Effect of Immersion
on
Visual Attention and Alertness by Comparison of Two Dimensional Display Environments and Desktop Virtual Reality Environments

A Dissertation submitted in partial fulfillment of the requirements for the award of degree of

Master of Engineering
In
Electronic Instrumentation and Control

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June 2012

DECLARATION

I hereby certify that the work which is being presented in the thesis entitled, " **Effect of Immersion on Visual Attention and Alertness by Comparison of Two Dimensional Display Environments and Desktop Virtual Reality Environments"** in partial fulfillment of the requirements for the award of degree of Master of Engineering in Electronics Instrumentation and Control Engineering submitted in Electrical and Instrumentation Engineering Department, Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of **Mr. Sushil Chandra,** Scientist 'F' Institute of Nuclear Medicine and Allied Science (INMAS), DRDO, New Delhi and **Dr. Ravinder Agarwal**, Professor, Department of Electrical and Instrumentation Engineering, Thapar University,Patiala,Punjab.

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ACKNOWLEDGEMENT

The real spirit of achieving a goal is through the way of excellence and austere discipline. I would have never succeeded in completing my task without the cooperation, encouragement and help provided to me by various personalities.

With deep sense of gratitude I express my sincere thanks to my esteemed and worthy supervisors, **Mr. Sushil Chandra,** Scientist 'F', Head of Department of Bio-Medical Engineering, INMAS, DRDO, New Delhi and **Dr. Ravinder Agarwal,** Professor**,** Department of Electrical and Instrumentation Engineering, Thapar University, Patiala for their valuable guidance in carrying out this work under their effective supervision, encouragement, enlightenment and cooperation. Most of the novel ideas and solutions found in this thesis are the result of our numerous stimulating discussions. Their feedback and editorial comments were also invaluable for writing of this thesis.

I shall be failing in my duties if I do not express my deep sense of gratitude towards **Dr. Smarajit Ghosh,** Professor and Head of the Department of Electrical & Instrumentation Engineering, Thapar University, Patiala who has been a constant source of inspiration for me throughout this work. I am also thankful to Mr. Ram Singh, Scientist 'B' and Mr. Manoj Prabhat, Ms. Greeshma Sharma, J.R.F., INMAS DRDO for their full cooperation and help.

This acknowledgement would be incomplete if I do not mention the emotional support and blessings provided by my friends. I had a pleasant enjoyable and fruitful company with them.

My greatest thanks are to all who wished me success especially my wife and family members, whose support and care makes me stay on earth.

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ABSTRACT

The Desktop Virtual Reality (DVR) environments are new types of human-computer interaction interfaces in which users perceive and act in a three-dimensional world. It is use in both as a tool and as an experimental area for the studies. In this study, it is used as an experimental area since it is an application where perceptual information became an essential key for success. Furthermore, it is also used as a research technique, because of its ability to provide the participants with the previously unseen environment in which the experiment of the study is conducted.

In this research work eight subjects were participated. Three different park scenarios were used in this research. The scenarios were in both desktop virtual reality environment and two dimensional display environments. Each subject has to watch the park scenarios in two dimensional scenarios and desktop virtual reality scenarios and simultaneously EEG signals were recorded. The EEG signal indicates the electrical brain activity. The EEG signals were recorded by Emotiv Head Set. The questionnaires of immersion were created. The Immersion Questionnaire (IQ) was related to the fine details of the each scenario. After each scene the questionnaires were asked to the subject.

The results show decrease in energy and power spectral density of alpha band and increase in gamma band in desktop virtual environment. The changes in electric brain activity in presence of virtual reality indicate the change in human attention and alertness level. Electric brain activity could be considered as an objective measure of presence in virtual environments. The objective score of immersion questionnaires were more in desktop virtual reality when compare with conventional two dimensional displays.

The findings showed that visual attention and alertness level can be attained in desktop virtual environments. Therefore VR technology have been applied for assessment and training purposes in the areas of military, safety training and flying simulators.

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Chapter-1
Introduction

1.1 Background

During last several years, computer based display system have gained wide attention. Today, the technology has changed in designing of high quality virtual environments with the improvements in the quality of displays. In real-world, human perceives the environment by means of many sources of visual information such as occlusion, relative size, *etc*. The technology provides different types of sources for visual perception, the effectiveness and efficiency of visual and cognitive tasks in these simulated environments can be affected either in a positive or a negative way. To understand these effects, it's necessary to examine our visual perception and the mechanisms of human cognition in virtual environments.

The human cognition is measured by the different kind of sensors. Now a day's the new sensor technology, analysis advancement in signal processing and machine learning make it possible to noninvasively monitor brain signals and use them in aspects of a human cognitive state in near real time [1, 2]. It is now possible to integrate this new technology into real-world and real-time systems to enhance cognitive ability across a wide range of application domains including clinical, industrial, military and gaming [3 – 6]. Immersion, the sense of being in a virtual reality environment, is analyzed in an embodied cognition framework. Immersion, like involvement and presence, it is something new experiences. The study in this dissertation utilizes virtual reality techniques to bridge the gap between standardization and ecological validity in human attention and alertness level.

The human brain is a complicated system and exhibits rich spatiotemporal dynamics. Among amounts of techniques probing brain activity, electroencephalography (EEG) is one of the most important tools. It is especially useful in diagnosis of neurological diseases [7].

This study involves the evaluation of EEG signals in analysis of attention and alertness level by desktop virtual reality scenarios as well as in two dimensional scenarios. The quality of depth in virtual reality increases the immersion that will causes some changes in our brain signals which are measured by EEG signals which indicate the change in attention and alertness level.

1.2 Objective

The Virtual Reality (VR) environment can enhance the immersion as compare to the conventional two dimensional scenarios and it will be used to analyze the human attention and alertness level. That is the aim of this study to observe the positive effects of virtual reality environment on human brain. The basic principles involve the visual stimuli in both Cathode Ray Tube (CRT) based two dimensional display system and desktop VR display system. The various features of EEG signals give the information about the immersion. The level of immersion indicates the involvement in the scenarios and how the cognitive parameters like attention and alertness changes. The work was carried out with following objectives;

1. Creation of a convincing questionnaire of immersion
2. To assess the influence of immersion on performance in VR system and show the results about the alertness, experimentally
3. Correlate EEG signal features to determination attention and alertness

Finally, the features of EEG were evaluated for interpretation of attention and alertness using analyzing the energy and power spectral density of alpha and gamma bands. In short the attention of the subject was measure by EEG signal analysis and the alertness was analyzed by immersion questionnaires.

