to the present study is stated.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

Electroencephalogram (EEG) is very useful tool to the physician which reads the electrical activity of brain to diagnose various irregularities gives an insight into the brain functions. In 1875, recorded as the first electrical oscillations in the brain. Richard Caton, British neurophysiologistfirst trace the electrical activity of the brains of monkeys and rabbits directly from the psyche (Caton 1875). The first achievement of electrical activity of human was recorded in 1924 a German psychiatrist, Hans Berger (Berger 1929). The recordings of the Berger are verified by Jasper and Carmichael (1935). From Then, EEG has engaged its position as an investigative tool in standard laboratories of neurology and clinical neurophysiology. This EEG test is widely used in the checking the diagnosis of epilepsy, sleep disorders and disorders of the nervous system. EEG recordings were also used widely in psychological research and drug testing (pharmacology) (Pryse-Phillips 1997).

2.2. Technical Aspects in EEG

Now a days, EEG is acquiring more precisely from the the locations suggested by the international EEG societies using electrode cap. The Ag-Agcl disk electrodes which are in less than 3cm of diameter are positioned over the scalp on required locations. The electrode gel places as a contact between electrode and the scalp to increase the conductivity. The reference electrode is placed on the ear. The differential measurement is done between active electrode and reference electrode known as a channel. The high gain instrumentation amplifier with high Common Mode Rejection Ratio (CMRR) is used to develop the brain potential signal. This differential signal is filtered based on the applications. 50Hz noise filter is used to remove the line noise contaminating into the EEG signal. Although, the bandwidth applicable for the EEG signal is 100 Hz but, the clinical range bandwidth of EEG signal is 0.3-30 Hz. A typical sensitivity value for EEG is 7 μV/mm. For ideal EEG voltage pen deflection is 20-30mm.

2.3. EEG Acquisition

EEG is a complex signal, equally an indication of active potentials of several nerve cells called as neurons. Electrical impulses originated due to discharges of neurons in the brain diffuse through the head and can be measured using electrodes placed over the scalp. Subdural electrodes are used as an invasive method while performing any surgery.

In the present work, single channel EEG acquisition system has been developed using NI myRIO with NI LabVIEW interfaces and the results has been correlated with the standard EEG acquisition system such as Neuromax from MEDICAID system.

2.3.1 Interfacing to NI myRIO

The central task in developing a Data Acquisition system is to measure or generate real time physical signals. Data acquisition typically involves acquisition of signals and processing to get desired data. Here, DAQ is a data acquisition system. NI myRIO is a processor along with data acquisition system.

NI myRIO is a data acquisition system with a processor which consists of two Analog Input with 16 bits, and two Analog Output channels with 16 bits. It also comprise 3.5mm stereo jack for interface to other hardware, counters (counter, timer), Digital I/O (8 DIO lines) and power supply (+/- 15V). All the specifications of myRIO are given in Appendix B.

Acquiring data is a process of computing the electrical potential or physical progression such as current, voltage, temperature, etc. this acquisition can be made using various types of sensors. In this scenario, for the EEG application, the analog output of the bio-potential amplifier is connected to the parallel input of the NI myRIO i.e., A0. This system is connected to the computer via USB for online monitoring.

The code is developed in NI LabView, by processing analog input from the myRIO palette in the rear panel. Smoothing and filtering of acquired EEG signal done with advanced signal processing tool kit for NI LabVIEW. The resultant output of single channel can be monitored in the waveform chart displayed on the front panel. Entire developed code for EEG acquisition is placed in while loop to have continuously acquired. Depending on Waveform chart, we can define the input and output waveforms. Set-up time is used for stopping of the waveforms for our required use. In filtered signal block we have different types of signals, as per our requirement,

we can take the filter blocks. After that it is related to another Waveform chart for desired output signals.

As EEG signals are in the order of microvolt and can easily contaminate with artifacts and other noise. Consequently, filters are used to improve the signal. Frequency range of 0.5 to 33 Hz band pass filter is used to consider the EEG signal for clinical practices. This Band pass filter rejects the acquired signal frequencies that are not present in clinical frequencies.

After writing code in NI LabVIEW, this can be deployed into the NI myRIO. This NI myRIO can be utilized as a central processing unit which can store and execute the NI LabVIEW code when it is powered on. Interfacing myRIO to the information processing system can be removed once the code gets deployed into the NI myRIO

2.3.2 Acquisition using Neuromax MEDICAID system

Standard Neuromax acquisition system from MEDICAID system used for 32 channel EEG acquisition. Each recording is processed and smoothed using filters and line noise is rejected using 50Hz notch filter. EEG readings are held open in European Data Format (. edge) and changed to wave format and split up to individual channel using EDF/EDF+ to wave converter. Each obtained wave is analyzed using MATLAB. The frequency response of each wave is obtained by performing FFT analysis.

2.4. Contamination of EOG In EEG

EEG extracts, bio-potentials from the electrodes positioned over the scalp are generated due to the discharge of the neurons in the brain. These EEG potentials are in the order of microvolts are prone to the artifacts such as electrical activities generated from human organs like Eye, Muscle and Heart etc. The overlapping of the Artifacts on normal EEG may affect the physician's interpretation about EEG, leading to incorrect diagnosis. Thither are many artifacts such as undesired bio-potentials from other organs such as Eye, an artifact from equipment used for acquisition of EEG and other extraneous disturbances. Among all these artifacts, Ocular artifact (OA) is the dominant artifact.

There are many artifact elimination methods existing in the previous literature like Eye fixation method, EOG Rejection, Regression, PCA, ICA, Wavelet Transform,

Adaptive filters, Soft computing are used to remove the ocular artifacts. Various blink detectors are also proposed using cameras, IR sensors, Image processing algorithms.

But, All these methods are post processing methods which performed after acquisition. Hence, it repeats the examination time. EEG practitioner or Neuro physician has less awareness on these signal processing, artifact removal techniques.

Weerts et al., 1973, gives the effect of the eye fixation method on the EEG. States that this eye fixation method affected the contingent negative variation. Because this technique imposes other demands on the field and makes the EEG interpretation difficult. Verleger., 1991, also states auditory P3 and N1 amplitude are also affected when the subjects are instructed to make their eyes onto particular target. Here the efficiency of this practice is uncertain. As this method is very difficult to do with subjects like kids and mentally handicapped people. Croft et al., 2000 gives the important aspect that closure of the eyes also affects the alpha frequency in the occipital area.

This is an artifact removal technique based on the initial detection of the artifact by visual testing. If the EEG has amplitude (Voltage) expected to be in range of 50 microvolt, then the episode of the EEG signal which exhibits more than 50 microvolt are treated as an artifact and that episode is removed. If the artifact is below 50 microvolt it can't be removed. Small JG., (1971), reported that a visual ERP experiment conducted on autistic children produced OAs nearly 100% of the trails.

Regression is a statistical process for estimating the relationships among variables. It needs reference signal EOG to subtract it from the true EEG signal. In this analysis, the Regression coefficient is calculated to estimate the amount of EOG on the true EEG. This artifact removal regression algorithm can be performed as Frequency Domain Regression (FDR) and Time Domain Regression (TDR).

Croft and Barry (1998b) proposed the Aligned Artifact Average (AAA) method to examine whether propagation is constant across eye movement types and frequencies. This method differs from previous statistical methods methods, where instead of calculating regression coefficient from EOG and EEG data, it calculates the regression coefficient B from EOG and EEG averages aligned on eye movements. Semlitsch et al (1986) also proposed similar method, in which they corrected blinks with B, calculated from averaged blinks. Croft and Barry (1998b) concluded that EOG propagation is constant across eye movements, cases, and frequencies. A more

accurate correction procedure is to find B, using AAA, which removed the variability between different eye movement types. It is mentioned in later works that the regression coefficients of saccade B do not always correct blink data adequately with the AAA method. the revised AAA (RAAA) is proposed by Croft and Barry (2000b) and they concluded that when employing EOG correction procedures, blink and saccade data can be corrected using a common set of B, provided that vertical, horizontal, and radial EOG channels are used appropriately.

Berg and Scherg (1991b) proposed another technique for removing ocular artifacts using Principal Component Analysis (PCA) (Joliffe 1986). Principal Component Analysis Basically is an algorithm that transforms a number of probably correlated variables into a smaller number of uncorrelated variables called principal components by singular value decomposition. PCA will give the prime components of the acquired EEG signal by representing eye blinks and movements. These ocular components are distinguished from the EEG signal by simple inversion computation. The accuracy of this algorithm depends on the availability of separate and accurate inverse solutions for EEG and EOG. It exhibits a prime drawback that it cannot separate completely eye artifacts from brain signals, especially when they both have comparable amplitudes.

Scott Makeig et al., 1996, reported first application of ICA for EEG data analysis. As in the study of the EEG signal that it faces the problem with the artifacts, which bring the task of separating them using Blind Source Separation (BSS) to obtain components that are approximately independent. On that point are four assumptions made to have good separation of the contaminated signal into individual portions.

Tzyy-Ping Jung et al., 1998 showed that ICA can detect, separate and, remove activity in EEG records effectively from a wide variety of artificial sources. Vigor et al (2000) used FastICA algorithm for recognition of artifacts in EEG and MEG. They demonstrated that the FastICA algorithm can be utilized for pulling up different types of artifacts from EEG and MEG data, even when these artifacts are smaller than the background brain activity. Invariably, ICA algorithms used by various researchers for artifact removal use ICA to separate the EEG into its constituent independent

components (ICs) and then eliminate the ICs that are thought to contribute to the artifact sources.

Tatjana et al., 2002 proposed a signal processing technique to get rid of the artifacts from the contaminated EEG signal, even the artifact is underlying in the EEG signal and this method is efficient in transferring the low frequency OA, with maintaining the brain signal. WT divides an artifact contaminated signal into smaller sections, each corresponding to a different frequency. It is the most potent tool in presenting non-stationary signals like EEG where the signal does not contain same frequency all over. Multi-resolution property exhibit by the Wavelet decomposition adjusts with different frequencies which plays a critical part in separating artifacts in these biomedical signals. As the EEG signal is broken down into different frequencies using Wavelet Transform then, entire artifact contaminated EEG signal is split into individual frequencies as wavelet exhibits multi-resolution and non-stationary properties.

The adaptive interference cancellation is a very efficient method to resolve the problem when signals and interferences have overlapping spectra. The input signal of the EEG corrupted with artifacts (EEG+EOG). This algorithm is an approximation of the original EOG in EEG signal. This undesired EOG signal is subtracted from the acquired EEG signal to create error free EEG without artifacts. Various Soft computing techniques are also proposed to estimate the EOG content in EEG recording by analyzing large amount of data

All these methods are post processing methods which performed after acquisition. Hence, it repeats the examination time. EEG practitioner or Neuro physician has less awareness on these signal processing, artifact removal techniques. Various EOG artifact detectors are produced for utilization in assorted applications. T. Morris et al., 2002, Chou., 2012, Jibo He et al., 2017 proposed various blink detectors using IR sensor, USB cameras and perform image processing algorithms. These algorithms not linked with spectral frequency of the brain. But, these algorithms figure out the eyelid closure and open actions.

Ulrika Svensson., 2004 developed a driver safety system using various algorithms like thresholding and with image processing algorithms. For this there is

lot of components to be required to develop proposed sysem. But the present invention provides a simple and accurate system for the detection, capture, amplification, filtering and comparison of the eye potential for the brain, eye coordination and for the application of the various real time utilities.

2.5. Impact of Light on EEG

A. Maher et al., 2001, gives the effect of light intensity on EEG frequencies. That research also states that alpha wave in the occipital region is synchronized with the luminous intensity experienced by the subject. Bryal et al., 1993, gives the immediate physiological changes in the human system for different light intensities. C. Cajochen et al., 2000, Christian Cajochen., 2007, correlated these physiological changes to the EEG frequencies that are varied due to the variation in light intensity. C. Cajochen et al., 1998, states that release of melatonin hormone is synchronized with light intensity and states that the release of melatonin hormone is inhabited when light intensity falling on the eye is increased. Changes in physiological variables due to variation in luminance inturneffect the neural behavior. C Cajochen et al., 2000, gives an overall survey on the parameters varying with regard to light intensity, such as body temperature, Subjective alertness, incidence of slow eye movements, etc. But, here in the literature there no synchronization with any other frequency range raise up in any other part.

There is no particular research literature available which correlates the optical power glasses with the EEG recordings. Here, light is studied as a variable which get converged and diverged with respect to optical power. Hence, in the previous literature, as A. Maher et al., 2001 assured synchronization of light with alpha frequency in occipital region can be seen as a light through optical powered glasses.

Light through optical powered glasses also creates impact on Visually Evoked Potential test. According to the guidelines of American clinical electroencephalographic society, 2016 to perform a VEP test, light is also a considerable factor states that, analysis of VEP parameters like latency and amplitude of P100 wave show up the abnormalities associated with the visual pathway and optical nerve which is stated in following literature J. Jutai et al.,1984, J. Odom et al., 2009, M. Murugappan et al., 2009, N. Yadav et al., 2012, R. Kothari et al., 2016, V. Fimreite et al., 2015.

2.6. Problem Identified from the Previous Literature

All the methods or algorithms proposed to remove the ocular artifact in EEG given by A. Kandaswamy et al., 2005, B. Lee et al., 2014, C. Zhang et al., 2015, C. Zhang et al., 2016, J. Woestenburg et al., 1983, M. Scott et al., 1996, Michel Jounee., 2015, Y. Khan et al., 2015, Z. Tatjana et al., 2002 are studied.

These artifact removal methods are post possessing methods which performed after acquisition. Thus, it doubles the examination time. EEG practitioner or Neuro physician has less awareness on these signal processing, artifact removal techniques. Some of the methods are using existing artifact removing algorithms. Advantages and disadvantages of the each existing algorithms are described and tabulated in next chapter.

Light varies various physiological parameters like melatonin hormone given by I. Mclntyre et al., 1989. Variations of lightening parameters are correlated only with occipital region A. Maher et al., 2001, B. Brown et al., 1970, B. Myers et al., 1993, C. Cajochen., 2007, C. Cajochen et al., 2000, C. Cajochen et al., 1998, , J. Park et al., 2013, K. Shieh et al., 2005, M.Toscani et al., 2010, S. Bong et al., 2010, S. Hillyard et al., 1970, S. Narayan et al., 2013, S. Xie ., 2011).

Previous literature does not state the variations in EEG frequencies due to light intensity in other regions like frontal etc. Variation of light through optical powered glasses is not correlated with the variation in light intensity.

The influence of light on VEP of EEG is given but it is not correlated with Variation of light intensity through optical powered glasses. The literarure correlates lighting parameters with the visually evoked potential parameters like amplitude and latency given in J. Jutai et al.,1984, J. Odom et al., 2009, M. Murugappan et al., 2009, N. Yadav et al., 2012, R. Kothari et al., 2016, V. Fimreite et al., 2015.

2.7. Summary

In this chapter the technical aspects required for the EEG acquisition system are revised. Interfacing bio signal amplifier to the Digital device like a computer via NI LabVIEW is presented. Various methods to remove the ocular artifacts are briefly introduced and detail discussed in Chapter 3. The problems identified from the previous literature is highlighted. The reasons that identified problem leads to the

research objective are also put forward. The objective of this thesis is structured based on the limitations of previous literature and to elevate the variations of EEG frequencies with respect to light stimuli through ocular organ.

CHAPTER 3

OCULAR ARTIFACTS IN EEG

3.1. Introduction

Electroencephalogram (EEG) can be differentiated as Electro + Encephalo + Gram / Graph. This can be rephrased as Electricity + Brain + Picture, which is integrated as a study of variation in brain electric potentials. EEG readings can be used to study the entire spectrography of firing of neurons. EEG is a complex waveform consists of Delta, Theta, Alpha, Beta and Gamma. The clinical range to analyze EEG waveform is 0.3 Hz to 30 Hz.

3.2. EOG Artifacts

EEG potential acquired over the psyche is in the range of few micro volts. Hence, it is easily contaminated with signals from other organs and noise due to other equipment, etc. The additional signal component which is present in the EEG is said to be an artifact. The artifacts arisein the incident where the potential from ocular organ is overlaid on the true brainactivity of the brain is known as ocular artifacts. Based on the type of the movement done by the subject's eye, ocular artifact potential will vary in shape and magnitude in Front (F) and Front Polar (Fp) regions are affected by ocular artifact. Because eye acts as a dipole, where the cornea is positively charged than the retina. The potential difference between the cornea and retina is around 100mV (Anthony B.J et al., 1985, American Electroencephalographic Society., 1994, Carrie Joyce., 2004, Delorme., 2001.)

Eye acts a dipole, the movements or deflections of eye ball makes EEG contaminated with artifacts. if the eye ball moves upwards the charge of the cornea is applied As an eyeball acts a dipole, when the eyeballs moves vertically upwards . Now the charge of the Cornea is induced on to the nearest frontal electrodes. On the other hand, if the eye ball move downwards, then the charge of the retina is developed and induced on to the nearest electrode. if the eyeball deflects downwards, then the charge of the retina gets induced onto the electrodes. (Brunia et al., 1989, Cardoso., 1999, Gratton et al., 1998, Gasser et al., 1992, Gratton et al., 1983, Percival et al., 2000, Smith et al., 2005, Singh et al., 2014).

.This artifact comes with the sudden closing and open of an eyelid. In this scenario, eyelid act as the sliding electrode or as a bridge that connect the scalp to the positively charged cornea. As the eye lid slides over the eyeball that cornea (positively charged), then eye lid picks up the potential from the cornea and imposed onto the nearby electrode which it become more positive, results as an eye blink OA (Akay M et al., 1994, Beloucharani., 1997, Schiff et al., 1994, Vincent et al., 1999).

.The ocular artifacts are recognizable up to a certain extent. Upright, horizontal, and round eye movements which produces square shaped EOG waveforms, while eye blink produces spike-like waves.These potential waves get overlaidonto the EEG signal and introduces difficulty in the interpretationandanalysis of brain electrical activity (Comon et al., 1994, Corby., 1972, D. Bansal et al., 2015, Gasser et al., 1985, Greg., 2004, Kenemans et al., 1991).

3.3. Mathematical Modelling

By correlating fundamental electrostatic physic to the ocular organ, the electric field due to Cornea-Retina dipole potential induced on to the electrode is given in equation (1.1).

$$V_{Dipole} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_c}{r_c} - \frac{q_r}{r_r}\right] \tag{1.1}$$

Where q_c and q_r are the charges respectively accumulated on cornea and retina of an Ocular dipole. In which cornea is more positive than the Retina where r_r and r_c are the distance between them and the nearest electrode respectively.

The net voltage across the electrode when artifact potential in bright illumination is added with desired neuro potential, it is given by:

$$V_{Electrode} = V_{\ Neuro\ Potential} + V_{Dipole} \tag{1.2}$$

$$V_{Electrode} = Neuro\_potential + \frac{1}{4\pi\varepsilon_0}\left[\frac{q_c}{r_c} - \frac{q_r}{r_r}\right] \tag{1.3}$$

So, the accumulated total EEG potential is a sum of neuro potential and ocular artifcat. This additional ocular artifact potential can be removed, which is mentioned below.

3.4. Methods For Removal of Ocular Artifacts From EEG

Many methods have been proposed by numerous researchers to remove artifacts from EEG recordings, especially those arising from eye movements and blinks. Few methods are explained in the following sections.

3.4.1 Eye fixation method

For removing the ocular artifacts in the EEG, all the subjects asked to stare at the particular object. To perform this method, all the participants are close their eyes intentionally to control the movements of an eye. On this process the alpha activity is developed in the occipital region which also affects the Contingent Negative Variation (CNV). The prime drawback of fixation method is not possible with the subjects who are mentally challenged and children.

3.4.2 EOG rejection

In this technique which is depend on preliminary detection of the artifact by visual inspection. Here, the threshold algorithm is used to remove the ocular artifact in EEG. The amplitude of the true EEG signal is compared with ocular artifact contaminated EEG. This algorithm rejects the EEG segments when the amplitude of the ocular artifact is more compared to the EEG signal. It cannot reject the artifact which underlying EEG signal. Much amount of brain electrical data is lost due to rejection. Small (1971) reported that, a visual ERP experiment conducted on autistic children produced OA in nearly 100% of the trials.

Hence, the rejection procedure for removing OA is not recommended. The basic disadvantages of the rejection technique have led several researchers to develop methods for removing OA from EEG records. In contrast to rejection method in which, removes the EEG data affected by OA, the correction procedures attempt to remove the effect of OA from the EEG. This selection of the EEG data to perform artifact rejection is shown in Fig 3.1. EEG data after rejection of selected artifact episode is shown in Fig 3.2.

There is big amount of brain electrical activity recording data lost from the episode of rejection. This algorithm is performed on visual inspection of EOG artifact contaminated into true EEG signal. Artifact which is not caught by visual inspection is underlay in the EEG signal and cause misinterpretation.

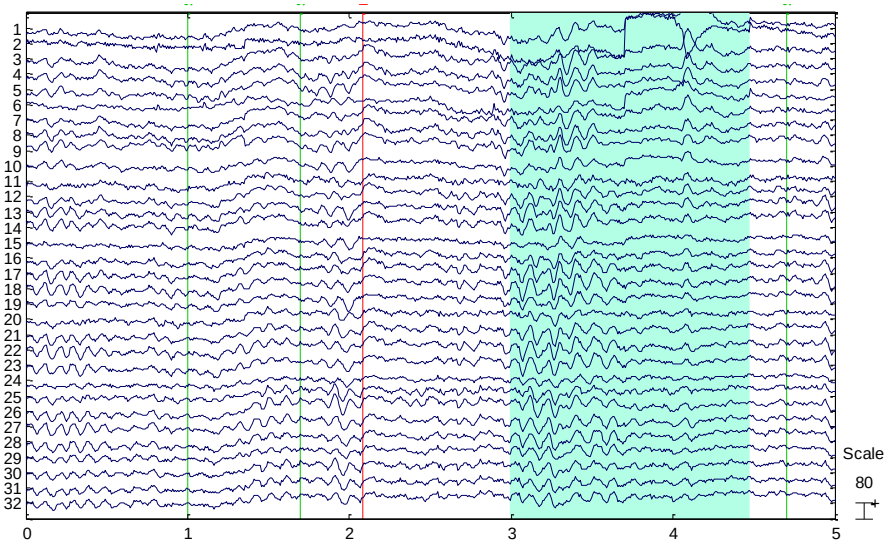


Fig 3.1. The selection of EEG Episode to perform Rejection Operation

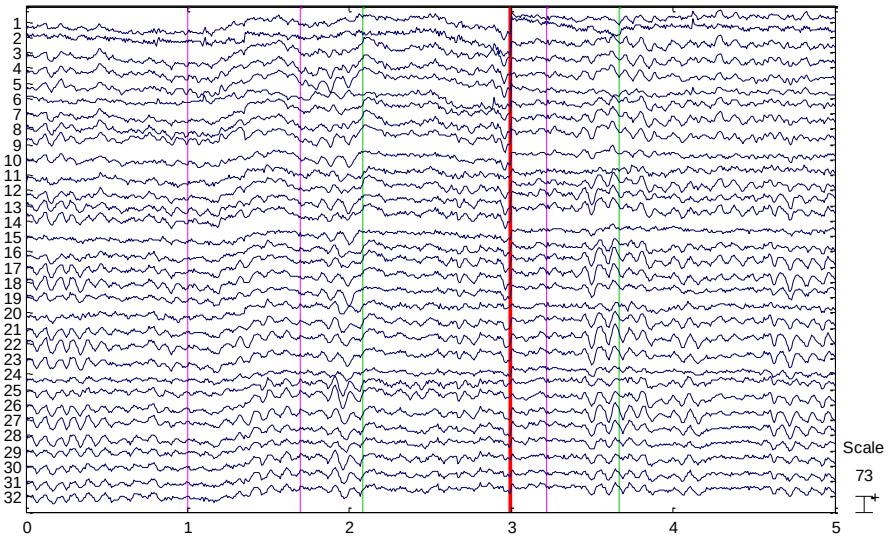


Fig 3.2. The resultant EEG signal after rejection of selected episode

3.4.3 Regression

It is a statistical process for estimating the relationships among several variables. It needs reference signal of EOG to subtract it from the true EEG signal. In this analysis, the Regression coefficient B is calculated to estimate the amount of EOG on the true EEG. Regression can be done in both Frequency Domain Regression (FDR) and Time Domain Regression (TDR). In which TDR gives the amount of EOG and EEG at each point of the time irrespective of the frequency. Measured EEG $x(t)$, True EEG due to the brain activity $x_{tr}(t)$, ocular artifact from eye into EEG $e_0(t)$, Y-intercept of the Regression Equation C at the time interval i.Regression Coefficient represented B given as.

$$x(t) = x_{tr}(t) + B.e_0(t) + C \tag{3.1}$$

$$B = \frac{\sum (x_i - \overline{x_i})(y_i - \overline{y_i})}{\sum (x_i - \overline{x_i})^2} \tag{3.2}$$

$$C = \overline{x_i} - (y_i - B) \tag{3.3}$$

Since, for every different movement of the eye produces different voltages with different frequencies. Then Fourier Transform is a tool which divides the signal into different frequencies. Now, the Regression coefficient B is calculated for different frequencies in frequency domain.

3.4.4 Aligned Artifact Average (AAA) and Revised AAA (RAAA) methods

Croft and Barry (1998b) proposed the Aligned Artifact Average (AAA) method for examine, whether the propagation is constant across an eye movement and its corresponding frequencies. This Technique is different from previous technique and more accurate also, in which Coefficient B is calculated for every instant of the time or at different frequencies from the raw EOG and EEG. Here, B is calculated from the Averages Aligned on movement of an eye. RAAA concluded that saccade and blink can be corrected by having same set of B, by use of horizontal and Vertical Radial EOG channels appropriately.

This technique is different from traditional methods, where instead of calculating B, from EOG and EEG data, it calculates the regression coefficient B , from EOG and EEG averages aligned on eye movements.

3.4.5 Principal component analysis (PCA)

Generally, it transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components by singular value decomposition. Berg and Scherg (1991b) proposed another technique for removing ocular artifacts using Principal Component Analysis (PCA) (Joliffe 1986). Here, EEG Signals are taken, when subject perform some typical eye blinks and movements. Then, a PCA will give the key components by representing eye blinks and movements. These components can be eliminated by the simple inversion computation. The accuracy depends on an availability of separate and accurate inverse

solutions for EEG and EOG. PCA bear with a prime drawback that it cannot be separate completely eye artifacts from brain signals, in that case when they both have comparable amplitudes. In this approach, EEG and EOG signals are collected simultaneously, when the subject performed some standard movements and eye blink. Then, a PCA of the variance in these calibrating signals gave major components representing blinks vertical and horizontal eye movements. Corrected EEG was obtained by removing these components through the simple inversion computation.

3.4.6 Independent component analysis (ICA)

The study of the EEG signal that it faces the cocktail problem with the artifacts, which bring the task of separating them using Blind Source Separation (BSS) to obtain components that are approximately independent. The cocktail problem exhibiting by the mixing model and its separation by Unmixing model is depicted in Fig. 3.3.

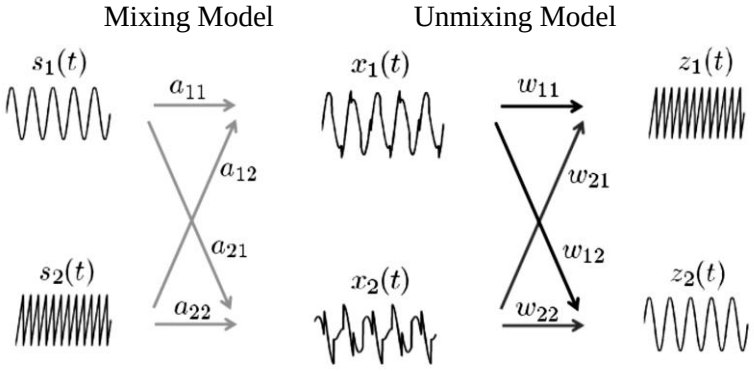


Fig. 3.3. Mixing and Unmixing of two signals (Michel Jounee., 2015)

Here, consider the two signals $s_1(t)$ and $s_2(t)$ forms a liner mixture matrix A. as $\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$ the resultant mixed signals stated as $x_1(t)$ and $x_2(t)$. The mixing model equation can be Witten as $X = AS$.

The separation of independent components from cocktailed signals $x_1(t)$ and $x_2(t)$ done by blind source separation. The equation for Unmixing model can be written as $Z = W^T.X$, where $z_1(t)$ and $z_2(t)$ are separated signals. W^T Extends ability for performing BSS on linear mixtures.

ICA is a technique which may be used to recover independent source signals from a set of measured signals. In which ICA technique is well suited for performing source separation in domains where,

(i) Source signals are statistically independent

(ii) Measured signals are linear mixtures of source signals

(iii) Propagation delays of the mixing medium are negligible

(iv) The number of measured signals is the same as the number of source signals (Scott Makeig et al 1996).

With respect to EEG signals, the first assumption is reasonable, because the sources of the eye activity, muscle activity, line noise, and cardiac signals are not generally time locked to the sources of EEG activity. This actually reflects the activity of cortical neurons. So, assumption is satisfied since, it is assumed that the multichannel EEG recordings are mixtures of underlying brain and artifactual signals. Since volume conduction in brain tissue is instantaneous, assumption three is also satisfied. With respect to EEG, assumption four is questionable, because the number of statistically independent brain signals contributing to the EEG recorded from the scalp is not known. ICA can be used for performing blind source separation on EEG data. Scott Makeig et al (1996) reported the first application of ICA for EEG data analysis by using the algorithm of Bell and Sejnowski (1995) for ICA. Separation of blink components in the true EEG signal using Independent component analysis is given in Fig 3.4.

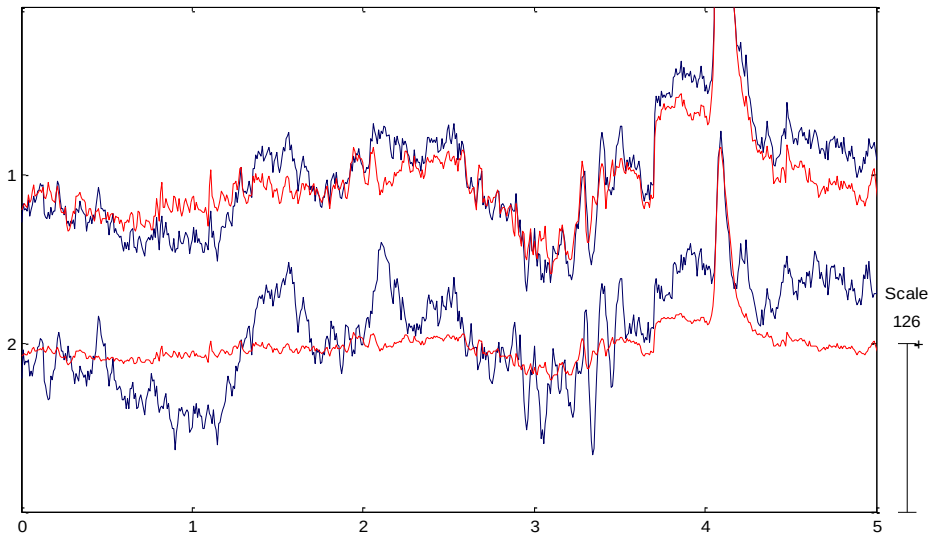


Fig 3.4 Separation of artifact components from EEG signal

3.4.7 Wavelet transform

In signal processing technique has possible to remove the artifacts from the contaminated EEG signal, even the artifact is underlying in the EEG signal and this method is an efficient in removing the low frequency OA, with preserving the brain signal. WT divides an artifact contaminated signal into smaller segments, each corresponding to a different frequency. It is the most powerful tool in representing non-stationary signals like EEG where the signal does not contain same frequency all over. Multi-resolution property exhibit by the Wavelet decomposition adjusts with different frequencies which plays a vital role in separating artifacts in these biomedical signals. A sequence of wavelet can be generated by dilating and translating the mother wavelet, given in the equation 3.4.

$$\varphi(x)_{(a,b)} = \frac{1}{\sqrt{a}} \varphi\left[\frac{x-b}{a}\right] \tag{3.4}$$

Discreet wavelet Transform (DWT) can be obtained by filtering through the series of digital filters at different scales. The scaling operation is done by changing the resolution of the signal by the process of sub sampling. However, the threshold limit is calculated from the uncontaminated baseline EEG which is a limitation to this technique. The six level wavelet decomposition is given in Fig.3.5

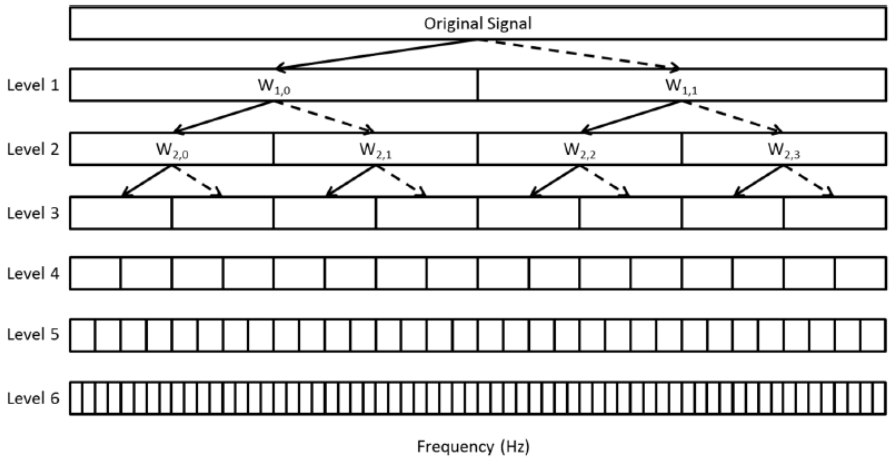


Fig.3.5 Six level Wavelet decomposition of EEG signal.

As the EEG signal is decomposed into different frequencies using Wavelet transform then, entire artifact contaminated EEG signal is divided into separate frequencies as wavelet exhibits multi-resolution and non-stationary properties. Now, artifacts can be removed by assuming proper threshold value which rejects artifacts.

A wavelet depend denoising technique for removal of OA from EEG is reported in the literature (Tatjana Zikov et al 2002). Using the time- frequency localization property of wavelet transform, the proposed method has shown its potential in removing the low frequency OA, while preserving the underlying brain signal. However, the threshold limit was empirical and it is calculated from the uncontaminated baseline EEG signal. The recording procedure to obtain such an uncontaminated EEG calls for a co-operative subject and is not only tedious but also very rarely free from contaminations.

3.4.8 Adaptive filtering

The adaptive interference cancellation is a very efficient method to solve the problem when signals and interferences have overlapping spectra. The input d(n) is the EEG corrupted with artifacts (EEG+EOG). The reference signal x(n) is an original EOG (without artifact) . The output of H(z) is y(n), which is an estimation of the original EOG. This signal y(n) is subtracted from the corrupted d(n) to produce the error e(n), which is the EEG without artifacts shown in Fig 3.6

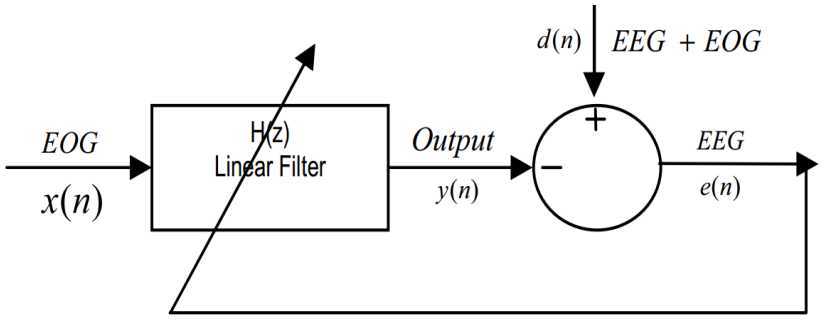


Fig 3.6 Adaptive filtering algorithm to remove ocular artifacts in EEG

3.4.9 Soft computing techniques

In early days the BCI need for real time analysis of EEG and ERP has been felt. Soft computing and Linear technique analysis are the two most promising approaches here. In contrast to classical approach of exact computation at a greater cost, which may be prohibitive for the complex problems like multidimensional EEG analysis, soft computing strives to achieve tangible results at reasonable cost by allowing inexactness and uncertainty to be parts of the computational models. It includes fuzzy logic, statistical discrimination, neural networks, genetic algorithm and Bayesian inference.

Removal of OA from EEG is an exigent task, summary of different methods discussed given in Table 3.1.

Table 3.1 Summary Of methods, its drawbacks And benefits

Algorithm	Demerits	Merits
Eye fixation method.	It increases Alpha activity, due to lack of vision	Major Ocular Artifact can be removed
EOG Rejection	Loss of information from brain activity for diagnosis.	Preliminarily, Noticeable artifact can be removed
Regression	Good reference of EOG needed.	EOG in EEG is Known at a particular time and frequency
AAA and RAAA	Need in use of proper vertical, horizontal and radial EOG channels	Accurate than regression
PCA	It cannot correct when the artifact and the true EEG signal has same amplitude.	Separation of major components easily
ICA	Have to decide by inspection of independent components	Artifact underlying brain activity can also be removed
Wavelet Transform	Identifying the scaling parameters is a crucial task	Artifact at different scales can be identified
Adaptive Filtering	Reference input is essential for artifact filtering.	Fast convergence and effective artifact filtering
Soft Computing Techniques	Training and detection plays a complex role.	This technique is used to detect artifact in large data.

In the above described Ocular artifact removal methods, ICA and Wavelet Transform gives utmost quality of removal of Ocular artifacts from the artifact contaminated EEG signal. There are other methods proposed by in view of above ocular artifact removal methods to separate artifact and other by methods like adaptive filtering and Artificial Neural Networks and other soft computing techniques can also be used for automatic rejection of artifacts from the contaminated EEG signal.

3.5. EEG Artifact Detector

The detection of eye blink plays a vital role in various applications of brain computer interface. In that eye acts as a dipole consisting of the cornea and retina, wherein the cornea is much more positive than the retina providing typically around microvolts to 100mv between them. When the eyelid slides over an eye it acquires potential of an eye. This potential varies with various factors like light intensity, nature of blinking. This potential can be acquired using electrodes positioned near to

the ocular region, which is connected to bio signal amplifier and filters for signal processing as shown in Fig 3.7. The electrodes are kept near or around the ocular region for collecting and acquiring the potential of fewer micro volts to milli volts from the eye region. The amplifier amplifies the differential voltage between the active electrodes positioned in and around the ocular region and the reference electrode positioned on the lower region of the ear for further processing.The developed signal is connected as analog input to the Mini System Port(MSP) of connector C in NI my RIO i.e, AI0/AI1. This has to be powered with external power supply and interfaced to a computer with USB.