1.3 Cognitive Signal Processing

Cognitive Psychology, Cognitive Neuroscience focuses on studying human brain activity. It studies human brain encodes and processes information from the external and internal environment. This information is stored as a representation in mind and it is retrieved to generate actions in response to stimuli. Cognitive Neuroscience covered sensation and perception of information from different modalities (*e.g.* visual, auditory and tactile information), the interaction between information in different modalities, the formation of memory, the speech and action elicited by memory, and the attention resources spent on processing the information.

Based on the research methods of Cognitive Psychology, Cognitive Neuroscientists manipulate the parameters in different stages of information processing, and record the behavioral responses (*e.g.* reaction time and accuracy) by research participants in different experimental settings in order to examine the cognitive processes involved. Cognitive psychologists research on external behavioral data to draw inferences on the corresponding internal cognitive processes and cognitive neuroscientists measure the neural activities in addition to behavioral data when subjects perform experimental tasks.

The research method of drawing inference on cognitive processes based on the differences of neural activities in different experimental settings. Cognitive processes and neural activities are related to each other in a definite way. By comparing the differences in the location and intensity of neural activities while research participants perform different experimental tasks and with examination on behavioral data as well, cognitive neuroscientists develop a better understanding on different cognitive activities which are linked to neural activities. The neural activities of brain are sensed by the EEG and process the signals.

Signal processing is an area of applied mathematics that deals with operations on or analysis of signals, in either discrete or continuous time to perform useful operations on those signals. Depending upon the application, a useful operation could be control, data compression, data transmission, de-noising, prediction, filtering, smoothing, de-blurring, tomographic reconstruction, identification, classification. Signals of interest can include sound, images, time-varying measurement values, sensor data and biological data such as electrocardiograms, EEG, control system signals, telecommunication transmission signals such as radio signals, and many others.

This research work deals with the signal processing of the physiological data i.e. electroencephalograph (EEG signal). The wavelet techniques were employed to evaluate the EEG signals.

1.4 Organization of Dissertation

The report details are as follows

Chapter 1 deals with **“Introduction”** about the research work and its background description.

Chapter 2 deals with **“Literature Review**” *i.e.*, overview of the previous work done.

Chapter 3 deals with **“Virtual Reality”** with the basic details about the VR and its type.

Chapter 4 deals with **“Anatomy of Brain”** it provides the brief idea about the human brain

Chapter 5 deals with **“Electroencephalograph (EEG)”** it gives the brief description about the EEG signals and its recording techniques.

Chapter 6 deals with **“Description of Attention and Alertness”** it describe about the attention and alertness and their types.

Chapter 7 deals with **“Material and Methodology”** introduces about the tools and material used to do this research work, *i.e.*, MATLAB software, Emotiv Neuro headset *etc*. This chapter also includes the explanation about the analysis method *i.e.*, wavelet technique and filtering.

Chapter 8 deals with **“Results and Discussion”** of change in alpha and gamma band in desktop virtual environment and 2D display system.

Chapter 9 deals with **“Conclusion and Future Recommendation”**.

Chapter-2
Literature Review

There are many research studies that have been conducted for examining the effect of Virtual Reality Environments. A number of them are also related to Cognitive psychology. In this section, related studies will be mentioned briefly.

Sutherland I.E., the very first idea of Virtual Reality was presented by Ivan Sutherland in 1965: "make that (virtual) world in the window look real, sound real, feel real, and respond realistically to the viewer's actions". It made fundamental contributions in the area of human computer interaction, being one of the first graphical user interfaces. It exploited the light-pen, predecessor of the mouse, allowing the user to point at and interacts with objects displayed on the screen. This anticipated many of the interaction conventions of direct manipulation, including clicking a button to select a visible object, and dragging to modify it. It was limited by how to reduce the cognitive challenges of abstract manipulation. It was not immersive system [8].

Nielson G., a virtual sphere controller was made with a simulation of 3D interactive rotating system and positioning of three-dimensional objects with the use of simple 2D desktop mouse and monitor. It has low level of resolution [9].

F. Brooks Jr., the first attempts to apply VR as a visualization tool. It was an architectural walkthrough system. New paradigm of the 3D user interface and its use in the modeling process – 3D widgets were proposed. It encapsulates the geometry and behavior, and therefore they were flexible virtual controls that can be elaborated individually for the application needing [10].

Eckhorn R., Bauer R., Jordan W., tested the neuro-physiological relevance to the visual system. Single and multiple spikes as well as local field potentials were recorded simultaneously from several locations in the primary visual cortex [11].

Posner M., & Petersen S.E., studied the brain signals in presence of visual stimuli. The importance of attention was its unique role in connecting the mental level of description of processes used in cognitive science with the anatomical level common in neuroscience. This paper not to able to describe which part of the brain was more activated in different visual stimuli [12].

Cartwright G.F. and Zanni C.A., the electroencephalograms were used in various experiments in visual perception and can be used to examine the cortical activity which occurs during the perception of real and apparent movement. The alpha rhythms has been shown to be related to the visual system and visual perception, and associated with attentional demands and degree of task difficulty [13].

Pausch R., it was one of the first attempts to quantify immersion in VR, using a visual search task to measure immersion. The task involved looking for a specific target letter in a set of similarly shaped letters distributed around the walls, floor and ceiling of a virtual room [14].

Boyd C., has also studied the effects of immersion. In this study, three different kinds of virtual environments were compared. Boyd's results showed that the HMD with head tracking was superior to the other systems [15].

Robertson George *et al*., this paper explores techniques for evaluating and improving immersion in desktop Virtual Reality (VR). A visual search paradigm was used to examine navigation in desktop VR both with and without navigational aids. This research introduced a new navigation aid called Peripheral Lenses, intended to provide simulated peripheral vision [16].

Maguire E.A., has applied Positron Emission Tomography (PET) to measure regional cerebral blood flow changes while 11 normal subjects explored and learned in two virtual environments, one containing salient objects and textures and the other one was empty. The findings showed that learning in both cases activated a network of bilateral occipital, medial parietal, and occipitotemporal regions. The first environment resulted in increased activity in the right parahippocampal gyrus, while the region was not activated in the empty environment. These findings contribute to the encoding of object location into virtual environments [17].