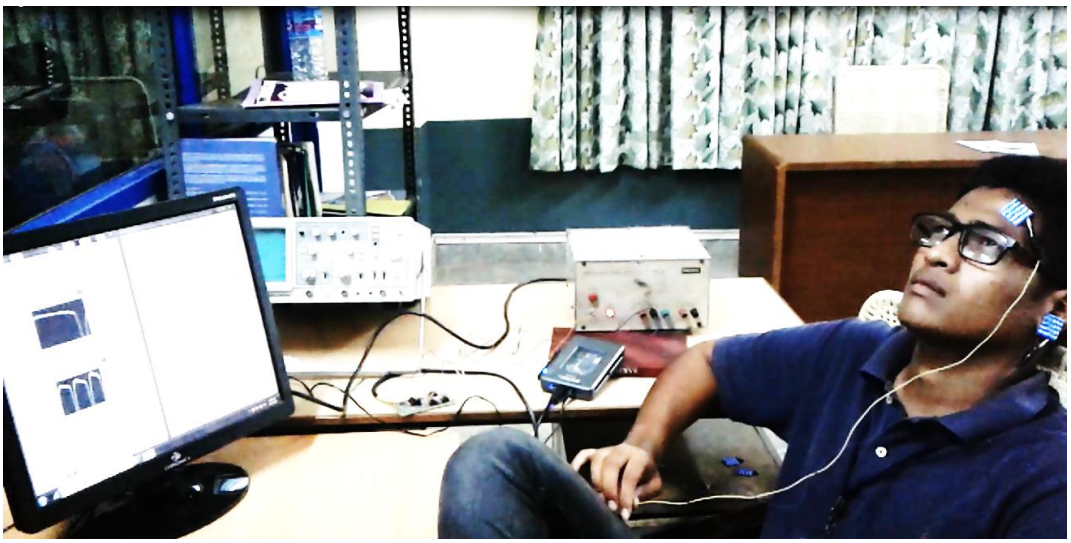


Fig 3.7. Automatic EOG artifact detector using NI myRIO

To detect an ocular blink the analog input is placed onto the block diagram panel of VI using myRIO Toolbox in the palette. This analog input is connected to the waveform chart of front panel to view and analyse the analog signal voltage. This analog signal voltage is compared with threshold voltage. If the voltage of an analog signal is more than given threshold, that should be showed up as blinking the LED's on the myRIO. The output of the comparator is assigned to the on board LED's of the myRIO palette. This entire code is kept inside of the while loop from a structure pallete with Stop control Button for loop condition. Assign time interval for acquisition. The threshold, which is to be compared with analog input voltage is given to the myRIO. Threshold voltage value has to be selected in such a way that it is less than the average of the peaks of the blink. If the analog signal voltage overtakes the selected threshold voltage then LED's has to blink as assigned show up as blink takes

place. EOG artifact detector device is developed to recognize the blink artifact in the EEG which is used for Real time examination and to recognize blinks in EEG while acquisition itself. The fundamental flow chart can be given as Fig 3.8.

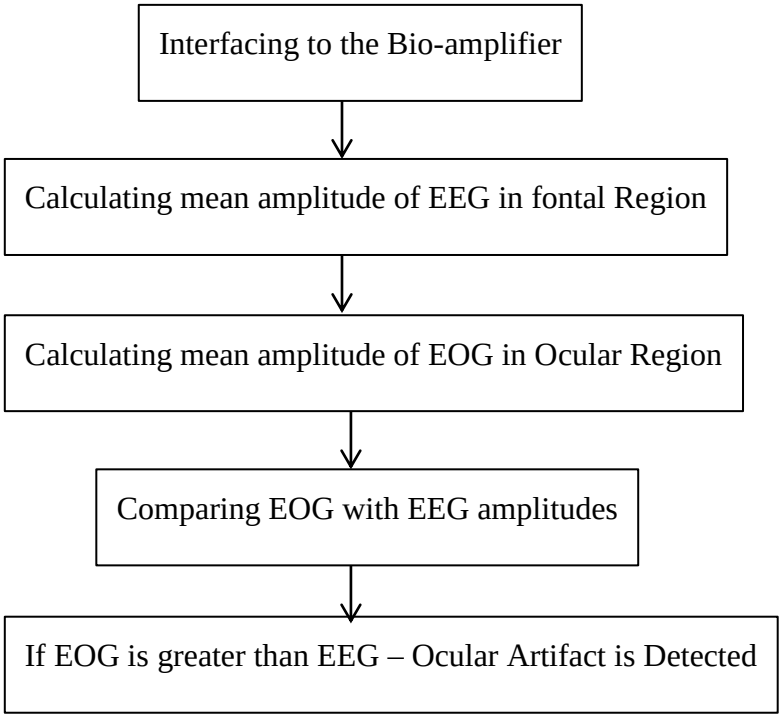


Fig 3.8. Flow diagram of process of detection of EOG artifact in myRIO

The physician can ignore the episode of the blink which correlates with the blink detector. The advantages of developed hardware is

1. Can be connected to any Bio-potential amplifier
2. On board LED light blinks as a sign of EOG detection
3. Can be easily interfaced to any EEG medical analysis system
4. Plug and play device, can be used by the physician without performing any algorithm.
5. 80 trails are performed, out of this 77 blinks are detected by developed hardware with 96.2% accuracy

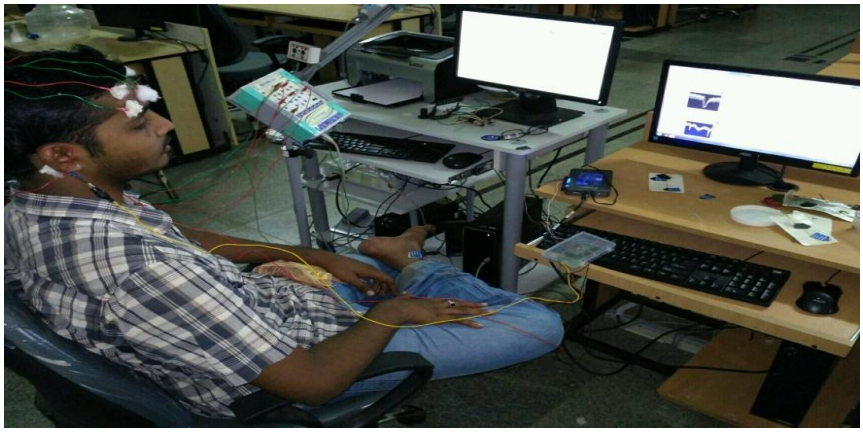
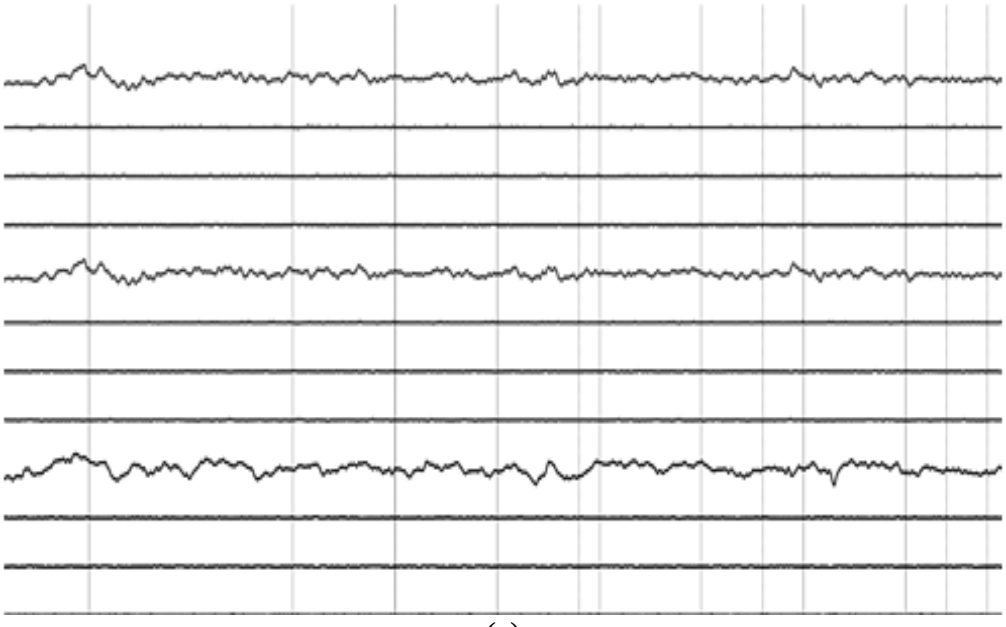
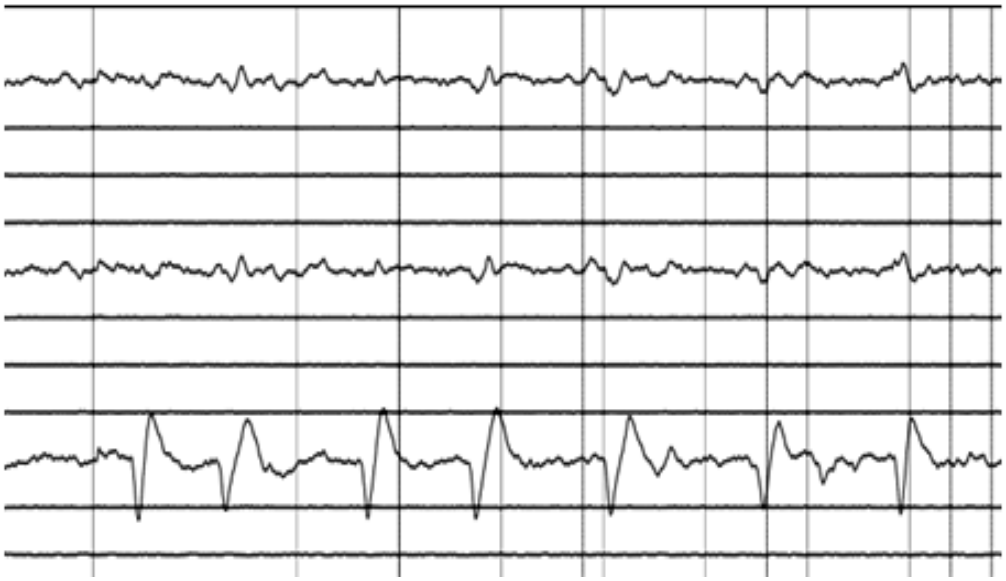


Fig 3.9. Interface of EOG Detector using NI myRIO to Neuromax

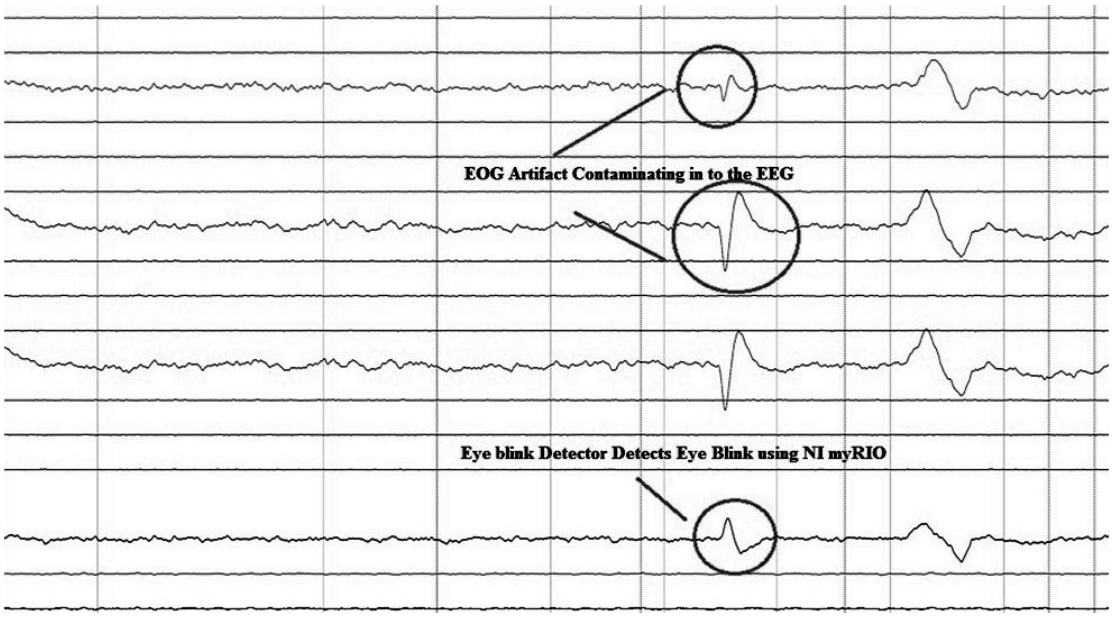
The NI myRIO is interfaced to the Neuromax MEDICAID EEG standard acquisition system this can be given in Fig 3.9. The results acquired, when experiment is performed, Fig 3.10(a) shows that the normal EEG of the frontal and front polar channels. The contaminations of the blinks in the true EEG signals are shown in Fig 3.10(b). Fig 3.10(c) shows that the detection of eye blink artifact with the developed EOG artifact detector using NI myRIO. When the developed EOG artifact detector hardware is interfaced to the standard neuromax system, the blink event observed in the neuromax and the developed blink detector is at the same time.



(a)



(b)



(c)

Fig 3.9 EEG Frontal region without EOG artifact (b) EOG contaminated EEG signal (c) Detection of Eye blink detector using NI myRIO

The various applications of the said system includes but not limited to the following.

1) **Biomedical instrumentation**

Eye blink detection plays a vital role in analyzing and interpretation of the Electroencephalogram (EEG) signal. Here, in the study of the EEG the Ocular Artifact is the chief artifact as it occurs by the blink of an Ocular organ. The physician can

easily recognize that such a spike episode is an artifact using the above algorithm. If not, physician may make a wrong analysis of blink artifact spike as a seizure of brain and call subject for diagnosis, which become very serious issue.

2) **Detection of state of alertness**

There is a scope for finding subject's state of alertness. If person blinking rate increases in a period of time along with the change of frequency of lower level in the frontal region of the brain, the state of alertness of a subject is drowsiness.

3) **Blink controlled robot**

This algorithm can be used to control the robots. Robots can be commanded with blinks differently with the number of blinks in a particular time period.

4) **Automatic controlled camera**

The camera can be controlled using this blink detector. If eye blink takes place voluntarily, then it can be coded as the camera will click photograph after certain time period (≤1s).

5) **As an eye controlled switch**

This detector can be used as a switch. This can be programmed in such a way, if a certain number of blinks occur in a certain time interval it is ON, another number of blinks to make it OFF.

6) **Light Intensity finder**

It is observed in the experiments that the peak of blink increases with the increase of the intensity of the light falling on the eyes. Thus, it can be used to measure the light intensity up to some extent.

7) **As a remote control**

This blink detectoras illustrated in fig. 1 can be used as a remote control. As blink emits change in potential. Such that, it can also be used as a blink controlled remote control.

There is research being performed to utilize the potential that is generated when the eyelid moves over the eye during the blink process for the control of the solid state devices through the brain eye coordination. When the eyelid moves over the eye as a result of the eye blink as a factor of high light intensity or dryness or moistness, the potential accumulated in the ocular region varies correspondingly which can be harnessed for the eye brain coordination of the device control.

3.6. Summary

In this chapter, background literature of the EEG artifacts is described and illustrated their contamination in EEG signals. Methods for the removal of ocular artifacts are reviewed and their benefits and drawbacks are discussed. Various external influences interfering into the EEG signal is also presented. Internal EOG artifact on EEG was detected by a hardware system developed using NI myRIO processor to detect the ocular artifact in EEG.

CHAPTER 4

IMPACT OF LIGHT ON EEG

4.1 Introduction

Light is an electromagnetic and transverse wave experienced by the subject by sensitivity of vision. According to the previous literature, there are many number of variations occurs in human physiology when subject exposed to bright luminance conditions conditions. Factors of Ocular Physiology and Neurophysiology are prominently varied. The light intensity received by into the eyes of humans causes variations in the recordings of electroencephalogram. Angle of the incidence, type of the surface and spectral charecterstics are the important aspects responsible to review the lighting parameters. If the EEG recording room is painted with silver colour causes more reflection and effects subject brain activity. However, a bright lighting condition brings amendments in physiology of human like suppression of melatonin hormone and core body temperature etc. Therefore, it in turn disturbs the measures of neurobehavioral factors like reaction time, performance and alertness which leads to alterations in EEG frequencies. While considering neural behaviour changes, centrally weighted up on the alpha activity which is correlated with the light intensity which arises in occipital region. Another important observation that in poor lighting conditions affects other region frequencies along with the occipital region as stated in the previous literature.

4.2 Effect of Light on Various Physiological Factors

Various case studies have been performed in the previous literature to study the variations in physiological parameters with respect to light intensity. Without changing the behavioural task, when a subject exposed to a bright illumination condition, many changes in the physiological parameters such as release of plasma melatonin hormone in the pineal gland, changes in subjective alertness, incidence of slow eye movements, core body temperature and other ocular physiological changes.

From a distance *d* the illumination caused by the luminous object is given in equation (4.1).

$$E = I / d^2 \tag{4.1}$$

Where illumination caused by the light source from a distance *d* is denoted as *E*, luminous intensity of a respective light source can be given as *I*. In equation (4.1), it is related that, the illumination condition caused by the particular light source is entirely dependent on the distance between the illuminating region and the light source. Some of the physiological effects in humans due to variation in light intensity experiencing by the subject are studied below.

4.2.1 Effect of light on melatonin hormone

Melatonin is the natural hormone which is found in the human brain, which is originated in the pineal grand. From the previous literature, Melatonin hormone extends the correlation between the physiological variables and parameters of the light intensity. It is completely dependent on the circadian rhythm generated by the dark and light cycles. Inhabitation of release of melatonin hormone happens when the retinas of eyes detected the amount of light. Iain M. McIntyre, et al. (1989) gives the relation and response between the light intensity experienced by the subject to the percentage suppression of Melatonin. The percentage of melatonin hormone has been suppressed with an increase in light intensity levels. This results in increase of subject's alertness. Thus, EEG spectra has been changed with change in illumination. The response curve of percentage suppression of melatonin hormone to illuminance (Lux) is shown in below Fig.4.1.

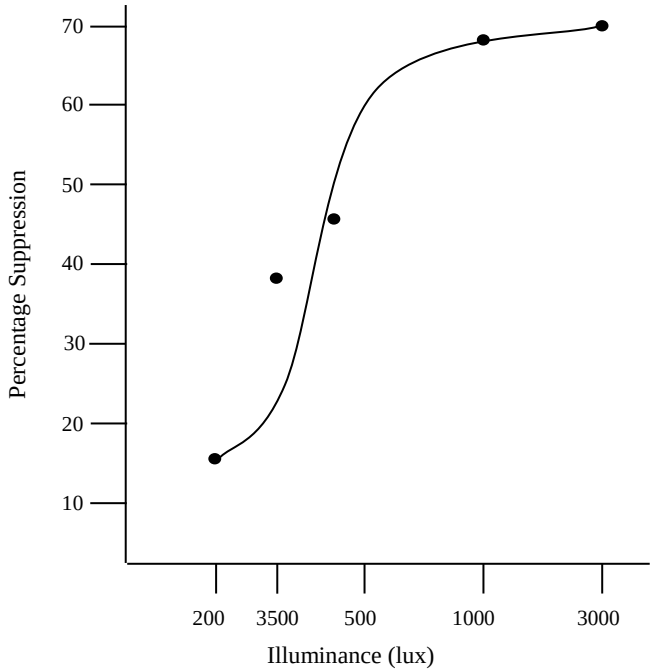


Fig 4.1. Percentage Suppression of a Melatonin to illumination levels

4.2.2 Effect of light on subjective alertness

Suppression of discharge of melatonin hormone affects the alertness of the subject due to bright illuminations. The subjective alertness, response is obtained to the different levels of illumination given by Christian cajochen (2007) has given the relation between range of illuminations and the subjective alertness shown in below Fig. 4.2. Subjective alertness response to the increment of illumination levels is proportional. When subject is exposed to beyond illumination of 100 lux, the suppression of release of melatonin hormone from pineal grand is greater than 50%. Incidence of Slow eye movements which is inversely proportional to light intensity levels and subjective alertness is another physiological change. Here, the incidence of slow eye movements is optimal till the subject is exposed to less than 100 lux. The incidence of slow eye movements has decreased when the melatonin hormone is suppressed to more than 50% with an increment of light intensity levels. Where symbol of closed representation recognizes characters whose suppression of melatonin hormone is less than 50%. While open symbol representation identifies individuals whose melatonin suppression is greater than 50%.

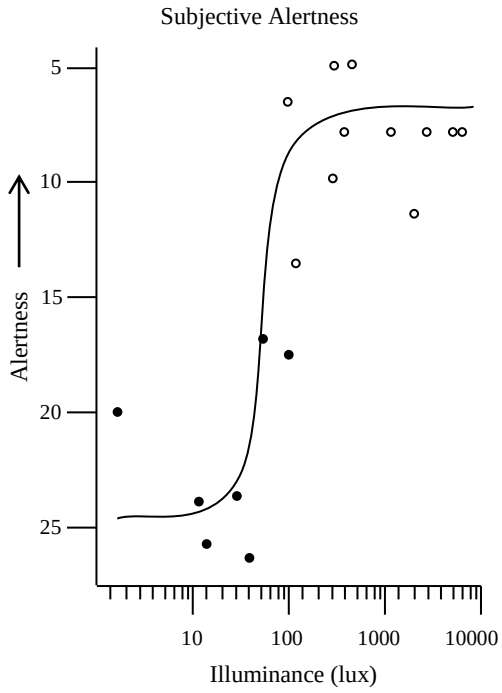


Fig 4.2. The subjective alertness response to with increment of illumination level

4.2.3 Effect of light on incidence of slow eye movements

Incidence of slow eye movements is inversely proportional to subjective alertness and vice-versa shown in Fig. 4.3.

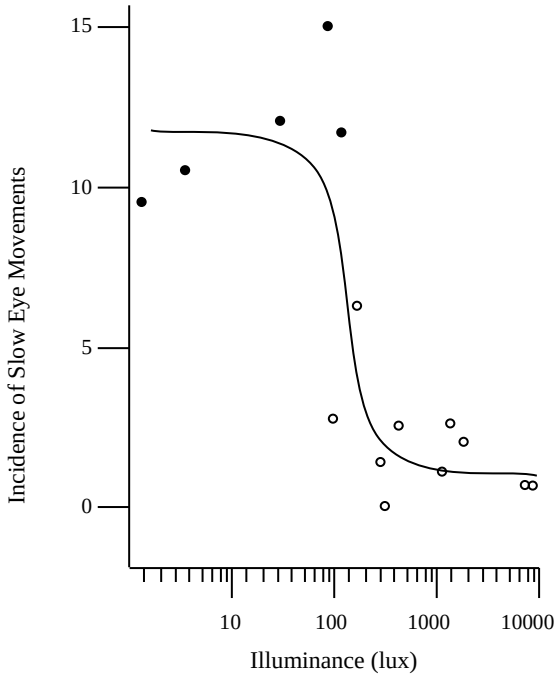


Fig.4.3. The reduction of incidence of slow eye movements with increase of illumination levels

4.3 Effect of Light Intensity on EEG Frequencies

As light results in various physiological changes, this also in turn affects readings of electroencephalogram.

4.3.1 Effect on aplpha frequency

From the previous literature, when subject is in relaxed state and in low concentrating mode, alpha rhythm shows up in occipital and temporal region when subject is in relaxed state. The spectra range of 8-13 Hz, an alpha frequency component in EEG complex wave which the frequency range falls between theta and beta frequencies. It is the frequency range usually occurs between subconscious to more conscious state. By studying this frequency component gives the alertness status of the subject. It is also stated that when subject eyes are closed and makes suppression of vision for duration results in increase of alpha activity in the occipital region. Alpha blocking a phenomena that alpha activity is reduced in occipital region when subject exposed light intensity.

4.3.2 Effect on EEG spectral density

Power spectral density is an important and additional electroencephalographic change due to variation in light intensity. It is observed from the previous literature,

that percentage of total power in theta and lower alpha frequency is reduced. Presence of theta and lower alpha frequency were originated in the normal during drowsiness and sleep. As a result of exposure to bright light, EEG power density of the frequency 5-9 Hz has been supressed and cause increase in state of alertness. The percentage of total power of frequency 5-9 Hz to different illumination levels response is given by Christian cajochen, et al. (2000) shown in Fig 4.4.

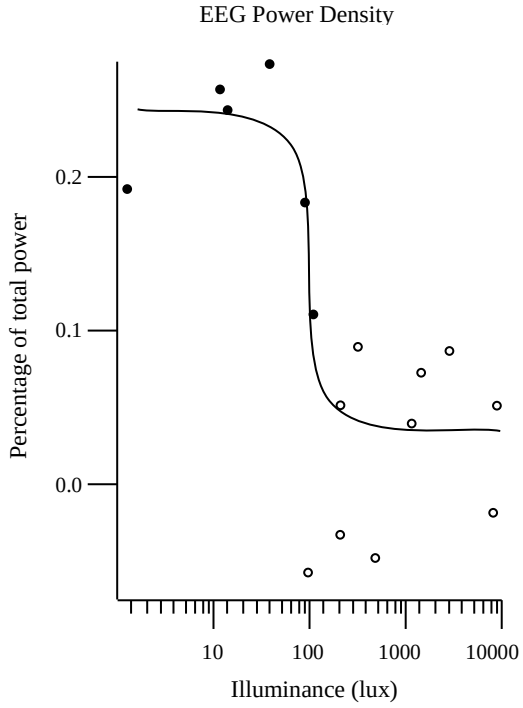


Fig. 4.4 Percentage Reduction of EEG Power Density of frequency 5-9 Hz with Increment of Illumination

4.4 Effect On EEG Frequencies In Low Luminance Condition

A hypothetical behavioural task has been performed in poor luminance condition which consequences in increment in the frequency of frontal region. Experimental and subjective analysis has been performed to analyse the amendments caused by the case study performed.

4.4.1 Methods

This experiment has been carried out on 25 subjects in the research laboratory, where the temperature of the room is sustained at 25°C. EEG Examination room is set to perform examination in low luminance and not allowed and light reflections. In order to eradicate contamination of muscular artifacts (EMG) into true EEG, all the individual subjects during the test were instructed to sit on a proper base with headrest. AgCl electrodes are positioned in the front polar and frontal regions of

international 10-20 standard over the scalp. The electrode which is considered as a reference is clipped on lower end of ear. Now, each subject was instructed to perform different behavioural task like objects locating in their place in poor luminance as they were interchanged from earlier.

The bio potential acquired from the electrode is amplified using bio amplifier and filters are used to smooth the signals. The subjective analysis is performed after experimental study and results are compared with obtained EEG. The acquired EEG waveform from standard acquisition system (neuromax) is saved and exported into EDF format. The obtained EDF data is converted into WAV format using EDF/EDF+ to WAV converter shown in Fig 4.5. Here, each channel of EEG is separated to individual waveform. The individual channel waveform is loaded in to the MATLAB and FFT analysis is performed.

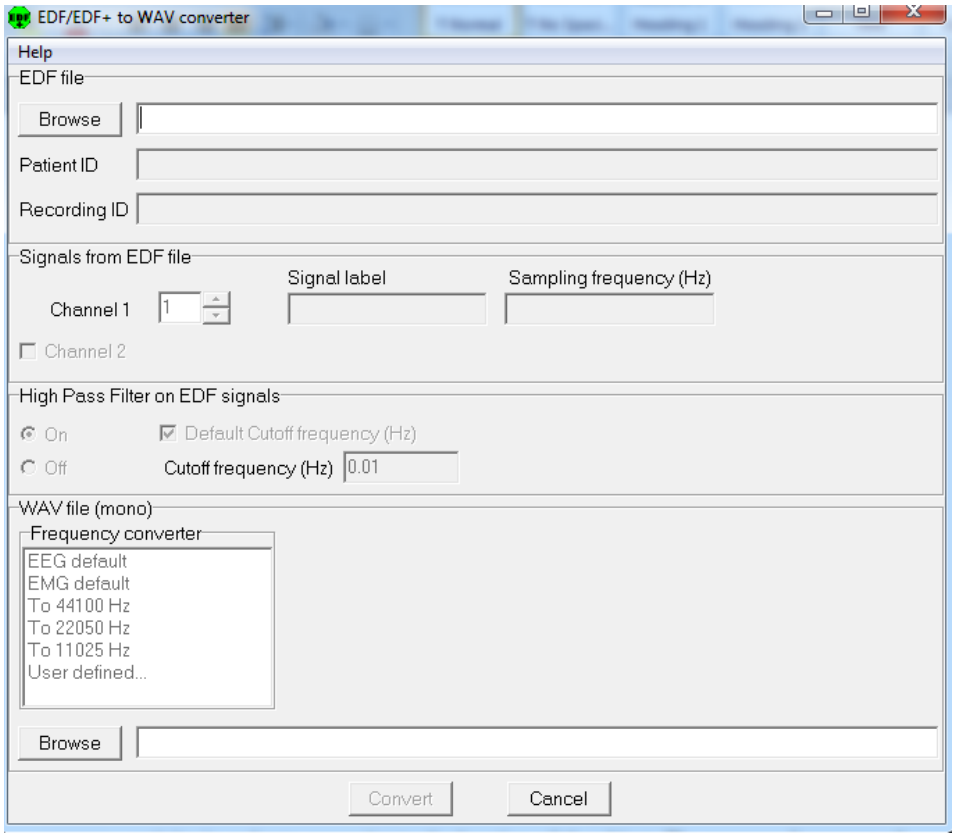


Fig 4.5. EDF/EDF+ to WAV converter

4.4.2 Results

As predicted, from the experimental and subjective analysis, there is increment in the frontal region frequency to beta range when the subject applies more mental

activity to perform behaviour task. Frequency range shown up as a range of 12-25 Hz falls in to the Beta frequency range. The frequency results are tabulated in Table 4.1.

Table 4.1 Frequency characteristics for each subject obtained by performing FFT analysis

Subject ID	Age	Gender	Frequency
1	20	M	15 Hz
2	26	M	18 Hz
3	19	M	21 Hz
4	21	F	13 Hz
5	24	F	16 Hz
6	42	M	22 Hz
7	31	M	21 Hz
8	26	M	18 Hz
9	20	M	20 Hz
10	28	M	17 Hz
11	45	M	16 Hz
12	21	F	22 Hz
13	21	F	24 Hz
14	24	M	22 Hz
15	23	M	24 Hz
16	31	M	19 Hz
17	27	F	17 Hz
18	21	F	23 Hz
19	23	M	14 Hz
20	20	M	22 Hz
21	41	F	25 Hz
22	34	M	16 Hz
23	39	M	12 Hz
24	23	F	19 Hz
25	21	F	22 Hz

To perform subjective analysis, after finishing the examination in the EEG laboratory, each subject were asked to give the rating for mental ability or stress applied to do any behavioural task in the poor luminance condition. Ratings are ranges from point 1 to 5. If subject applied very less mental ability it is to be rated as rating1 and rating 5 specifies subject applies high mental ability to perform such behavioural task. Many of the subjects feel to apply more mental ability to do any behavioural task with 3-5 rating. 4 and 5 rating shows necessity of high mental application. From the results of subjective analysis, 76% of the participants feels to apply high mental activeness to do any behavioural task in poor luminance condition. The graphical representation of a subjective analysis is given in below Fig. 4.6.

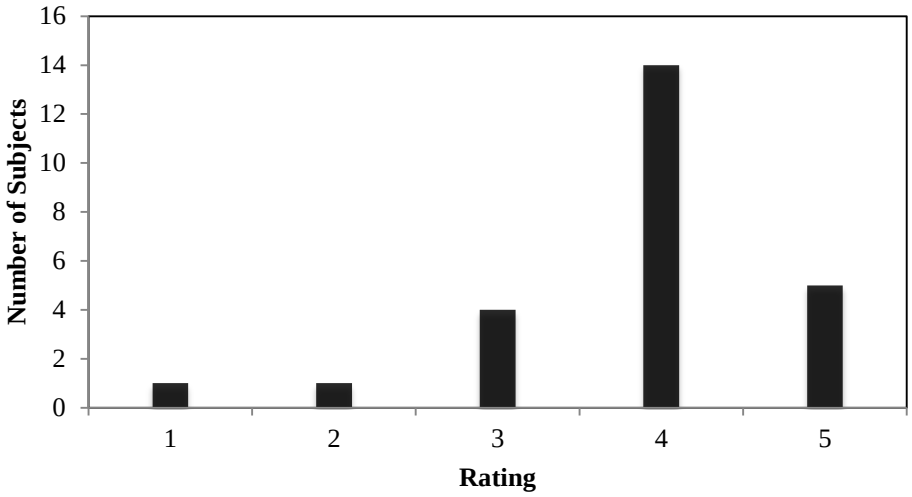


Fig 4.6 Graphical representation of ratings given by the number of subjects to do any behavioral task in darkness

The acquired EEG in low luminance conditions that affect the frontal region is shown in the Fig 4.7. The alpha frequency present in the occipital region shows that the subject is in low luminance conditions. Beta frequency in the frontal region shows that subject applies more mental stress. FFT analysis is shown in Fig 4.8.

4.4.3 Observation

The beta frequencies show up in the electroencephalographic readings when more mental activity is applied by the subject. Up on correlating results with the charecteristics of beta frequency, it is observed that subject applied more mental stress to perform any behavioural task under poor luminance condition.

When comparing the results of subjective analysis with the electroencephalographic rhythm in frontal region found to be similar characteristics.

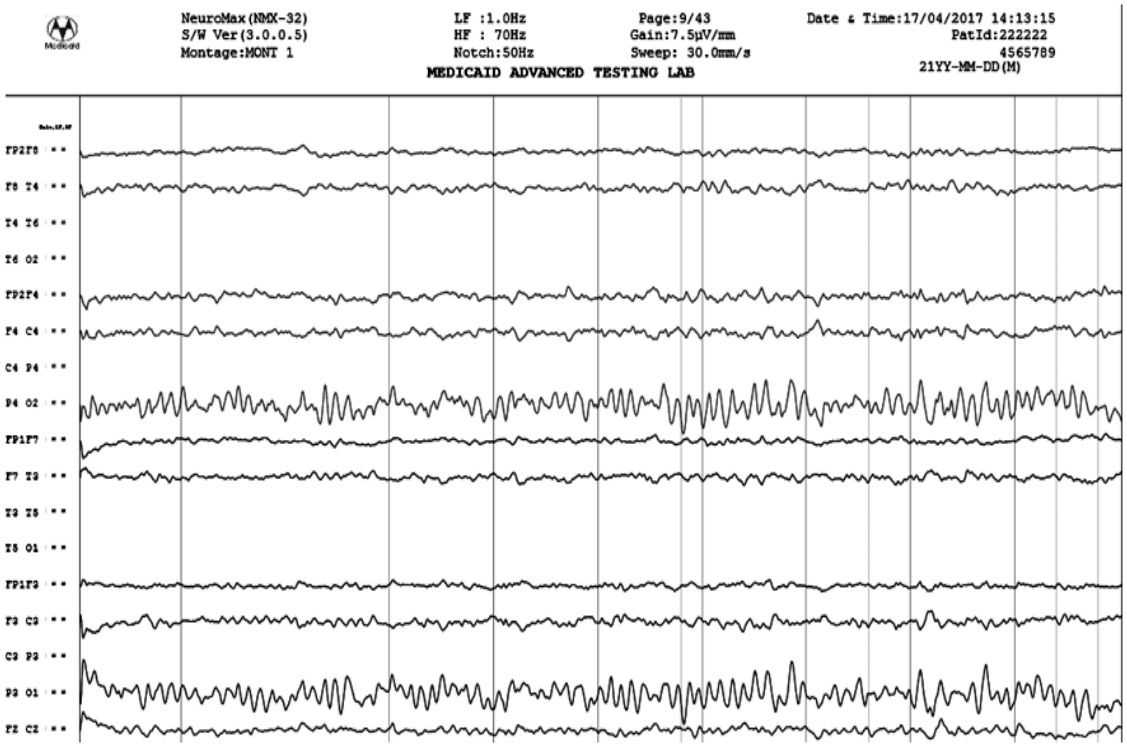


Fig 4.7 EEG frequencies which shows the beta frequency in the frontal region and alpha frequency in the occipital region when low luminance condition

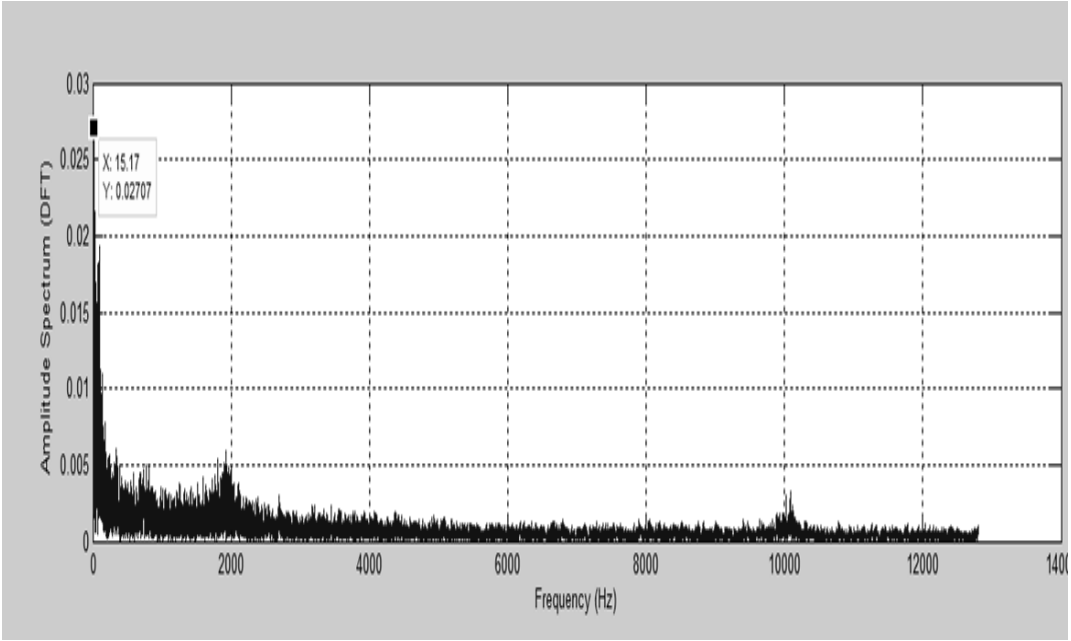


Fig 4.8 FFT spectrum of the frontal region frequency EEG

4.5 Effect of Light on EEG Ocular Artifacts

If light is also contaminated with the ocular artifact on EEG. Here, if eye is considered as a dipole, the cornea is more positively charged with respect to retina when it exposed to light. This makes increment in the peak or amplitude of the ocular artifact potential impact on the EEG recording. This is given in equation (4.2).

Light on Ocular Artifact Potential = Dipole Potential + Potential due to light (4.2)

By correlating basic electrostatic physics to the ocular organ, the equation (4.3) formulated when electric field due to Cornea-Retina dipole potential induced on to the electrode is given as

$$V_{Dipole} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_c}{r_c} - \frac{q_r}{r_r}\right] \tag{4.3}$$

Where q_c and q_r are the charges of the poles of ocular dipole. Cornea is more positive than the Retina where r_c and r_r are the distance between the poles and the nearest electrode respectively. The total Ocular artifact potential along with light potential induced on to the nearest frontal can be specified as V_{OA} in equation (4.4).

$$V_{OA} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_c + q_{light}}{r_c} - \frac{q_r}{r_r}\right] \tag{4.4}$$

The resultant voltage across the electrode when artifact potential in bright illumination is added with desired neuro potential, which is given in (4.5)

VElectrode= V Neuro Potential + VOA (4.5)

4.6 Summary

As the light brings variations in many physiological variables, it also varies the electrical rhythm observed from various regions of the brain. The luminous objects which cause illumination in the EEG recording room bring intense alterations in response of brain electrical activity. Inadequate lighting conditions, which do not match the EEG atlas or luminance conditions suggested by the EEG societies also bring unusual results in neural behaviour which can be misinterpreted by the physician and call subject for diagnosis. The review on Melatonin hormone analysis with effect of light brought various physiological changes are brought onto the screen.

Hypothetical observation has been done using experimental and subjective analysis. The behavioural task performed in poor luminance results in increment of frequency in the frontal region which falls into the beta range. From the subjective and experimental results, it is to be understand that poor luminance condition affects both the behavioural task and brain electrical activity. Light also effects the impact of ocular activity in EEG seems to be like a seizure. As lightening conditions in the recording room increases, the amplitude of the EOG artifact in EEG signal also increases.