Schier M.A., recorded electric brain activity during a driving simulation task. Alpha activity (8 – 13Hz) decrease was interpreted as users' more attentional activity. Greater alpha activity was consistent with fewer attentional resources required for an experienced driver [18].

Mikropoulos T., this research reported electric brain activity during the navigation of 12 students in a VE. The students showed more attentional activity in the virtual rather in the real environment and lower theta activity in the VE indicating less mental effort [19].

Moore and Engel's, the fMRI study recorded increased brain activity in the occipital complex during users' interaction with VEs. Their findings showed a neural activity increase with perceived volume in comparison with two dimensional shapes. These results were correlated to scene realism and information consistent with the objective world [20].

Tassos A. Mikropoulos, this article reports to assess the cognitive processing that took place in virtual environments, by measuring subjects electrical brain activity using Fast Fourier Transform analysis. The aim of the study was the evaluation of virtual learning environments using the above methodology in addition to the standard methodology of social sciences and educational research, namely quantitative and qualitative empirical research [21].

Baek-Hwan CHO, Jeonghun KU, Dong Pyo jang, the main goal in this research was to validate the possibility of Virtual Reality (VR) for attention enhancement in cognitive training program, developed some cognitive training tasks using VR technology [22].

Bischof and Boulanger, the brain activity as a measure for evaluating VEs by assessing the ease of navigation in virtual mazes. These results were related with active search, degree of movement perception and physical environment modifiability, factors that affect presence [23].

Farrer C. investigated the feeling of being causally involved in an action that is a constituent of the sense of the self. This research studied eight subjects' degree of control of the movements of a virtual hand in four different conditions using PET. The results showed that the less the subject felt in control of the movements of the virtual hand, the higher was the level of activation in the inferior part of the right parietal lobe, as well as a reverse co-variation in the insula [24].

Tassos A. Mikropoulos, Tzimas Evangelos, electric brain activity of seven students was recorded and analyzed during their interaction with four different versions of the same virtual environment, a representation of a room. The results were able to detect some sensory, realism and distraction factors that were related with presence result on differences in electric brain activity, indicating attentional activity and visual awareness as a virtual environment was enriched with textures and objects [25].

Aston-Jones G., this research involve in transformation between sleep and wakefulness are regulated by complex neurobiological mechanisms, which ultimately can be correlate as oscillations between two opponent processes--one promoting sleep and the other promoting wakefulness [26].

Baumgartner Thomas, Valco Lilian and Jäncke Lutz, using electroencephalography (EEG), psychophysiology, and psychometric measures, this was the study about the investigation of neurophysiological underpinnings of spatial presence. Spatial presence was considered a sense of being physically situated within a spatial environment portrayed by a medium (*e.g.*, television, Virtual Reality) [27].

Lenggenhager Bigna, Halje Par and Blanke Olaf, neuroscience of the human has focused on high-level mechanisms related to language, memory or imagery of the self. This research used Virtual Reality technology to study the low-level mechanisms and manipulate where participants experienced their self to be localized (self-location). Frequency analysis and electrical neuro-imaging of co-recorded high-resolution electroencephalography revealed body-specific alpha band power modulations in bilateral sensorimotor cortices [28].

Shiau-Feng Lin, Chiuhsiang Joe Lin, Rou-Wen Wang, Wei-Jung Shiang, the superior and high reliability VR training system is very important in immersion. Manipulation training in immersive virtual environments made it easy to use. In this paper, the convincing questionnaire of immersion was created and an experiment to assess the influence of immersion on performance in VR training system. The Immersion Questionnaire (IQ) included spatial immersion, Psychological immersion, and Sensory immersion [29].

Chapter-3
Virtual Reality

3.1 Introduction

The relationship between our actions and perceivable results is rule by laws of nature. In general the understanding of our actions act upon real objects which react according to the laws of nature and that can be perceived. VR simulates the action perception relationship in a physically correct manner but without involving real objects or real events. A typical dictionary definition of the term VR is “an image produced by a computer that surrounds that person looking at it and seems almost real” [30].

VR is now being developed and validated to focus on component cognitive processes including: attention and alertness process, spatial abilities, learning and memory. The ability of Virtual Environments (VE) to create dynamic, immersive, three dimensional stimulus environments, in which all behavioral responding can be recorded, offers assessment and rehabilitation options that are not available using traditional assessment methods. Much like aircraft simulators have been developed to assess and train piloting ability under a range of controllable stimulus conditions.

Virtual reality can be defined as a class of computer-controlled multisensory communication technologies that allow more intuitive interactions with data and involve human senses in new ways. This technology enables the people to deal with information more easily. VR provides a different way to see and experience information, one that is dynamic and immediate. It is also a tool for model building and problem solving. The virtual world is interactive; it responds to the user’s actions. Virtual Reality evokes a feeling of immersion, a perceptual and psychological sense of being in the digital environment presented to the senses. Immersion is a key feature of VR systems as it is central to the paradigm where the user becomes part of the simulated world, rather than the simulated world being a feature of the user's own world [31]. The idea is to tailor the visual presentation to take better advantage of the human ability to recognize patterns and see structures.

3.2 History

VR is a change in display technology. The idea of inclusion of VR within an artificial environment is not new. In fact VR can be considered an extension of ideas which have been around for some considerable time such as flight simulation and wide screen projectors. Using such systems, the viewer is presented with a screen which takes up a large portion of the visual field giving a powerful sense of presence or 'being there' [32].

Two major inventions occurred in the 1960's with the arrival of the minicomputer and the work of Ivan Sutherland in 1965 entitled "The Ultimate Display ". Sutherland prophesied the development of the first HMD. Sutherland also realized the potential of computers to generate images for flight simulation, where, previously images were generated using video camera. These ideas were combined by two NASA Ames scientists, Fisher and McGreevy, working on a project called the 'virtual workstation' in 1984. From these ideas NASA Ames developed the first commercially viable HMD, called the visual environment display (VIVED), which was based on a scuba divers face mask with the optical screen displays supplied from two Sony Watchman hand-held televisions [32]. This development was unprecedented, as NASA had an HMD that could be produced at an affordable price and the VR industry was born.