CHAPTER 5

EFFECT OF LIGHT THROUGH OPTICAL POWERED GLASSES ON EEG FREQUENCIES

5.1 Introduction

Generally, people use optical powered glasses to correct their refractive error. These powered optical glasses help subjects with abnormal refraction to have perfect vision and correct focus to perform any optical task. Abnormal refractive conditions like near and farsightedness and astigmatism of an eye, which makes an image fail to focus properly upon the retina. Negative powered glasses are used to correct the near sightedness refractive error or myopia. This refractive error is a result of the eyeball being too long than usual leading to misfocus the target object. On other side, positive powered optical glasses are used to correct the hypermetropia or farsightedness, which occurs when the eyeball becomes shorter than usual. Presbyopia and Astigmatism are other kinds of refractive errors which occur due to age and other factors, which can be corrected using combination of different powered optical glasses. Light enters the eye through these refractive error corrective lenses, it brings noticeable variation in the light intensity experiencing by the subject compared to the subject without using optical powered glasses. This variation in light intensity experiencing by the subject in turn cause variation in the human physiology and neural behaviour. In previous chapter, when a subject is exposed to bright luminance conditions, remarkable changes in the human physiological were observed. These effects the neurobehavioral measures such as change in EEG frequencies and EEG spectral density when exposed to light. Another important case study has been performed on 80 subjects that improper focused lens which is not suitable for the refractive error of the subject effect EEG frequencies. The experimental and subjective tests are performed to conclude the results and to formulate the recommendations. Mathematical modelling for the change of light intensity through optical glasses is formulated. LDR test is performed to show up the variation in light intensity through optical powered glasses. The positive powered optical glasses increase the light intensity while the negative powered optical glasses reduces the light intensity refracting from the optical glasses.

5.2 Process of Human Vision and Development of Electric Impulse In Visual Cortex

Human Brain contains many sensing organs and it is also associated with the task of controlling several functions of the human sensors and integrates them as a living organism. Human eye acts as a light sensor controlled by the human brain. The visual cortex located in the human brain is also known as the visual centre of human being located in the occipital region of the brain, which is responsible for the interpretation of the light stimulation.

Initially, light waves coming from an object enter the eye through cornea and further get transmitted through the pupil, a circular opening in the centre of the iris. The size of the pupil varies with respect to the intensity of the light to which it is exposed. The pupil dilates when light entering into the eye is of low intensity or dim and contracts for high intensity light.

In this way, cornea acts as a converging lens, by converging the received light onto the cornea. Then, light passes through the crystalline lens, located immediately after the iris and pupil also converges light wave to the nodal point, where the image gets inverted. Afterwards, light passes through the vitreous humor, which is a semi-transparent gel like material making up to 80 percent of eyes' volume. At last, light rays fall on the small central area located on the retina, called the macula, which provides good vision.

The layers of the retina act as transducers and convert light stimuli into electric impulse signals. These electric impulses are analysed and interpreted by the brain as an image. All the electric impulses generated by the retina are sent to brain through the optic nerve along the visual pathway. Optic nerve acts as a connecting cable between the eye and the brain.

5.3 Variation of Light Intensity through Optical Glasses

Spectacle lens or optical power glass is a transmissive optical device that modifies the focus of a light beam over refraction. The power of optical glass recommended by the ophthalmologist is to correct the visual refractive errors of human. But, these remedial optical powered glasses used to defend ametropic circumstances cause a variation in light intensity experienced by the subjects. Optical lenses are unlike normal lenses. Eyeglasses are convex in front and concave at the back surface. Positive powered lens is also identified as convex lens which is bulged in the middle and contracted at the

edges. While negative powered lenses are concave lenses which are bulged on the edges than in the middle.

Positive powered optical glasses are suggested by the ophthalmologist when one experiences hypermetropia. This exertion occurs, when the light rays entering the eye focus behind the retina. When the positive powered correcting lens is used, the light intensity coming from the light source fall on it and gets concentrated at the focal point. It is observed that there is a variance in light experienced by the normal subject compared to subjects with hypermetropia, with same illumination conditions. The subjects who are having hypermetropia and get their refractive error corrected with positive powered lenses experience more light intensity than the normal. There are many physiological and Neuro behavioural changes occurring due to these refractive error corrections.

Negative powered or diverging lens is an optical glass which is suggested by the ophthalmologist for the subjects experiencing myopia. The light rays coming from the light source and falling on the diverging lens deviate from the principal axis. By wearing these types of glasses, there will be less light intensity experienced by the subject with myopia when compared to the normal subject.

5.4 LDR Test to Observe the Variation in Light through Optical Powered Glasses

In order to analyse, the variations in light intensity a light from the light source is passed through different powered optical glasses. The prime use of optical powered glasses is to correct the focus of the vision and attain a sharper image. But, these vision improvement practices also bring some noticeable changes in the human physiology and neural behaviour. Here, it is proved and verified that optical glasses used alter the light intensity which enters into an eye. To examine the alterations in the light intensity with respect to optical powered glasses, Light Dependent Resistance (LDR) test has been performed.

5.4.1 Methods

In order to study the variation of light through optical glasses, a light dependent resistor (LDR) was placed on the breadboard and its leads are connected to the multimeter. At first, the LDR was allowed to calibrate to its resistance value for the available lighting parameters in the test room. Now, optical glasses with different positive and negative powers are to be placed before the face of the LDR. Change in the resistance developed by the LDR due to variation in light intensity has to be noted.

The same optical powered glasses are also kept at distances 3cm, 5cm, 7cm before the face of the LDR and repeat the process. Now, variation in LDR readings obtained digital multimeter. The experimental setup used to perform LDR test is presented in Fig. 5.1.

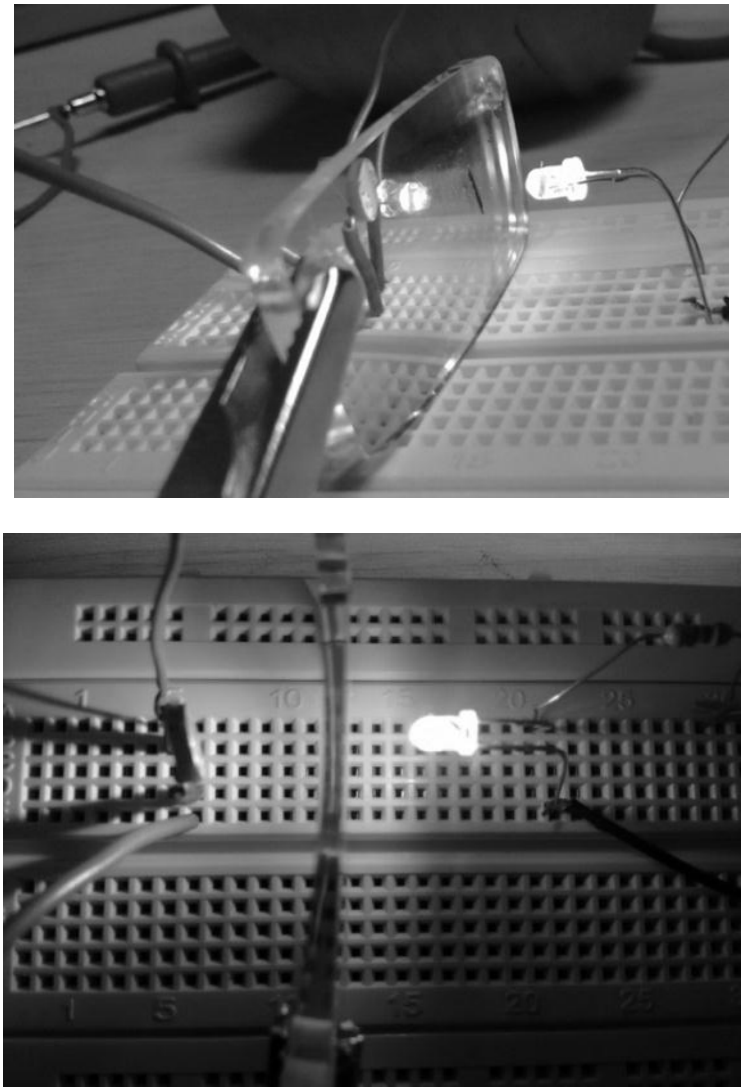


Fig 5.1 An LDR test to study the variation of light intensity through optical lenses

5.4.2 Results

When no optical powered glasses or obstacle is placed before the face of the LDR, for the illumination caused by the luminous objects in the recording room, a resistance of 5.2 K Ω is developed by the LDR and it is shown in digital multimeter. Now, available optical powered glasses are to be placed before the face of the LDR. The variations of light intensity due to different optical powered glasses cause the variation in LDR readings, which are tabulated in Table 5.1.

Table 5.1. LDR Reading for the different optical powered lens

Prescription of lens (DIOPTERS)	**LDR reading (KΩ)**
+15	2.80
+12	3.15
Reading glasses Add +2	5.10
Ambient Light *(Without Any Lens)*	*5.20 (Initially calibrated value)*
-1.75 Cyl	5.64
-2.5-0.5-X90	5.87
-2.5-0.5-X180	5.80
-3 Sph	5.97
-3.5 Sph	6.12

As an additional experiment, to study the variation of light intensity, if the optical powered glasses are placed at the distances 3cm, 5cm, 7cm between the light source and the face of the LDR. Here, White LED is taken as a light source. Now at the available lighting conditions, the LDR is calibrated to 11.10 K Ω. The variation of the light intensity due to optical powered glasses placed at various distances varies the resistance developed in the LDR. Now, the new developed resistance for each optical power glasses which is placed at various distances is tabulated in Table 5.2.

Table 5.2 LDR Reading for the different optical powered glasses placed at distances 3cm, 5cm, 7cm from LDR

Prescription of lens (DIOPTERS)	**LDR reading (KΩ)**		
	3Cm	**5Cm**	**7Cm**
+15	7.21	6.74	6.42
+12	9.01	8.79	8.23

Reading glasses Add +2	10.3	10.4	10.1
When no Lens is placed between LED and LDR	*11.10*		
-1.75 Cyl	12.3	12.8	12.6
-2.5-0.5-X90	13.09	13.8	13.5
-2.5-0.5-X180	13.11	13.6	13.5
-3 Sph	13.21	13.9	13.6
-3.5 Sph	13.48	14.09	13.9

5.4.3 Observation

The universal exploit of the light dependent resistor (LDR) is to change the resistance, which is correlated to the light intensity falling on the face of the LDR. Here, resistance of the LDR attain to its optimal, when the light dependent resistor is not exposed to light intensity or it is placed in poor luminance test room. This resistance developed by the LDR, which show up in the multimeter exhibits inverse proportional to the light intensity falling on the LDR. If the LDR is exposed to the more light intensity, the resistance developed by the LDR is also decreased and vice-versa. When optical powered glasses are placed before the LDR cause variation in the resistance developed by the LDR which is shown in the digital multimeter. Positive powered optical glass is placed before the face of the LDR, due to convergence, the light falling on LDR increases. For the negative powered optical glasses, due to the property of divergence, the reading developed by the LDR increases.

From the above case study performed, it is observed that the high powered negative or positive optical lens will bring impactful change in the light intensity at focal point is compared to the light falling on to the lens used to correct refractive error. Table 5.2 represented that the back vertex distance from the lens to LDR also plays a vital role. The light intensity experiencing by a subject varies as the change in the distance between the back vertexes of optical lens to an eye.

5.5 Mathematical Modelling

Light intensity through optical powered glasses can be explained from the basic physics,

$$\text{Planks light equation, } E = hf \tag{5.1}$$

Relation between voltage and energy can be given as,

$$V = \frac{E}{Q} \tag{5.2}$$

Equation 5.2 can be written as,

$$V = \frac{hf}{Q} \tag{5.3}$$

Influence of light on neural activity can be given as,

$$V_{Electrode} = V_N + \frac{hf}{Q} \tag{5.4}$$

Where f is the frequency of the light, Q is charge induced on to the neuron due to light andV_N is the neural charge.

Effect of light through positive powered optical powered glasses shown in equation (5.5).

$$V_{Electrode(PositivePoweredGlass)} = V_N + \frac{hf}{Q} + \frac{hf_1}{Q_1} \tag{5.5}$$

Where f_1 and Q_1 are the frequency of excess light and charge induced on to the neuron when, subject uses positive powered glasses.

Effect of light through Negative powered optical powered glasses given in equation (5.6).

$$V_{Elecetrode(NegativePoweredGlass)} = V_N + \frac{hf}{Q} - \frac{hf_2}{Q_2} \tag{5.6}$$

$$\text{Here, } \frac{hf}{Q} \leq \frac{hf_2}{Q_2}$$

Where f_2 and Q_2 are the frequency of excess light and charge induced on to the neuron when, subject uses Negative powered glasses.

Frequency f of the light can be found using FFT spectrum analysis.

Percentage variation in positive powered glass is given in equation 5.7.

$$\frac{\left[V_N + \frac{hf}{Q} + \frac{hf_1}{Q_1}\right] - \left[V_N + \frac{hf}{Q}\right]}{\left[V_N + \frac{hf}{Q}\right]} \times 100 \tag{5.7}$$

Percentage variation in negative powered glass is given in equation (5.8).

$$\frac{\left[V_N + \frac{hf}{Q} - \frac{hf_2}{Q_2}\right] - \left[V_N + \frac{hf}{Q}\right]}{\left[V_N + \frac{hf}{Q}\right]} \times 100 \tag{5.8}$$

5.6 Variation In EEG When Subject With Improper Focused Lenses

Improper focused lens used by the subject or with incorrect prescription causes variation in neuronal behaviour. Subjective and experimental analysis are performed to verify the findings.

5.6.1 Methods

The experimental analysis was conducted on 80 subjects, 38 male and 42 female participants available in the University of Age ranges from 20-55. Among these participants, 28 subjects are with hypermetropia and 52 subjects are with myopia. Subjects with refractive error are set with different positive and negative optical powered glasses with different prescription given by the licensed ophthalmologist. All the subjects participated in test were called individually to the lab in which temperature is held at around 25°C. The prescription of every individual subject is noted and observed. Now, AgCl electrodes are placed over the scalp in occipital and frontal of the international 10-20 standard. All the EEG readings are taken with respect to the reference electrode, which is located on the left ear with electrode gel.

At this moment, each subject was asked to have a different prescription powered optical glass rather than suggested by the ophthalmologist. Each participant was instructed to read with an improper focused lens of the chart with good font size at the distant or to read a book which is nearer. The resultant changes in the EEG readings are studied. EEG recordings obtained from the standard EEG acquisition system Neuromax MEDICAID. Entire data is saved in European data format (.edf) and converted into Wave format (.wav) using EDF/EDF+ to WAVE converter. The

obtained EEG signal in Wave format is analysed in MATLAB. The frequency characteristics can be known for a signal by performing FFT analysis.

After completion of experimental analysis subjective analysis is also done. Each individual subject was required to apply the evaluation for their mental stress used to scan the chart with different prescription with improper focused optical powered glass. The ratings given by the subject based on mental activity as rating 1 to 5. Rating 1 shows as no mental stress ability used to scan the chart or to focus an object. Where rating 5 shows as high mental stress during activity is performed by the subject.

5.6.2 Results

At the detail when the subject attempts to peruse the chart with improper focused lens, it is found that the subject is utilizing more mental capacity than expected. Frontal frequency is affected when the field attempts to focus and tries reading the chart posted in the lab. Due to this frontal frequency is instrumented. The frequency response for the mental activity done by the subject is exhibiting up in frontal region as 12-25Hz. This can be considered as lower beta frequency. The state of occurrence of the beta frequency activity in frontal and front polar region is when subject applies more mental activity than usual. The increase of beta frequency in the frontal region is shown Table 5.3. For each subject and frequency of each signal is analysed using FFT analysis in MATLAB. The obtained result is shown in Fig 5.2.

Table 5.3 Frequency of a frontal region for case study performed

SUBJECT ID	AGE	GENDER	OCULAR ABORMALITY	FREQUENCY
1	22	M	Myopia	22 Hz
2	27	M	Myopia	21 Hz
3	32	M	Hypermetropia	24 Hz
4	26	F	Myopia	23 Hz
5	46	M	Hypermetropia	21 Hz
6	26	F	Myopia	23 Hz
7	43	M	Hypermetropia	18 Hz
8	22	M	Hypermetropia	20 Hz
9	24	F	Hypermetropia	21 Hz

10	20	M	Myopia	16 Hz
11	26	M	Myopia	21 Hz
12	22	F	Myopia	22 Hz
13	21	F	Hypermetropia	24 Hz
14	24	F	Myopia	22 Hz
15	42	F	Myopia	14 Hz
16	31	M	Hypermetropia	20 Hz
17	26	M	Myopia	16 Hz
18	20	F	Hypermetropia	18 Hz
19	28	M	Hypermetropia	25 Hz
20	45	M	Hypermetropia	17 Hz
21	21	M	Myopia	22 Hz
22	21	F	Myopia	24 Hz
23	24	M	Myopia	26 Hz
24	51	F	Hypermetropia	22 Hz
25	31	F	Hypermetropia	19 Hz
26	27	F	Myopia	21 Hz
27	21	F	Myopia	16 Hz
28	23	M	Hypermetropia	21 Hz
29	20	M	Myopia	19 Hz
30	41	F	Hypermetropia	22 Hz
31	34	F	Myopia	23 Hz
32	39	M	Myopia	23 Hz
33	23	F	Hypermetropia	15 Hz
34	21	M	Myopia	18 Hz
35	20	F	Hypermetropia	21 Hz
36	26	F	Myopia	23 Hz

37	20	M	Myopia	24 Hz
38	55	F	Hypermetropia	21 Hz
39	37	F	Myopia	20 Hz
40	24	M	Hypermetropia	17 Hz
41	26	F	Myopia	16 Hz
42	26	F	Myopia	21 Hz
43	25	F	Hypermetropia	19 Hz
44	31	M	Myopia	21 Hz
45	35	M	Hypermetropia	23 Hz
46	25	F	Myopia	14 Hz
47	22	F	Myopia	16 Hz
48	28	F	Myopia	19 Hz
49	28	F	Hypermetropia	22 Hz
50	21	M	Myopia	25 Hz
51	22	M	Myopia	21Hz
52	45	F	Myopia	19Hz
53	44	F	Hypermetropia	16 Hz
54	29	F	Myopia	21 Hz
55	21	M	Myopia	23 Hz
56	21	M	Hypermetropia	25 Hz
57	24	M	Myopia	21 Hz
58	23	M	Myopia	21 Hz
59	21	M	Myopia	15 Hz
60	22	F	Hypermetropia	18 Hz
61	23	F	Myopia	23 Hz
62	24	F	Myopia	21 Hz
63	21	M	Myopia	23 Hz

64	22	M	Myopia	21 Hz
65	22	M	Hypermetropia	24 Hz
66	24	F	Myopia	22 Hz
67	25	F	Myopia	21 Hz
68	21	F	Myopia	21 Hz
69	21	F	Hypermetropia	24 Hz
70	26	M	Myopia	16 Hz
71	25	M	Myopia	21 Hz
72	23	F	Myopia	20 Hz
73	24	F	Myopia	21 Hz
74	25	M	Hypermetropia	16 Hz
75	31	F	Myopia	18 Hz
76	23	M	Myopia	17 Hz
77	40	F	Myopia	21 Hz
78	38	F	Myopia	24 Hz
79	28	M	Hypermetropia	21 Hz
80	23	M	Myopia	21 Hz

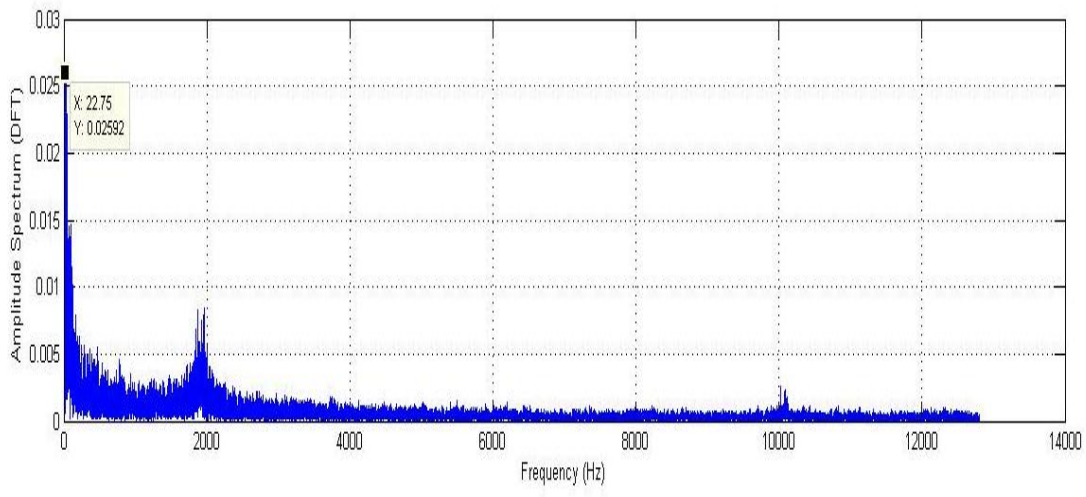


Fig. 5.2. Frequency characteristics of frontal region

For individual subjective analysis, utmost of the subjects participated in the case study performed on 80 subjects given a rating of 4 to 5. There exhibits a similar characteristics between experimental and subjective analysis. This shows improper focused optical powered glasses cause subject to use more mental activity than usual. The graphical representation of ratings given by subjects with myopia and hypermetropia to carry out the subjective analysis is given below.

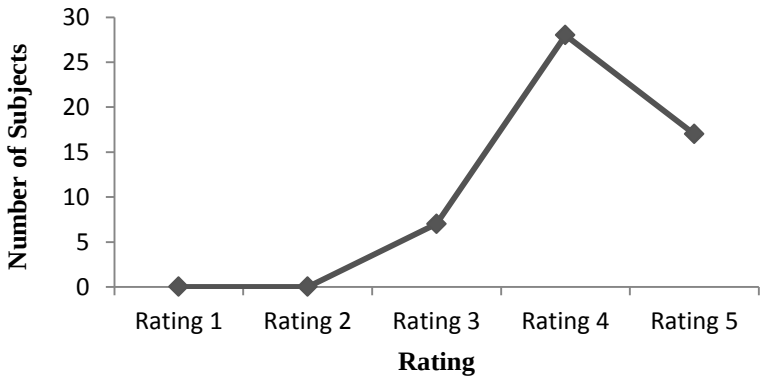


Fig. 5.3. Subjective analysis performed on 52 subjects with Myopia.

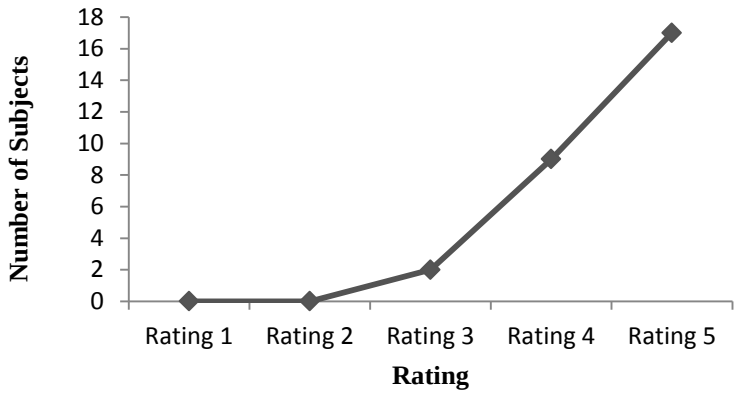


Fig. 5.4. Subjective analysis performed on 28 subjects with Hypermetropia.

5.6.3 Observation

Human physiological and neurological parameters have been changed when the optical power recommendation given by the licensed ophthalmic practitioner is not corresponding to the refractive error of the study. Primarily, improper vision causes the field to experience tiredness and strain on use of unmatched powered glasses. Long time stains to the eye while acquiring vision through improper focused lens results in headache. Squinting is also noticeable consequence and symptom when the study is using different powered optical lens.

It is recommended to the physician or EEG practitioner that to confirm optical powered glasses used by the subject is able to correct the refractive error of the eye properly. If not, the frontal frequency gets increased and may suspect as seizures or other any abnormality.

5.7 Summary

Light through optical powered glasses can bring a many changes in the neuronal readings. Hence, in this study, the roots for the variation in light intensity through the optical powered lens have been confirmed. Light Dependent Resistor (LDR) test has been demonstrated to verify and analyse variation of light intensity through optical powered glasses. Subject with Positive powered glasses experiences more light intensity compared to normal subject. While, negative powered optical glasses diverges all the light rays falling on the lens make the subject to feel less light intensity than normal. This variation in light brings alterations in EEG readings.

It is also observed that vision through improper and unmatched optical powered glasses makes subject feel fatigue easily and which is prone to the headache and development of seizures in human brain. Subjective and Experimental analyses are given a similar results on the case study performed on 80 subject with improper focused lenses make increase in the frontal frequency, as subject require to do apply more mental ability to focus a vision.

CHAPTER 6

EFFECT OF LIGHT THROUGH OPTICAL GLASSES ON VISUALLY EVOKED POTENTIALS

6.1 Introduction

Visually Evoked Potential (VEP) VEP measures the electrical activity in the vision system. When the light from source enters eye, it is converted into electrical energy at the retina and travels through the optic nerve to the visual cortex of the brain which processes vision. Sensory evoked potentials measure electrical activity in the brain in response to stimulation of sight, sound, or touch. When the brain is stimulated by sight, sound, or touch, signals travel along the nerves to the brain. Non-invasive studies that measure the evoked responses of neurons intended for particular visual stimuli, which illustrate the abnormalities associated with Visually Evoked Potentials (VEPs) (A. Houwelingen et al.,1993).

Visually evoked potentials are the response of the neurons especially in Occipital region for different Visual stimuli (M. Brigell et al.,1996). This visual stimulus can be in the form of a pattern reversal of checker board and flash light. There are many stimuli parameters that influence on the VEPs such as luminance, contrast, spatial frequency (Check size), color and orientation. On the study of these VEP parameters, Latency and Amplitude are found to be the chief factors that to be affected and considered for clinical utility. VEPs are interpreted by the identification and measuring parameters of P100 wave in patients with any ocular or neurologic disease. VEPs consist of three separate phases as an initial negative deflection N1 usually occurs at 70ms N70, a prominent positive deflection P1 at 100ms (P100) and soon after negative deflection (N2) at 140ms (N140). The numerical termed in milliseconds were used to represent the waveform latency/sweep time. Each laboratory has to maintain their own standardized normative atlas of VEPs, to determine latency and amplitude which describes the abnormality of the patient. Pictorial diagram of the acquired visually evoked potential for checker board stimuli is given in Fig 6.1.

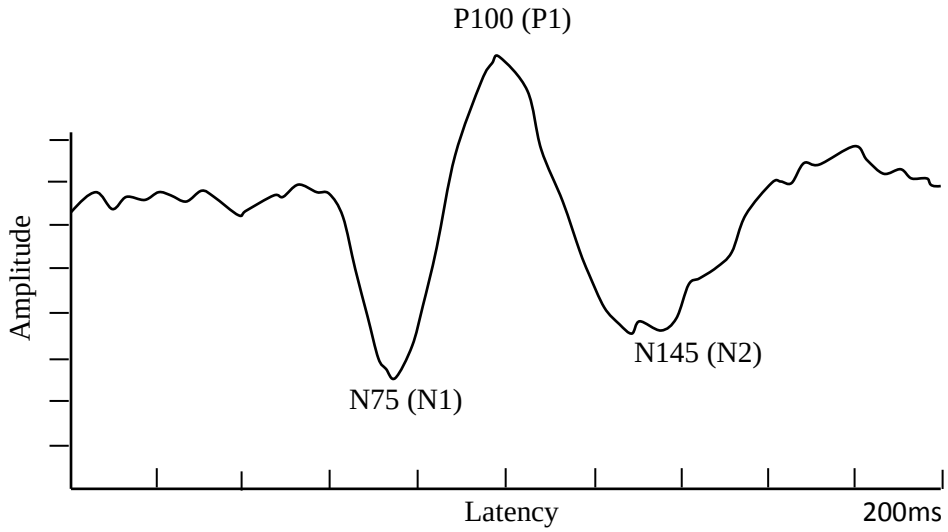


Fig 6.1. Normal pattern reversal VEP recorded from mid-occipital scalp using checkerboard pattern stimuli.

There are many numerous technical and physiological factors may affect the response of the VEPs. The prime factors of the patient that make foundation for change in VEPs are discussed below.

Visual acuity: Visual sharpness also alters the parameters of the VEPs. Less visual acuity requires large check size and the impact on VEP latency to show up its optical abnormality.

Pupillary size: Intraocular differences in P100 latency can be caused due to asymmetrical Pupillary diameters. The miotic condition of the pupil make the pupil reduces luminance, which increase in P100 latency and the cause reduction the amplitude.

Age: latency differences were observed in the experimental analysis that the subjects beyond 60 years are prone to increase in latency compared to latency of subjects with younger age.

Gender: it is also observed that the female subjects have shorter P100 latency than men subjects.

All the above prime factors are considered while performing VEP test to the subjects for confirming the abnormality of the subject based on the latency and amplitude of the VEPs.

6.2 Effect of Light on Visually Evoked Potentials

Although, light affects Electroencephalographic readings due to variation in many physiological factors, it also creates its impact on the parameters of the VEPs. Experimental analysis is performed to observe the changes in VEPs due to variation in luminance and contrast levels (J. Jutai et al.,1984, J. Odom et al., 2009, M. Brigell et al.,1996).

6.2.1 Methods

15 participants consist of 8 males and 7 females, who are of age 21 to 46 years. Subjects were chosen in normal and healthy by oral questionnaire to perform experimental analysis. All the participants are drawn with good visual acuity. The corrective lenses suggested by the ophthalmologist are used when needed. All the participants are explained about the experiment before conduction of the test. The block diagram to perform visually evoked potential test to measure various parameters such as amplitude and latency is shown in Fig 6.2.

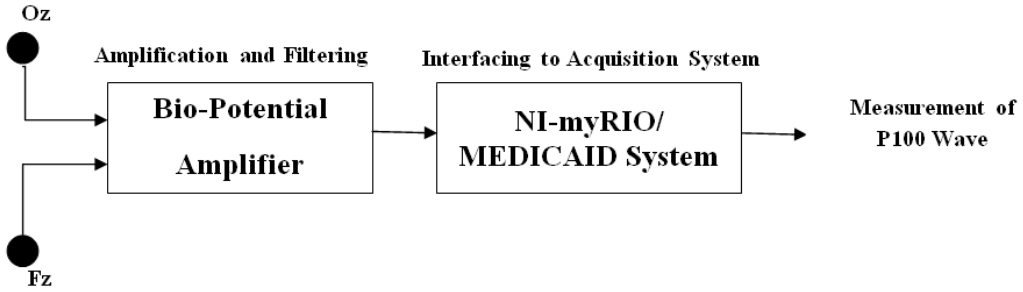


Fig 6.2. Block diagram representation of the Experimental setup for acquiring and measuring of VEPs.

In order to eliminate the muscular artifacts, all the subjects were asked to sit on the good base. According to the standards of ISCEV for clinical visual evoked potentials, AgCl electrodes whose impedance should be less than 5KΩ are placed on their scalp. VEPs are recorded from electrodes are placed at mid occipital region (Oz) with having reference from electrode placed at mid frontal region (Fz) of International 10-20 standard. P100 waveform is observed to be maximal in the region of mid occipital. The electrodes are connected to the bio-amplifier which equips filtering and processing. The band pass filter is used for having clinical frequency of range 0.5Hz to 100Hz with the sweep duration of 250-300ms. The output of the bio potential amplifier is connected to the analog input of the National Instruments myRIO processor. Further processing and signal conditioning of the Electroencephalographic waveform is processed through code developed in NI LabVIEW. The resultant EEG

waveform can be viewed in waveform chart in the front panel of the NI LabVIEW. This test also repeated using 100 samples performed using evoked potential test on MEDICAID system.

A Visual Stimuli test has conducted in monocular in order to unmask the abnormalities in binocular. All the participants were asked to focus only on the centre noticeable red dot placed at centre of a black and white pattern checkerboard, which is carried out to evoke brain potentials visually. Phase reversals of checks were done at frequency of 1Hz. Here, visual stimulating filed such as computer screen is placed at a viewing distance of 100cm from the subject.

The checkerboard pattern was kept in different luminance levels to observe the change in VEPs due to change in luminance and contrast. Two mean luminance levels were used to perform the VEP test i.e. 180cd/m2 and 10cd/m2. 90% Contrast is maintained throughout the test.

In turn to the alterations in contrast, two contrast levels of 85% and 10% were used in a stimuli of an average luminance of 55 cd/m2. Here, the checker board pattern was displayed on the computer monitor to modify the contrast conditions. The contrast is dependent on the maximum and minimum levels of the luminance. The resultant equation is shown in equation (6.1).

$$\frac{L_{Max} - L_{Min}}{L_{Max} + L_{Min}} \times 100 = Contrast \tag{6.1}$$

At least two trails in cases of luminance and contrast are performed before deciding the P100 latency and amplitude. Trails performed to be reproducible and with check size of around 30′ as per the guidelines of the American Electroencephalographic Society (AES). The test is carefully performed with regular intervals without making subject feels fatigue or discomfort during the test.

6.2.2 Results

To study the impact of individual factors affecting the VEPs of electroencephalographic readings, the check size has been kept constant. The VEP parameters such as amplitude and latency are affected due to change in luminance and contrast levels of checkerboard pattern.

Effect of luminance on VEPs is studied as the luminance levels are varied to different maximum and minimum luminance levels on average of 180cd/m2 and 10cd/m2 with 90% contrast. When the checkerboard pattern luminance is decreased to 10cd/m2, it is observed that there is vital change in P100 latency and amplitude. As

the luminance level of the pattern is decreased, the latency of the P100 wave is increased noticeably. On contrary, Amplitude of the P100 wave reduced. It is also observed that for all the check sizes, the average P100 latency for minimum luminance was considerably higher than the latency of the P100 wave for the maximum luminance levels.

VEPs also Effected of Contrast on Two contrast levels of 85% and 10% are considered for a stimulus with mean luminance of 55cd/m2. As the contrast of the checker board pattern reduced to 10%, it is noted that the variation in level of the contrast effects amplitude and latency of the P100 wave. Since the contrast level has been reduced, the latency of the P100 wave is prolonged and the amplitude of the P100 wave is turned down conspicuously. It is also to be noted that for all the check sizes, for maximum and minimum levels of the contrast, the average latency of the P100 wave for minimum contrast is much greater than P100 latency of the maximum contrast.

6.2.3 Observation

VEP parameters are varied with respect to the lightening parameters in the recording room. Latency and amplitude are considerable parameters which alters the position of the P100 wave. All the obtained readings of VEPs recordings are kept as an atlas. Now, these obtained databases of atlases on VEPs are compared with the Electroencephalographic readings of subjects with abnormal refractive conditions.This experiment is performed according to the previous literature to know the variation of luminance in visually evoked potentials (M. Murugappan et al., 2009, N. Yadav et al., 2012, R. Kothari et al.,2016, S. Narayan et al.,2013, V. Fimreite et al.,2015).

6.3 Effect of Light Through Optical Glasses on Visually Evoked Potentials

42 participants (20 male and 22 female) as a subjects selected of age ranges 21-60 years with good physical health. In these subjects, 29 subjects are having refractive error of myopia and 13 subjects with hypermetropia.

Observing that, visually evoked potentials exhibit similar characteristics for change in stimuli of luminance and contrast. The test is performed to observe the changes of VEPs when subject use corrective optical lenses to overcome ocular abnormality. The study went on for the cases of myopia and hypermetropia.

The variation of luminance through optical glasses used for correcting refractive error is studied using LDR test in chapter 5.

6.3.1. Effect of luminance and contrast on VEPs with Myopia.

Myopia or near sightedness is an abnormal refractive error condition, which cause the difficulty in reading far objects but able to focus the near objects. It occurs when the eye ball appears to be too long, compared to focusing power of the cornea and lens of an eye. Negative powered optical glasses are used to correct this refractive error condition. On use of these negative optical powered glasses, it is observed that there is a variation in luminance and contrast experiencing by the subject. This variation cause in turn alteration in the parameters of the visually evoked potentials.

It is to be noted that subjects with myopia are required to use negative powered lens which cause diverging of light. On this property of diverging lens, it is observed that subject with myopia uses negative powered lenses experience less luminance level than the normal subject. This can be proved and demonstrated by performing the LDR test to the negative powered glasses.

Up on variation in the luminance experiencing by the subject due to negative powered optical glasses, this also in turn affects the parameters of the VEPs. This variation is large for the subjects are required to use high negative power (Diopters) glasses. The hypothetical variation can be shown in Fig 6.3.

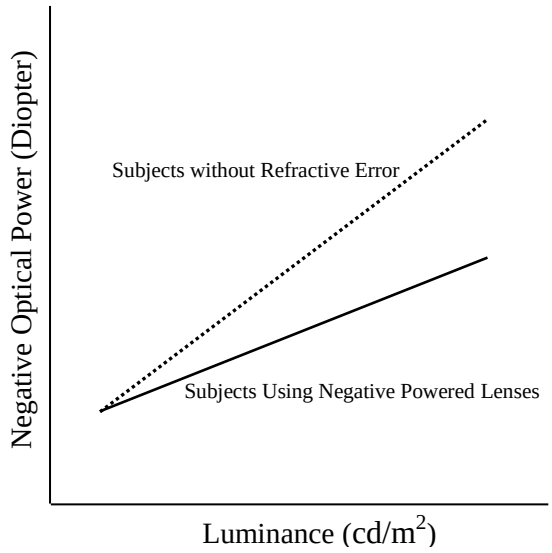


Fig 6.3. Variation of luminance through Negative powered lens to subjects without Refractive error.

6.3.2. Effect of luminance and contrast on VEPs with Hypermetropia.

Hypermetropia or far sightedness is an abnormal refractive error condition, which cause the difficulty in reading nearby objects but able to focus the far objects. It occurs when the eye ball appears to be too shorter, compared to focusing power of the

cornea and lens of an eye. Positive powered optical glasses are used to correct this refractive error condition. On use of these negative optical powered glasses, it is observed that there is a variation in luminance and contrast experiencing by the subject. This variation cause in turn variation in the parameters of the visually evoked potentials.

It is to be noted that subjects with hypermetropia are required to use positive powered lens which cause converging of light. On this property of converging lens, it is observed that subject with hypermetropia uses positive powered optical lenses experience more luminance level than the normal subject without wearing lenses. This can be proved and demonstrated by performing the LDR test to the positive powered glasses. This variation is large and noticeable for the subjects necessary to use high positive power glasses. The hypothetical variation of light in positive powered glasses can be given below Fig 6.4.

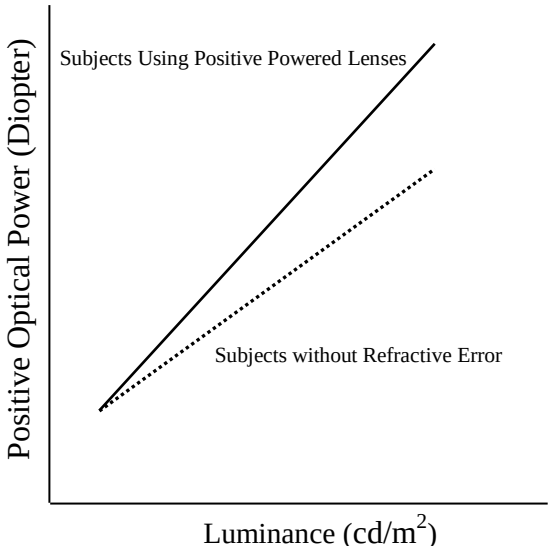


Fig 6.4 Variation of luminance through Positive powered lens to subjects without Refractive error.

6.3.3. Comparison of VEP parameters of Normal subjects to ARC

It is to declare that, subjects with abnormal refractive conditions (ARC) exhibits variations in response time to the stimuli and amplitude when compared to normal themes. This variation occurs due the usage of the optical powered glasses.