3.3 Types of VR system

VR systems can be mainly classified into four categories. Each category can be ranked by the sense of immersion or degree of presence it provides. Immersion or presence can be regarded as powerful in the attention of the user to focus on the task in hand. Immersion is generally believed to be the product of several parameters including level of interactivity, image complexity, stereoscopic view, field of regard and the update rate of the display.

3.3.1 Desktop Virtual Reality

3D graphical virtual world is displayed on a standard computer screen, it is called as Desktop Virtual Reality (DVR) in which PCs and workstations can be used as screen-based VR systems. Using the desktop system, the virtual environment is viewed through a portal or window by utilizing a standard high resolution monitor. After invention of LED display system the resolution and depth of immersion increased. The 3D display can be seen by special types of goggles. Interaction with the virtual environment can occur by conventional means such as keyboards, mice and trackballs or may be enhanced by using 3D interaction devices. The desktop VR system has advantages that they have good level of graphics performance, no special hardware is required. These systems can be regarded as the lowest cost VR solution which can be used for many applications.

3.3.2 Semi-Immersive Projection Systems

Semi-immersive systems are relatively new implementation of VR technology and borrow considerably from technologies developed in the flight simulation field. A semi-immersive system will comprise of relatively high performance graphics computing system which can be coupled with one of the following:

- A large screen monitor
- A large screen projector system
- Multiple television projection systems

By using a wide field of view, these systems can increase the feeling of immersion or presence experienced by the user. However, the quality of the projected image is an important consideration.

3.3.3 Shutter Glasses

This is an old technique. Liquid Crystal Shutter (LCS) glasses are an important technology when considering semi-immersive systems and consist of a lightweight headset with a liquid crystal lens placed over each eye. Stereoscopic works on the principle that in order to perceive depth in a scene, the observer must see slightly different images of the scene under regard in each eye. In the real world this occurs because the two eyes are placed slightly apart in the head, and so each eye views the scene from a slightly different position. The graphics computer used displays slightly different left and right views (known as a stereo pair) of the virtual environment sequentially on the display system. To achieve the stereoscopic effect, the glasses either pass or block an image that is produced on the screen or projected display. When the left image is displayed, the left eye lens is switched on, allowing the viewer's left eye to see the screen. The right eye lens, however, remains off, thus blocking the right eyes view. When the right image is displayed, the opposite occurs. This switching between images occurs so rapidly that it is undetectable by the user, who fuses the two images in the brain to see one constant 3D image.

3.3.4 Fully Immersive Head-Mounted Display Systems

The most direct experience of virtual environments is provided by fully immersive VR systems. These systems are probably the most widely known VR implementation where the user either wears an HMD or uses some form of head-coupled display.

HMD uses small monitors placed in front of each eye which can provide stereo, bi-ocular or monocular images. Stereo images are provided in a similar way to shutter glasses, in that a slightly different image is presented to each eye. The major difference is that the two screens are placed very close (50-70mm) to the eye, although the image, which the wearer focuses on, will be much further away because of the HMD optical system. Bi-ocular images can be provided by displaying identical images on each screen and monocular images by using only one display screen. The most commonly used displays are small Liquid Crystal Display (LCD) panels but more expensive HMDs use Cathode Ray Tubes (CRT) which increase the resolution of the image.

HMD design may partially or fully exclude the user’s view of the real world and enhances the field of view of the computer generated world. The advantage of this method is that the user is provided with a 360°; field of regard meaning that the user will receive a visual image if they turn their head to look in any direction. All fully immersive systems will give a sense of presence that cannot be equaled by the other approaches discussed earlier, but the sense of immersion depends of several parameters including the field of view of the HMD, the resolution, the update rate, and contrast and illumination of the display.

3.3.5 Comparison between Different VRs

There is a comparison between the various VR implementations (see Table 1). It is also important that these implementations are not regarded as distinct boundaries for implementations.

Table 1

Qualitative performance of different VR systems

Main Features	Desktop VR (LED Display)	Semi-Immersive (Projection)	Full Immersive VR (Head-coupled)
Resolution	Medium-High	High	Low-Medium
Scale (perception)	Medium –High	Medium-High	High
Sense of situational awareness(navigation skills)	Medium	Medium	High
Field of regard	Low	Medium	High
Sense of immersion	Medium-Low	Medium-High	Medium-High

3.4 Application of Virtual Reality

- Cognitive Enhancement
- Architecture & Construction
- Education & Training
- Business
- Marketing
- Clinical

Chapter-4
Anatomy of Brain

Brain is the most complex organ in the human body. A normal human brain weight is about 2% of the total body weight. Human brain grows up to 75-80% of the adult size with in the first two years and full size at the age of 6 years. It is situated in a bony case called cranium which protect it from injuries. Brain is covered with cranial meninges. Human brain is wrinkled surface and pinkish grey in color. It is formed of more than 100 billion nerve cells called neurons. Since each neuron can connect with about 25,000 other cells there are about 2.5 million billions inter linked nerve connection in the brain.

4.1 Major Parts of Brain

Brain is made of three main parts: the forebrain, midbrain, and hindbrain. The forebrain consists of the cerebrum, thalamus, and hypothalamus (part of the limbic system). The major parts of the brain are shown in Figure 4.1. The midbrain consists of the tectum and tegmentum. The hindbrain is made of the cerebellum, pons and medulla. Often the midbrain, pons, and medulla are referred to together as the brainstem [33].

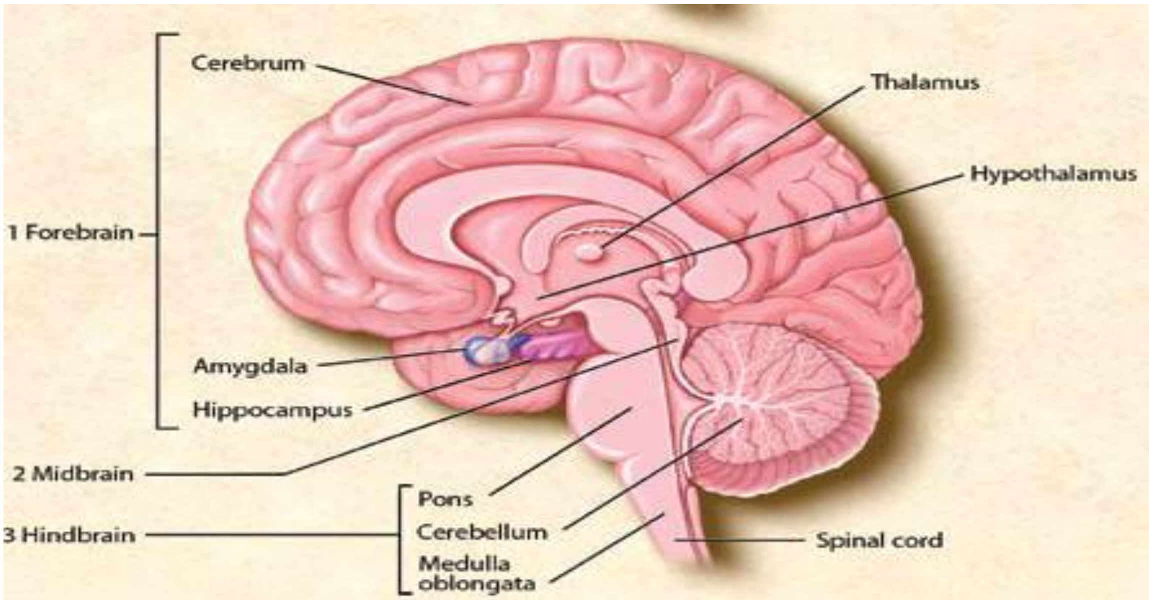

Figure 4.1 Major Parts of Brain [Online1]

4.1.1 Forebrain

Cerebrum is largest part and it is in the front portion. Its main functions include hearing, reasoning, problem solving initiation of movement, coordination of movement, sensing temperature and touch. It is divided by a longitudinal fissure into two hemispheres, each containing four lobes. The frontal, temporal, parietal, and occipital lobes cover the brain's surface which is shown in Figure 4.2. Although specific functions are attributed to each lobe, most activities require coordination of multiple areas in both hemispheres. For example, although the occipital lobe is essential to visual processing, parts of the parietal, temporal, and frontal lobes on both sides also process complex visual stimuli.

Function is extensively lateralized. Visual, tactile, and motor activities of the left side of the body are directed predominantly by the right hemisphere and vice versa. Certain complex functions involve both hemispheres but are directed predominantly by one (cerebral dominance). For example, the left hemisphere is typically dominant for language, and the right is dominant for spatial attention.

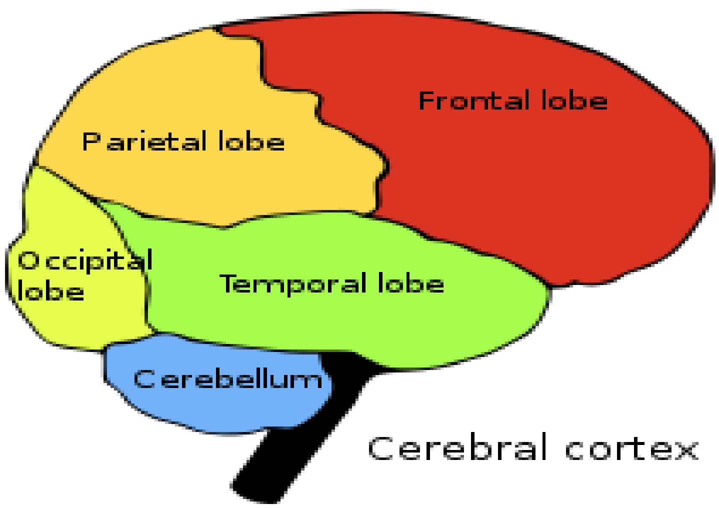

Figure 4.2 Lobes of Cerebrum [34]

The outer surface of the cerebrum is called cerebral cortex. It is a layer of 2-4 mm thick. Cerebral complex has a grayish brown appearance. Hence it is referred to as gray matter. The cerebral cortex contains the primary sensory and motor areas as well as multiple association areas. The primary sensory areas receive somesthetic, auditory, visual, olfactory, and gustatory stimuli from specialized sensory organs and peripheral receptors. Sensory stimuli are further processed in association areas that relate to one or more senses. The primary motor cortex generates volitional body movements, motor association areas help plan and execute complex motor activity. Some cortical areas are heteromodal. They are not restricted to any single motor or sensory function but receive convergent information from multiple sensory and motor areas of the brain. The areas in the frontal, temporal, and parietal lobes integrate sensory data, motor feedback, and other information with instinctual and acquired memories. This integration facilitates learning and creates thought, expression, and behavior.

Functions of the lobes are

Frontal Lobe: The frontal lobe is the largest part of the brain located in the front of the head. It involves in the inner monitoring of complex thoughts and actions and creative ideas. It helps in the translation of perceptions and memories in to action. Will power and personality is affected by the development of this lobe. Abstracting ability and decision making ability is controlled by this lobe. It is mainly associates with reasoning, planning, parts of speech, movement, emotions and problem solving.

Parietal Lobe: It is the middle part of the brain. It is the main area for feeling of touch, hot, cold and pain. It takes information's from surroundings and organizes it and communicates to the other part of the brain. It controls activities like reading a clock, dressing ourselves. It is mainly associated with movement, orientation, recognition, perception of stimuli.

Occipital Lobe: It is the back part of the cerebrum. Occipital lobe decodes and interprets the visual information's such as shape and color.

Temporal Lobe: It is situated at the side of the brain. Temporal lobe helps in the decoding and interpretation of sounds. It helps in the language comprehension. It is the centre for memory and emotions. It is mainly associated with perception and recognition of auditory stimuli, memory and speech.

4.1.2 Midbrain

It forms the middle portion of the brain. It controls the activity of voluntary muscles. It is also concerned with auditory and visual reflexes. Mid brain consists of four small lobes called corpora quadrigemina. The upper lobes are a pair of superior colliculi and lower lobes are called inferior colliculi. The superior part of colliculi receives sensory information from eyes and muscles of the head. They control all visual reflexes by coordinating the movements of head and eyes. The inferior pair of colliculi receives sensory impulses from the ears and muscles of the head. They control all auditory reflexes.