On usage of negative powered glasses, the latency variation is much increased than normal subjects. While amplitude of the P100 wave decreases on usage of negative powered glasses compared to normal subjects. While on use of positive powered glasses, the latency variation is much decreased than normal subjects. While

amplitude of the P100 wave increases on usage of positive powered glasses compared to normal subjects. The comparative representation of the variation in latency and amplitude for the positive and negative powered optical glasses are shown in figure 6.5 and figure 6.6.

The variation in VEP waveform due to light variation through optical powered glasses used for correcting Ocular Abnormality is given in Table 6.1.

Table 6.1 Variation of P100 wave characteristics due to ocular abnormality

Subject No	Age	Gender	Ocular Abnormality	$N75_1$ (ms)	$N75_2$ (ms)	$P100_1$ (μV)	$P100_2$ (μV)	$N145_1$ (ms)	$N145_2$ (ms)	N75-P100 (μV)	N75-P100 (μV)
1	26	Male	Hypermetropia	72.75	44.01	194.75	59.75	197.75	183.50	3.18	4.01
2	24	Female	Myopia	21.50	32.75	53.50	81.00	111.50	166.00	1.98	1.83
3	26	Female	Hypermetropia	64.82	38.03	134.75	71.36	175.71	159.50	2.92	3.94
4	26	Male	Myopia	23.51	34.95	57.96	92.20	115.50	175.01	2.12	2.01
5	28	Male	Myopia	17.60	28.15	47.50	78.13	106.40	161.00	1.73	1.66
6	31	Female	Myopia	21.96	33.11	59.30	88.96	113.13	173.48	2.16	1.98
7	29	Male	Myopia	19.90	31.15	48.50	71.28	106.40	156.45	1.78	1.59
8	21	Female	Myopia	24.30	33.96	57.90	92.20	118.50	168.96	1.83	1.67
9	32	Female	Myopia	21.50	32.75	52.60	77.40	115.60	159.18	1.78	1.59
10	32	Male	Hypermetropia	73.73	45.02	192.76	68.75	198.76	182.51	3.09	3.96
11	46	Male	Myopia	16.01	27.12	44.30	69.93	94.90	145.00	1.48	1.29
12	38	Male	Myopia	21.09	32.06	52.01	80.01	108.50	163.12	1.98	1.67
13	43	Male	Myopia	29.12	41.74	60.51	99.03	122.60	181.00	2.23	2.02
14	42	Male	Myopia	31.50	43.59	64.50	107.00	127.80	189.00	2.34	2.11
15	39	Female	Hypermetropia	77.75	48.10	199.57	69.71	192.41	161.50	2.73	3.99
16	22	Female	Hypermetropia	62.75	56.10	177.75	86.57	179.57	149.05	2.51	2.92
17	27	Male	Myopia	19.59	32.14	50.51	77.09	92.18	154.11	1.74	1.58
18	29	Female	Myopia	21.53	33.52	52.80	78.03	114.50	172.44	2.14	1.92

19	51	Female	Myopia	27.12	40.05	61.50	101.13	128.30	181.35	2.66	2.43
20	39	Female	Hypermetropia	71.57	43.13	187.54	57.51	188.54	171.01	3.01	3.91
21	63	Male	Myopia	21.96	30.63	57.90	94.42	114.16	172.22	2.45	2.29
22	58	Male	Myopia	24.01	38.15	62.90	102.16	126.90	179.39	2.86	2.74
23	63	Male	Hypermetropia	47.71	36.03	146.15	39.55	147.75	132.50	3.78	4.61
24	56	Female	Myopia	26.30	39.51	59.01	98.33	129.90	189.67	3.12	2.96
25	21	Female	Myopia	22.70	33.82	54.45	96.01	121.12	178.99	2.68	2.46
26	23	Male	Myopia	31.01	46.74	60.51	101.90	133.50	191.26	2.73	2.13
27	45	Male	Myopia	27.40	39.76	59.10	97.12	124.50	184.99	2.51	2.33
28	40	Female	Hypermetropia	59.43	47.01	174.75	43.72	171.75	153.50	3.24	3.84
29	38	Female	Myopia	26.40	35.71	59.50	101.12	131.18	188.32	2.58	2.36
30	43	Male	Myopia	28.19	39.81	57.90	96.00	120.50	178.39	3.22	3.13
31	49	Female	Myopia	24.80	33.98	55.18	91.20	114.91	161.55	2.98	2.76
32	32	Female	Hypermetropia	58.71	43.10	156.25	37.99	157.49	142.98	3.08	3.76
33	35	Female	Hypermetropia	63.51	48.01	186.57	79.71	179.87	137.80	2.99	4.78
34	37	Female	Hypermetropia	57.78	39.96	164.65	51.75	187.75	143.20	3.78	5.61
35	41	Male	Myopia	21.90	30.64	54.03	88.40	96.57	159.32	2.11	1.99
36	44	Female	Myopia	22.12	31.15	56.77	94.10	101.01	168.39	2.68	2.45
37	46	Male	Hypermetropia	61.53	40.01	134.74	49.75	165.71	141.60	2.38	4.01
38	36	Female	Hypermetropia	58.59	37.01	127.15	36.51	147.75	129.01	3.01	5.41
39	23	Female	Myopia	24.09	33.95	59.01	100.36	121.18	171.12	2.74	2.61
40	21	Male	Myopia	21.90	33.86	53.99	86.18	117.50	169.18	2.68	2.48
41	25	Male	Myopia	21.00	32.01	52.13	82.11	102.50	164.00	2.12	2.01
42	42	Female	Myopia	19.07	27.96	47.91	78.04	91.03	142.38	1.81	1.64

From the above data obtained from the case study performed on the 42 subjects, the hypothetical and comparative variation between the luminance and visually evoked potential parameters such as latency and amplitude is shown in Fig 6.5 and Fig 6.6 for subjects with optical powered glasses and normal subjects.

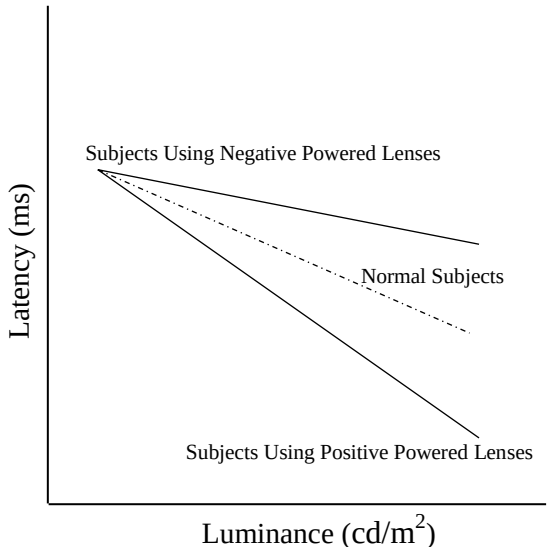


Fig 6.5 Variation in latency for positive and negative powered lenses compared to normal subjects.

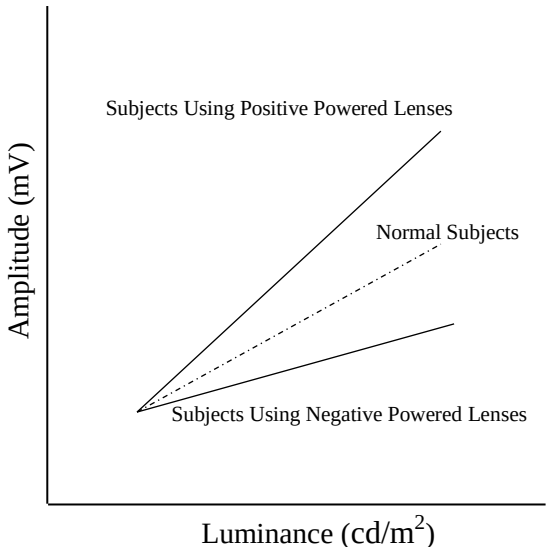


Fig 6.6 Variation in Amplitude of P100 wave for positive and negative powered lenses compared to normal subjects.

Up on the effects of the light intensity through optical glasses on visually evoked potentials discussed above, there are some dramatic changes in the parameters of the VEPs. The pictorial representation of variation in VEPs latency and amplitude in subjects with myopia and hypermetropia are shown in given in Fig 6.7 and Fig 6.8.

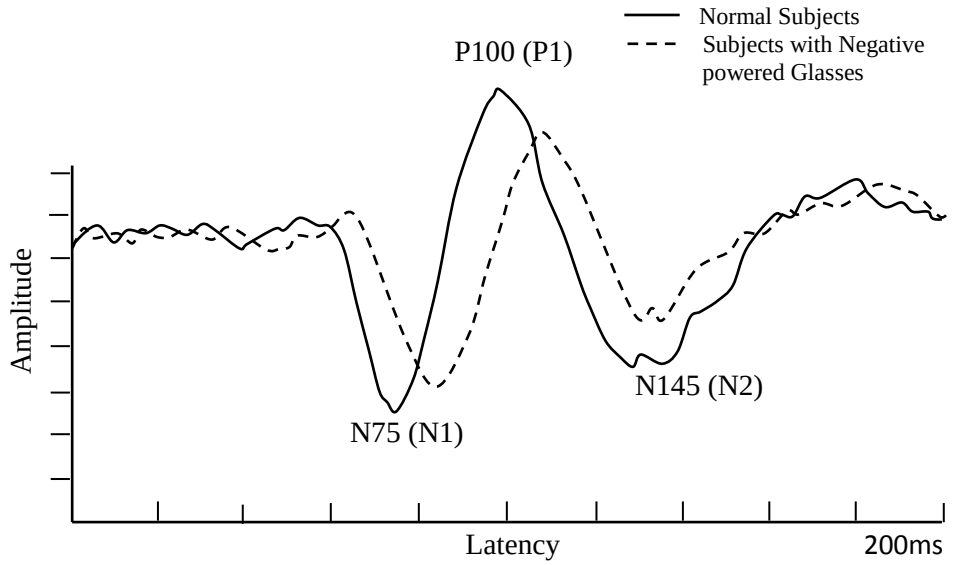


Fig 6.7 Variation in VEPs amplitude and latency of subject with myopia

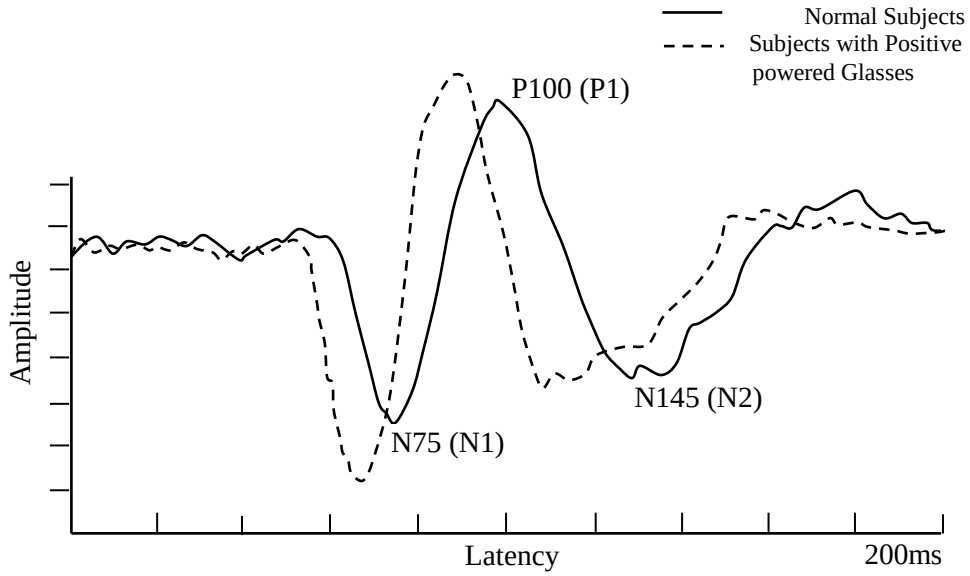


Fig 6.8 Variation in VEPs amplitude and latency of subject with myopia

Most of the cases, physician depends on VEPs to diagnose the subjects with abnormalities related to optic nerve and visual pathway such as multiple sclerosis, Optic neuritis, Ocular hypertension, Glaucoma and more. All the interpretation went on to find the variations in subject's latency and amplitude compared to the standard atlas of the laboratory. But, this variation in VEPs parameters due to change of light intensity through optical powered glasses may mask the abnormality or may show as high risk. Hence, light through high powered optical glasses is a considerable factor that affects the Visually Evoked Potentials. The checker board pattern used for the

VEP test and the obtained results is shown Fig 6.9. MEDICAID system for Evoked potential is used and results is given in Fig 6.10 and 6.11.

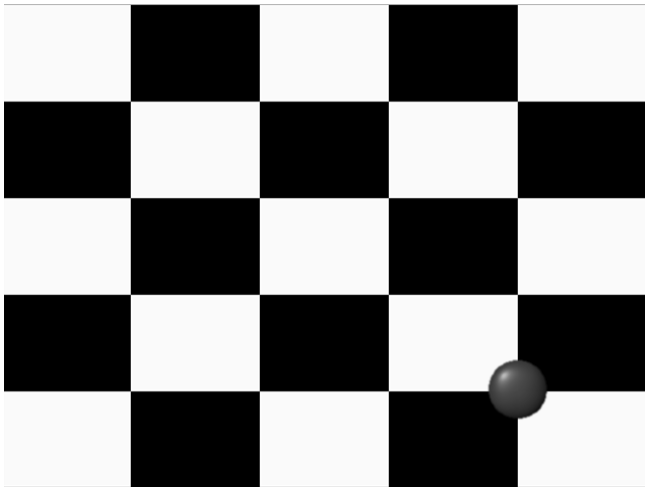
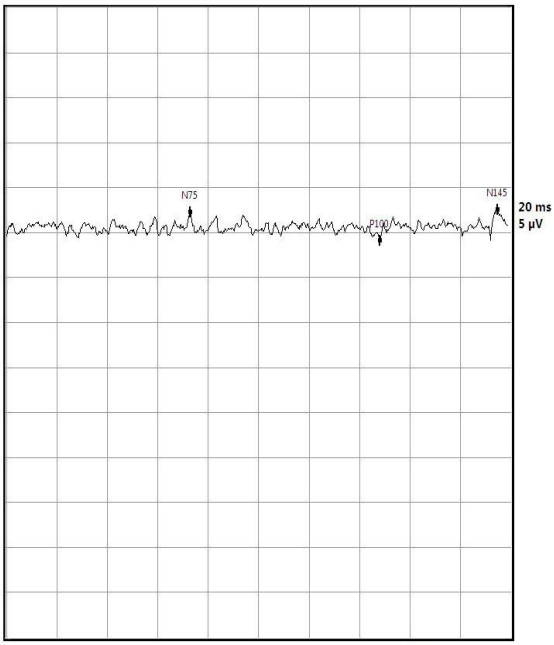
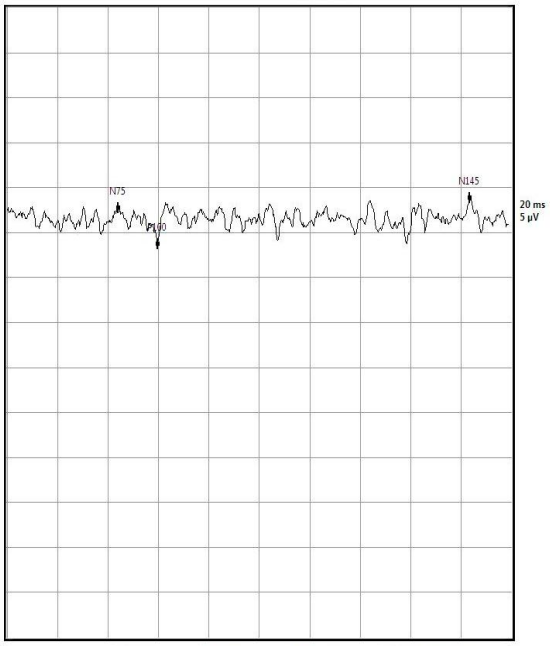


Fig 6.9 Checker Board pattern reversal test to perform VEP test



Recording Site	N75 (ms)	P100 (ms)	N145 (ms)	N75 - P100 (µV)
1. Fz-Oz	72.75	148.00	194.75	3.18
2. Fz-Oz				

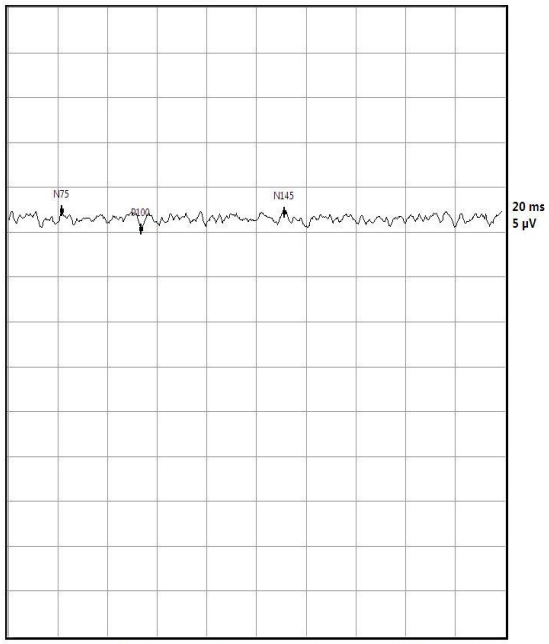
(a)



Recording Site	N75 (ms)	P100 (ms)	N145 (ms)	N75 - P100 (µV)
1. Fz-Oz	44.00	59.75	183.50	4.01
2. Fz-Oz				

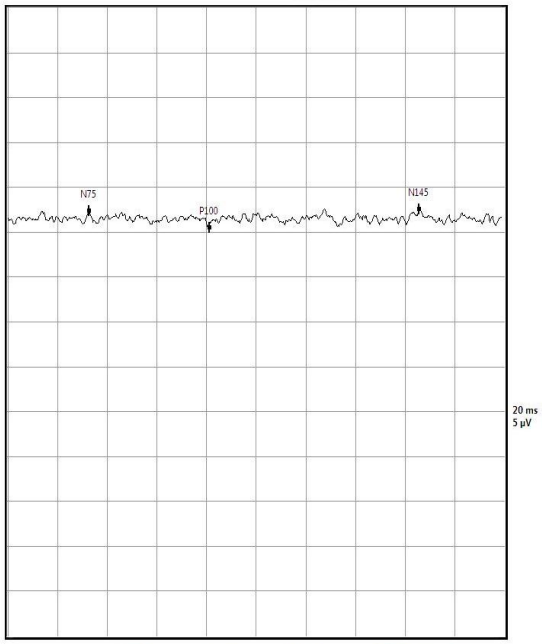
(b)

Fig 6.10 The variation in latency and amplitude on use of Positive powered optical powered glasses (a) without powered glasses (b) with powered glasses



Recording Site	N75 (ms)	P100 (ms)	N145 (ms)	N75 - P100 (µV)
1. Fz-Oz	21.50	53.50	111.50	1.98

(a)



Recording Site	N75 (ms)	P100 (ms)	N145 (ms)	N75 - P100 (µV)
1. Fz-Oz	32.75	81.00	166.00	1.83

(b)

Fig 6.11 The variation in latency and amplitude on use of Negative powered optical powered glasses (a) without powered glasses (b) with powered glasses

6.4 Summary

In this chapter, On examining and measuring of characteristics of visually evoked potentials, physician can draw information regarding the various abnormalities associated with optic nerve and visual pathway. From the demonstration of LDR test it is observed that, high powered optical glasses (> ± 3) also bring noticeable changes in the light intensity experiencing by the subject which in turn effect the visually evoked potentials. Hence, it is to affirm that power of the optical glass is also an important factor that to be considered by the physician. This factor has a supremacy which can mask the abnormality associate with the VEPs or to show up in excess of abnormality than encompassed in the subject.

CHAPTER 7

CONCLUSIONS AND SCOPE FOR FUTURE WORK

In this thesis, Novel and hypothetical case studies are performed to analyse the influence of ocular responses on the recordings of Electroencephalogram. Contamination of Ocular artifacts in true EEG recordings and its effects are described. Methods existing for the removal of ocular artifacts are also put forward. Research is concentrated to analyze the impact of EOG artifact and light on EEG. Mathematical models are developed which describes the effect of EOG, light and powered glasses on EEG readings. The same changes are also analysed by using subjective tests and experiments to see the ocular stimulus effect EEG. Especially, a system is developed to detec EOG blinks and EEG. Light Dependent Resistor (LDR) test is performed to observe the variation in light through optical powered glasses given in Table 5.1 and Table 5.2. Checker board pattern reversal test to study the variation in VEP parameters due to light.