4.1.3 Hind brain

Hind brain consists of cerebellum, medulla oblongata and pons varoli.

Cerebellum is the second largest part of the brain. It is placed between the cerebral hemispheres and brain stem. It is made up of two cerebral hemispheres. It maintains posture and equilibrium of the body. Cerebellum plays an important role in controlling all rapid muscular activities such as running, typing, talking etc

Medulla oblongata is the posterior most part of the brain. It connects the various parts of the brain with spinal cord. Medulla controls important subconscious activities such as breathing, digestion, heart beat etc.

Pons varoli forms the floor of the brain stem. It is a neural connection connecting the cerebral cortex with cerebellum. It relays the information between cerebrum and cerebellum.

4.2 Neurons

The brain contains one hundred billion nerve cells called neurons. Information is constantly exchanged between the brain and other parts of the body by both electrical and chemical impulses. Cells called neurons are responsible for carrying this information. Each neuron is capable making contacts with thousands of other neurons. It creates a complex network of neurons.

A neuron has three main parts. The **cell body** directs all the neuron’s activities. **Dendrites,** short branches that extend out from the cell body, receive messages from other neurons and pass them on to the cell body. An **axon** is a long fiber that transmits messages from the cell body to the dendrites of other neurons or to other tissues in the body, such as muscles. A protective covering, called the **myelin sheath,** covers the axons of many neurons. Myelin insulates the axons and helps messages from nerve signals travel faster, farther and more efficiently [33]. The parts of the neuron were shown in Figure 4.3.

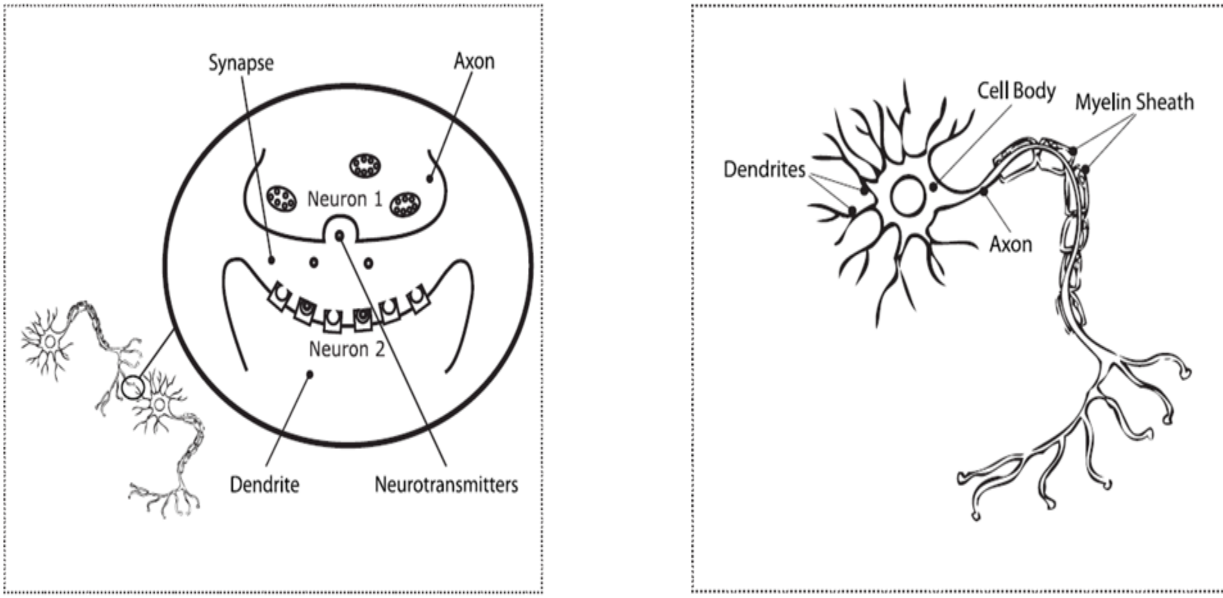

Figure 4.3 Neurotransmission and Single Neuron

4.3 Neuro-Transmission

The exchange of information between the axon of one neuron and the dendrites of another neuron is called neurotransmission which is shown in Figure 4.3. Neuro-transmission takes place through the release of chemicals into the space between the axon of the first neuron and the dendrites of the second neuron. These chemicals are called neuro-transmitters. The space between the axon and the dendrite is called a **synapse.**

When neurons communicate, an electrical impulse traveling down the axon causes neuro-transmitters to be released from the end of the axon into the synapse. The neuro-transmitters cross the synapse and bind to special molecules, called receptors, on the dendrite of the second neuron. Receptors are found on the dendrites and cell bodies of all neurons. The receptors convert the information into chemical or electrical signals which are then transmitted to the cell body and eventually to the axon. The axon then carries the signal to another neuron or to body tissues such as muscles.

Once a neuro-transmitter binds to a receptor, a series of events follow. First, the message carried by the neuro-transmitter is passed on to the receiving neuron. Second, the neurotransmitter is inactivated. It is either broken down by an enzyme or re-absorbed by the axon from which it was released. Other molecules, called transporter molecules, complete this re-absorption process. These molecules are located in the cell membranes of the axon that releases the neuro-transmitters. They pick up specific neuro-transmitters from the synapse and carry them back across the cell membrane and into the axon, where they are recycled for use at a later time.

The human body produces many different types of neuro-transmitters. Each neuro-transmitter has a specific role to play in the functioning of the brain. A neuro-transmitter binds to a receptor in much the same way that a key fits into a lock; a specific neuro-transmitter will bind only to its corresponding receptor.

Neuro-transmitter messages can be generalized as either excitatory or inhibitory messages. An excitatory neuro-transmitter is one that increases the activity of neurons, and an inhibitory neurotransmitter decreases the activity of neurons. In neurons, they have support cells called glial cells that provide nutrition and oxygen to the neurons. The glial cells are responsible for insulating one neuron from the neighbouring neuron and also for destroying the pathogens and removing dead neurons. It may be recalled that pathogens are biological agents that causes diseases or illness. These are called germs.

Chapter-5
Electroencephalograph (EEG)

Neural activity of the human brain starts between the 17th and 23rd week of prenatal development. It is believed that from this early stage and throughout life electrical signals generated by the brain represent not only the brain function but also the status of the whole body. The human brain is a complex system, and exhibits rich dynamics in cells. Among the noninvasive techniques for probing human brain dynamics, electroencephalography (EEG) provides a direct measure of brain activity with millisecond temporal resolution [33]. The activity is usually recorded over a small period of time. The main application of EEG is in diagnosing epilepsy. EEG signals are also being used in brain computer interface and have futuristic applications such as control of machines by thought process.

The concepts of electro - (referring to registration of brain electrical activities) encephalo - (referring to emitting the signals from the head), and gram (referring to graphy), which means drawing or writing, All the term were combined so that the EEG was henceforth used to denote electrical neural activity of the brain.

5.1 History of EEG

Carlo Matteucci and Emil Du Bois-Reymond were the first people to measure the electrical signals emitted from muscle nerves using a galvanometer and established the concept of neurophysiology [34, 35]. Richard carton C, a scientist from Liverpool, England, used a galvanometer and placed two electrodes over the scalp of a human subject and thereby first recorded brain activity in the form of electrical signals in 1875. The discoverer of the existence of human EEG signals was Hans Berger. He began his study of human EEGs in 1920 [36]. Depth electroencephalography of a human was first obtained with implanted intra-cerebral electrodes by Mayer and Hayne. Invention of intracellular microelectrode technology revolutionized this method and was used in the spinal cord by Brock et al. in 1952 and in the cortex by Phillips in 1961.

5.2 Neuro-Physiological Basis of EEG

The brain's electrical activity is due to firing of billions of neurons. Neurons are electrically charged by membrane transport proteins that pump ions across their membranes. The electric potential generated by single neuron is far too small to be picked up by EEG. Therefore EEG activity always reflects the summation of the synchronous activity of thousands or millions of neurons that have similar spatial orientation. The amplitude of the EEG is about 100 µV when measured on the scalp, and about 1-2 mV when measured on the surface of the brain. The bandwidth of this signal is from under 1 Hz to about 50 Hz, as demonstrated in Figure 5.1 [Online 2]. Only large populations of active neurons can generate electrical activity recordable on the head surface. Weak electrical signals detected by the scalp electrodes are massively amplified and then displayed on paper or stored to computer memory.

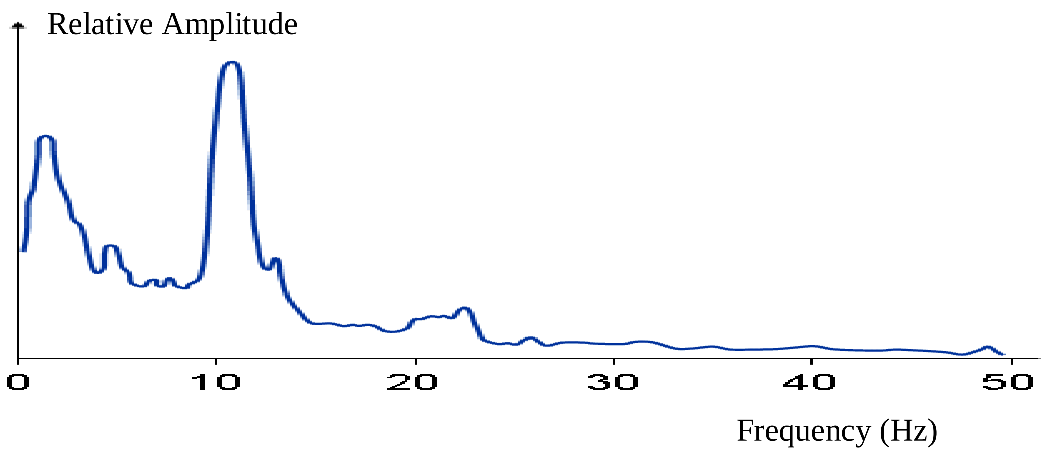

Figure 5.1 Frequency Spectrum of Normal EEG

Brain electrical current consists mostly of Na^{+}, K^{+}, Ca^{++}, and Cl^{-} ions that are pumped through channels in neuron membranes in the direction governed by membrane potential. The mechanism within neurons creates action potentials through the exchange between sodium and potassium ions in and out of the cell. Adenosine Triphosphate (ATP) provides energy for proteins to pump 300 sodium ions per second out of the cell while simultaneously pumping 200 potassium ions per second into the cell. Thus making the outside of the cell more positively charged and the neuron negatively charged.

This rapid ionic movement causes the release of action potentials, which are discrete electrical signals that travel down axons. Discrete signals mean either the neuron is fired to create action potential, or it remains inactive. The strength of signal travelling from axon of one neuron to the dendrite of subsequent neuron using synapse is determines by the effective area of contact through release of neuro-transmitters. The signal is produced by the extra-cellular ionic currents caused by electrical activity of dendrites. With every neural activity, this area keeps on changing, and the learning process takes place. All these signals are summed up and then if the final signal is above a threshold level, that neuron is fired, else it remain inactive.

The final signal reaches to scalp is the sum of all the signals created in brain, with different spatial orientation and distance from the scalp electrode. Neurons are mutually connected into neural nets through synapses. Adults have about 500 trillion (5×10^{14}) synapses. The number of synapses per one neuron with age increases, however the number of neurons with age decreases, thus the total number of synapses decreases with age too.

Scalp EEG activity shows oscillations at a variety of frequencies. Several of these oscillations have characteristic frequency ranges, spatial distributions and are associated with different states of brain functioning (*e.g.*, waking and the various sleep stages). These oscillations represent synchronized activity over a network of neurons.

5.3 Classification of EEG Waves

EEG signal is often measured in microvolt range and is typically described in terms of either rhythmic activity or in terms of transients. The rhythmic activity of brain is divided into five major bands and named delta, theta, alpha, beta and gamma, which are described below.