The main objective of the work is to characterize the impact of ocularity present in EEG. This is achieved by exploring internal and external ocular influences on EEG.

Internal EOG artifact on EEG was detected by a hardware system developed using NI myRIO processor to detect the ocular artifact in EEG. The developed hardware, automatic blink detector system is very accurate in detecting blinks with accuracy of 96.2%. it is robust, can be interfaced to any exixting EEG system. This performs acquisition and detection of blinks simultaniouly while acquisition itself. Results are shown in Fig 3.7, Fig 3.8, Fig 3.9 and Fig 3.10.

As an external influence through ocular sensor, the analysis on the impact of light on EEG is performed by using various case studies. It is observed that the amplitude of the blink artifact increases with increase of light intensity falling on eye. As per the previous research, the lightening conditions in the EEG recording room are affects only occipital region and synchronised with alpha activity. But, from the

current research performed on 25 subjects, it is observed that low lightening conditions increases beta activity in the frontal region given in Table. 4.1. This is due to more mental stress experienced by the awaken subject in the recording room which makes physician to misinterpret it as EEG abnormality.

Optical powered glasses used to correct the refractive error of an eye cause variation in the light intensity experiencing by the subject. This variation affects the alpha activity in occipital region. Usage of improper prescription optical powered glasses increases the subject mental activity to focus the vision. This makes increment in beta activity in the frontal frequency. This is confirmed from the experimental and subjective analysis performed on 80 subjects. The obtained results is tabulated in Table 5.3.

VEP test is performed on 42 subjects to know the abnormalities associated with the visual pathway and optical nerve. It is observed that, positive powered glasses increases the light intensity falling on eye and increases in amplitude of P100 wave and reduces its latency. Whereas, negative powered optical glasses cause reduces amplitude and increases the latency of P100 wave. The variations in amplitude and latency can be misinterpreted as lesion or abnormality in visual pathway and optical nerve by the physician are tabulated in Table 6.1.

SCOPE FOR FUTURE WORK

The developed EOG artifact detector has a limitation of discriminating the spike from the seizure and blink. As it works on the threshold algiorithm it is difficult to differentiate, when seizure spike and ocular artifact has same amplitude.

Further work can be done by implementing the better case studies for the effect of various colours light on Electroencephalogram readings. The test can be performed for the entire visible light electromagnetic spectrum. This make physician to suggest colour glasses for the photosensitive epilepsy subjects.

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APPENDIX A

MATLAB Codes

MATLAB Code for FFT analysis of EEG Data

```
clc;
close all;
clear all;
[y,Fs]= audioread('C:\Users\USER\Documents\MATLAB\Suna\WAV
converted\21.wav')
Nsamps =256;
Tsamp = 1/Fs;
t = (0:Nsamps-1)*Tsamp;
% Plot time-domain signal
subplot(2,1,1);
plot(t, y);
ylabel('Amplitude'); xlabel('Time (secs)');
axis tight;
title('Input Signal');
% Choose FFT size and calculate spectrum
Nfft =25600;
%%
xf=abs(fft(y) )/Nsamps;% compute the amplitude spectrum
P=xf.*xf;%compute the power spectrum
% Map the frequency bin to the frequency (hz)
f=[0:1:Nsamps/2]*Fs/Nsamps;%fk=k fs/N where k=0,1,2,...N-1
% now we will plot the DFT spectrums
subplot(2,1,2);plot(f,xf(1:Nsamps/2+1));grid
xlabel('Frequency (Hz)');ylabel('Amplitude Spectrum (DFT) ' ) ;
%%
%[Pxx,f] = pwelch(y,gausswin(Nfft),Nfft/2,Nfft,Fs);
% Plot frequency spectrum
%subplot(2,1,2);
%plot(f,Pxx);
```

```
%ylabel('PSD'); xlabel('Frequency (Hz)');
grid on;
% Get frequency estimate (spectral peak)
[~,loc] = max(Pxx);
FREQ_ESTIMATE = f(loc)
title(['Frequency estimate = ',num2str(FREQ_ESTIMATE),' Hz']);
```

Principal Component Analysis in MATLAB Tool box

```
clc;
close all;
clear all;
[ax b c]=plotyy(t,pf,t,cc);
%set(ax(1),'Linestyle','+');
Set(ax(1),'Linestyle','*');
Set(get(ax(2),'YLabel'),'string','Cumulative counts')
Set(get(ax(1),'YLabel'),'string','Peak Frequency (kHz)')
Set(ax(1),'YTick',[0:50:300]);
Set(ax, 'FontSize',[13])
Set(ax(1),'FontSize',[13])
Set(ax(2),'FontSize',[13])
Set(ax(2),'YTick',[0:1000:10000]);
Set(ax(1),'ylim',[0 300]);
Set(ax,'xlim',[0 1000]);
[ax b c]=plotyy(t,d,t,a);
Set(ax(1),'Linestyle','+');
Set(ax(2),'Linestyle','*');
Set(get(ax(1),'YLabel'),'string','Duration (µs)')
Set(get(ax(2),'YLabel'),'string','Amplitude (dB)')
Set(ax(2),'YTick',[0:10:100]);
Set(ax, 'FontSize',[13])
Set(ax(2),'FontSize',[13])
Set(ax(1),'FontSize',[13])
Set(ax(1),'YTick',[0:1000:10000]);
```

Source Code for Continuous Wavelet Transform

```
clc;
Clear all;
Close all;
x=import data ('w.txt');
x=x(1: end-3000);
n=length(x);
Fs=1e6;
dt=1/Fs;
Time=0:dt:(n-1)*dt;
t=Time*1e6;
Wname='db4';
Factor = 5/(2*pi);
Freq = [100:10e3:9e5];
Scale = factor * Fs. /freq;
Frequency=freq/1000;
coef = cwt(x,scale,wname);
Figure;
contour (t,Frequency, abs(coef));
Axis ('xy'); % flip the vertical axis over
Xlabel('Time (μs)');
Ylabel('Frequency (kHz)');
200
Color map(jet)
Colorbar('location','EastOutside')
Xlim([0,400])
Figure;
Mesh(t, Frequency, abs(coef));
[az,el]=view;
View(az-45,el);
Xlabel('Time (μs)');
Ylabel('Frequency (kHz)');
Zlabel('Wavelet Coeffs');
%title('3D scalogram');
```

```
Colormap(jet)
Colorbar('location','NorthOutside')
Xlim([0,400])
```

Source Code for Discrete Wavelet Transform

```
clc;
close all;
clear all;
S=import data('c3.txt');
L=length(S);
[C,L]=wavedec(S,4,'db4');
201
CA4=appcoef(C,L,'db4',4);
[CD1,CD2,CD3,CD4]=detcoef(C,L,[1,2,3,4]);
[A4]=wrcoef('a',C,L,'db4',4);
[D4]=wrcoef('d',C,L,'db4',4);
[D3]=wrcoef('d',C,L,'db4',3);
[D2]=wrcoef('d',C,L,'db4',2);
[D1]=wrcoef('d',C,L,'db4',1);
RS=A4+D4+D3+D2+D1;
figure(1)
%subplot(6,1,1); plot(A4); title('Approximation A4'); ylabel('A4');
subplot(5,1,1); plot(D4); title('Detail D4'); ylabel('D4'); xlim([0,1500]);
subplot(5,1,2); plot(D3); title('Detail D3'); ylabel('D3'); xlim([0,1500]);
subplot(5,1,3); plot(D2); title('Detail D2'); ylabel('D2'); xlim([0,1500]);
subplot(5,1,4); plot(D1); title('Detail D1'); ylabel('D1'); xlim([0,1500]);
subplot(5,1,5); plot(S); title('Analyzed signal'); ylabel('Signal S'); xlabel('No
of Samples'); xlim([0,1500]);
%subplot(4,2,2); plot(RS); title('Reconstructed signal');
%FFT program
L=length(S); L1=length(D1); L2=length(D2); L3=length(D3);
L4=length(D4);
fs=3e6;
n=2^nextpow2(L); n1=2^nextpow2(L1);
n2=2^nextpow2(L2);n3=2^nextpow2(L3);n4=2^nextpow2(L4);
```

202

```
F=fft(S,n); F1=fft(D1,n); F2=fft(D2,n); F3=fft(D3,n); F4=fft(D4,n);
Mag=abs(F);Mag1=abs(F1); Mag2=abs(F2); Mag3=abs(F3); Mag4=abs(F4);
Fr=(0:(n-1))*fs/(n); Fr1=(0:(n1-1))*fs/(n1); Fr2=(0:(n2-
1))*fs/(n2);Fr3=(0:(n3-1))*fs/(n3); Fr4=(0:(n4-1))*fs/(n4);
Fy=Fr/1000; Fy1=Fr1/1000; Fy2=Fr2/1000; Fy3=Fr3/1000; Fy4=Fr4/1000;
figure(2)
subplot(5,1,1); plot(Fy4,Mag4); ylabel('D4'); xlim([0,1500]);
subplot(5,1,2); plot(Fy3,Mag3); ylabel('D3'); xlim([0,1500]);
subplot(5,1,3); plot(Fy2,Mag2); ylabel('D2'); xlim([0,1500]);
subplot(5,1,4); plot(Fy1,Mag1); ylabel('D1'); xlim([0,1500]);
subplot(5,1,5); plot(Fy,Mag); xlabel('Frequency(KHz)'); ylabel('Signal S');
xlim([0,1500])
```

APPENDIX B

NI myRIO Specifications

Specifications

The following specifications are typical for the 0 to 40 °C operating temperature.

Processor

Processor type .....Xilinx Z-7010

Processor speed.....667 MHz

Processor cores 2

Memory

Nonvolatile memory .....256 MB

DDR3 memory.....512 MB

DDR3 clock frequency .....533 MHz

DDR3 data bus width.....16 bits

FPGA

FPGA type .....Xilinx Z-7010

Wireless Characteristics

Radio mode .....IEEE 802.11 b,g,n

Frequency band.....ISM 2.4 GHz

Channel width .....20 MHz

Channels ..... USA 1-11, International 1-13

TX power..... +10 dBm max (10 mW)

Outdoor range ..... Up to 150 m (line of sight)

Antenna directivity ..... Omnidirectional

Security..... WPA, WPA2, WPA2-Enterprise

USB Ports

USB host port ..... USB 2.0 Hi-Speed

USB device port..... USB 2.0 Hi-Speed

Analog Input

Aggregate sample rate ..... 500 kS/s

Resolution..... 12 bits

Overvoltage protection ..... ±16 V

MXP connectors

Configuration..... Four single-ended channels per connector

Input impedance ..... >500 kΩ acquiring at 500 kS/s

1 MΩ powered on and idle

4.7 kΩ powered off

Recommended source impedance ..... 3 kΩ or less

Nominal range ..... 0 V to +5 V

Absolute accuracy..... ±50 mV

Bandwidth..... >300 kHz

MSP connector

Configuration..... Two differential channels

Input impedance ..... Up to 100 nA leakage powered on;

4.7 kΩ powered off

Nominal range ..... ±10 V

Working voltage

(signal + common mode)..... ±10 V of AGND

Absolute accuracy..... ±200 mV

Bandwidth..... 20 kHz minimum, >50 kHz typical

Audio input

Configuration..... One stereo input consisting of two AC-coupled, single-ended channels

Input impedance ..... 10 kΩ at DC

Nominal range ..... ±2.5 V

Bandwidth..... 2 Hz to >20 kHz

Analog Output

Aggregate maximum update rates

All AO channels on MXP connectors.....345 kS/s

All AO channels on MSP connector

and audio output channels.....345 kS/s

Resolution .....12 bits

Overload protection .....±16 V

Startup voltage .....0 V after FPGA initialization

MXP connectors

Configuration .....Two single-ended channels per connector

Range .....0 V to +5 V

Absolute accuracy.....50 mV

Current drive .....3 mA

Slew rate .....0.3 V/µs

MSP connector

Configuration .....Two single-ended channels

Range .....±10 V

Absolute accuracy.....±200 mV

Current drive .....2 mA

Slew rate .....2 V/µs

Audio output

Configuration .....One stereo output consisting of
two AC-coupled, single-ended channels

Output impedance .....100 Ω in series with 22 µF

Bandwidth.....70 Hz to >50 kHz into 32 Ω load;
2 Hz to >50 kHz into high-impedance load

Digital I/O

Number of lines

MXP connectors .....2 ports of 16 DIO lines (one port per connector);
one UART.RX and one UART.TX line per
connector

MSP connector.....1 port of 8 DIO lines

Direction control .....Each DIO line individually programmable as
input or output

Logic level .....5 V compatible LVTTL input; 3.3 V LVTTL output

Input logic levels

Input low voltage, VIL ..... 0 V min; 0.8 V max

Input high voltage, VIH ..... 2.0 V min; 5.25 V max

Output logic levels

Output high voltage, VOH
sourcing 4 mA ..... 2.4 V min; 3.465 V max

Output low voltage, VOL

sinking 4 mA ..... 0 V min; 0.4 V max

Minimum pulse width..... 20 ns

Maximum frequencies for secondary digital functions

SPI ..... 4 MHz

PWM..... 100 kHz

Quadrature encoder input ..... 100 kHz

I2C..... 400 kHz

UART lines

Maximum baud rate..... 230,400 bps

Data bits..... 5, 6, 7, 8

Stop bits 1, 2

Parity..... Odd, Even, Mark, Space

Flow control..... XON/XOFF

Accelerometer

Number of axes..... 3

Range ..... ±8 g

Resolution..... 12 bits

Sample rate ..... 800 S/s

Noise..... 3.9 mgrms typical at 25 °C

Power Output

+5 V power output

Output voltage ..... 4.75 V to 5.25 V

Maximum current on each connector ..... 100 mA

+3.3 V power output

Output voltage ..... 3.0 V to 3.6 V

Maximum current on each connector ..... 150 mA

+15 power output

Output voltage.....+15 V to +16 V

Maximum current .....32 mA (16 mA during startup)

-15 V power output

Output voltage.....-15 V to -16 V

Maximum current .....32 mA (16 mA during startup)

Maximum combined power from +15 V
and -15 V power output .....500 mW
Power Requirements
Power supply voltage range.....6-16 VDC
Maximum power consumption .....14 W
Typical idle power consumption.....2.6 W

Physical Characteristics

Weight .....193 g (6.8 oz)

PUBLICATIONS BASED ON THIS RESEARCH WORK

Refereed International Journal:

- John William Carey M and Usha Rani N, "Impact of light through optical glasses on Electroencephalogram. Influence of light Through Optical Glasses on Electroencephalogram. Indian Journal of Pharmaceutical Education and Research. 51(2s):s54-s60, 2017.DOI: 10.5530/ijper.51.2s.50. **(SCI Expanded Cited)**
- John William Carey M and Usha Rani N, "Methods for the Elimination of Ocular Artifacts in EEG," International Journal of Biomedical Engineering and Technology, INDERSCIENCE publishers, Accepted, Article in press **(Scopus Cited)**
- John William Carey M and Usha Rani N, "Study on the Impact of Light on Human Physiology and Electroencephalogram," Journal of Biomimetics, Biomaterials and Biomedical Engineering, vol. 28, pp. 36-43, 2016. **(Scopus Cited)**

International Conference:

- John William Carey M and Usha Rani N, "Study of Normal and Abnormal EEG," in proceedings of the2016 IEEE International Conference on Advanced Computing and Communication Systems (IEEE ICACCS-2016), Coimbatore, India, January 22-23, 2016. (Scopus Cited)
- John William Carey M and Usha Rani N, "Removal of Ocular Artifacts in EEG," in proceedings of the2016 IEEE International Conference on Intelligent Systems and Control (IEEE ISCO-2016), Coimbatore, India, January 7-8, 2016. (Scopus Cited)
- John William Carey M and Usha Rani N, "Single lead EEG acquisition system for health care applications," in proceedings of the2016 IEEE International Conference on Inventive Computation Technologies (ICICT 2016), Coimbatore, India, August 26-27, 2016. (Scopus Cited)

Patent (Filed and Published)

- Invention Title: AUTOMATIC EYE BLINK DETECTOR USING NI MYRIO

  Publication Number: 18/2016

  Publication Date: 2016/04/29

  Application Number: 201641012928

  Application Filing Date: 2016/04/13

  Field Of Invention: (FI19) BIO-MEDICAL ENGINEERING

  Classification (IPC): A61B-3/00

INVENTORS

Name	Address	Country	Nationality
USHA RANI NELAKUDITI	DEPARTMENT OF ECE, VIGNAN'S UNIVERSITY, VADLAMUDI - 522 213, GUNTUR DIST,	IN	IN
JOHN WILLIAM CAREY MEDITHE	DEPARTMENT OF ECE, VIGNAN'S UNIVERSITY, VADLAMUDI - 522 213,	IN	IN

- Invention Title: Blink Controlled Home Appliance System

  Given for Novelty check and Drafting

CURRICULUM VITAE

Name of the candidate: JOHN WILLIAM CAREY MEDITHE

Father/husband name: Ceaser Benjamin Babji Medithe

Mother name: Esther Rani Medithe

Date of birth: 08/01/1991 Sex: Male

Married /Unmarried: Unmarried

Address for Correspondence: D.No 11-5-52, Calvary Grace, Gandhi Nagar-1,
Narsapur, West Godavari Dt, Andhra Pradesh, India
Pin – 534275
Mobile: 7780582627, 9247402443

E-mail address: careymedithe@gmail.com

Nationality: INDIA

Category SC/ST/OBC/General: OBC

Educational qualification: (Starting from SSC/matriculation onwards)

Name of the	Name of the Board/University	Subjects (with specialization in grad and post-grade)	Grade/ Division
SSC	CBSE	As Per Board	First Class
Intermediate	Board of Intermediate Education -AP	Mathematics, Physics, Chemistry (M.P.C)	First Class
B.Tech	JNTU-Kakinada	Electronics and communication Engineering	First Class
M.Tech	Andhra University	Communication Systems	First Class with Distinction

Publication/Presentations:

International Journals:

1. **John William Carey M** and Usha Rani N, "Influence of light through Optical Glasses on Electroencephalogram," ***IJPER***, Accepted, In press. **(SCI Cited)**

2. **John William Carey M** and Usha Rani N, "Methods for the Elimination of Ocular Artifacts in EEG," ***International Journal of Biomedical Engineering and Technology***, INDERSCIENCE Article in press, Displayed in forthcoming articles. **(Scopus Cited)**
3. **John William Carey M** and Usha Rani N, "Study on the Impact of Light on Human Physiology and Electroencephalogram," ***Journal of Biomimetics, Biomaterials and Biomedical Engineering***, vol. 28, pp. 36-43, 2016. **(Scopus Cited)**

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4. **John William Carey M** and Usha Rani N, "Study of Normal and Abnormal EEG," *in proceedings of the **2016 IEEE International Conference on Advanced Computing and Communication Systems*** **(IEEE ICACCS-2016),** Coimbatore, India, January 22-23, 2016. **(Scopus Cited)**
5. **John William Carey M** and Usha Rani N, "Removal of Ocular Artifacts in EEG," *in proceedings of the **2016 IEEE International Conference on Intelligent Systems and Control*** **(IEEE ISCO-2016),** Coimbatore, India, January 7-8, 2016. **(Scopus Cited)**
6. Bhavana G, Usha Rani N and **John William Carey M**, "Single lead EEG acquisition system for health care applications," *in proceedings of the **2016 IEEE International Conference on Inventive Computation Technologies*** **(ICICT 2016),** Coimbatore, India, August 26-27, 2016. **(Scopus Cited)**

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   Field Of Invention: (FI19) BIO-MEDICAL ENGINEERING
   Classification (IPC): A61B-3/00

I hereby declare that the information furnished above is true.

John William Carey Medithe