5.3.1 Delta Waves (0.5-4 Hz)

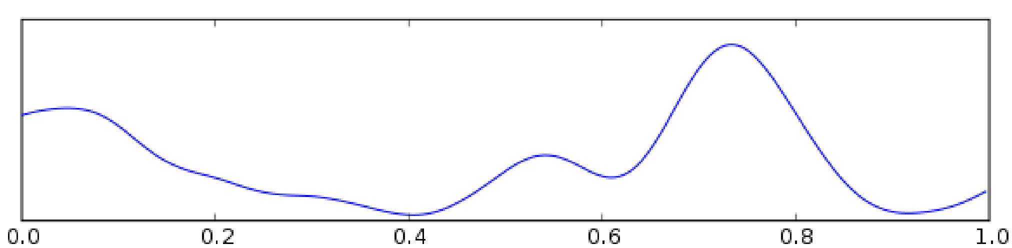

Figure 5.2 Delta Wave of EEG [Online 3]

Its amplitude ranges between 20-100μV. The pattern of delta wave is shown in Figure 5.2 [Online 3]. These rhythms basically reflect the EEG activity in sleeping infants and adults respectively. These waves are found during periods of deep sleep in most people and are characterized by very irregular and slow wave pattern, which is shown in Figure 5.2. Delta brainwaves are generated in the right hemisphere, though they may be observed in widespread patterns throughout various parts of the brain. The delta brainwave range is associated with empathy, the unconscious mind, and a decreased sense of awareness. These waves are useful in detecting tumors and abnormal brain behaviors.

5.3.2 Theta Waves (4-8 Hz)

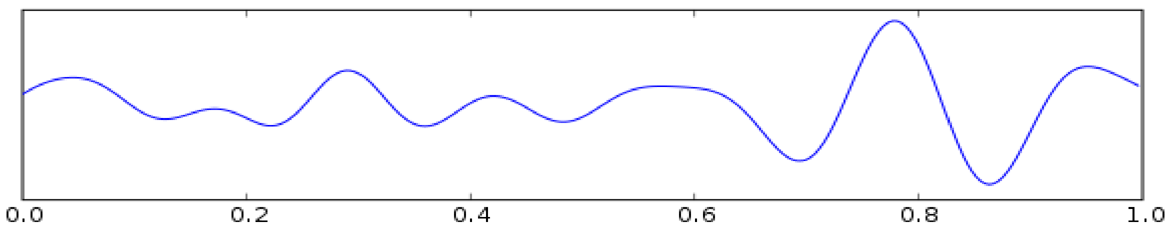

Figure 5.3 Theta Wave of EEG [Online 3]

Theta waves are frequently observed in young children. In older children and adults, it tends to appear during drowsy, meditative, or sleeping states, but not during the deepest stages of sleep. The pattern of theta wave is shown in Figure 5.3 [Online 3]. Active movements such as running, jumping, bar-pressing, or exploratory sniffing are reliably associated with theta; inactive states such as eating or grooming are associated with less irregular activity.

Theta brainwaves are generally thought of as the brainwaves that are dominant in people with Alzaimer disease, high levels of relaxation, high levels of creativity, and random thinking. Frontal midline theta is reported during tasks requiring self-control, internal timing, and assessment of reward; during working memory tasks and during tasks requiring memory retention and mental imagery.

5.3.3 Alpha Waves (8-12 Hz)

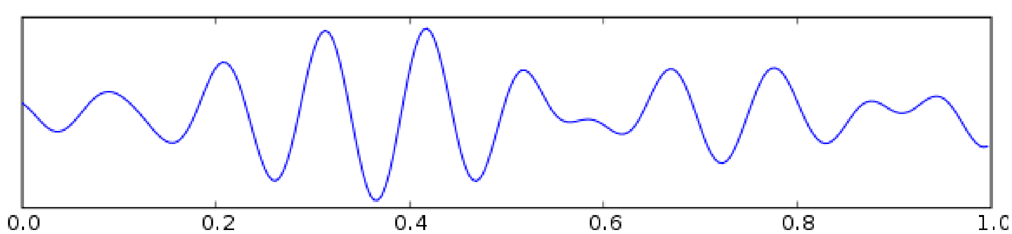

Figure 5.4 Alpha Waves of EEG [Online 3]

Its amplitude ranges between 20-60 μV. These waves are originated from occipital lobe when quietly sitting in relaxed position with eyes closed. The pattern of alpha wave is shown in Figure 5.4 [Online 3]. Alpha waves are generally seen in all age groups but are most common in adults. They occur rhythmically on both sides of the head but are often slightly higher in amplitude on the non dominant side, especially in right-handed individuals. Alpha activity disappears normally with attention for *e.g.*, mental arithmetic, stress, opening eyes. In most instances, it is regarded as a normal waveform. An abnormal exception is alpha coma, most often caused by hypoxicischemic encephalopathy of destructive processes in the pons (eg, intracerebral hemorrhage). In alpha coma, alpha waves are distributed uniformly both anteriorly and posteriorly in these patients, who are unresponsive to stimuli.

5.3.4 Beta Waves (12-30 Hz)

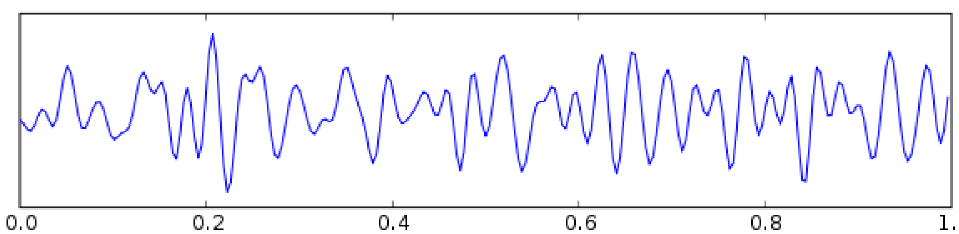

Figure 5.5 Beta Waves of EEG [Online 3]

Figure 5.5[Online 3] shows beta waves of EEG in the amplitude ranges from 2-20 μV. Beta waves are associated with normal waking consciousness. Beta activity is 'fast' activity. It is usually seen on both sides in symmetrical distribution and is most evident frontally. It may be absent or reduced in areas of cortical damage. It is generally regarded as a normal rhythm. It is the dominant rhythm in patients who are alert or anxious or who have their eyes open.

Beta waves are observed in all age groups. They tend to be small in amplitude and usually are symmetric and more evident interiorly. Over the motor cortex beta waves are associated with the muscle contractions that happen in isotonic movements and are suppressed prior to and during movement changes. Increasing beta activity concludes Ability to think quickly, Goal oriented, highest levels of focus, Positive thoughts, Increase in I.Q**.**

5.3.5 Gamma Waves (above 30 Hz)

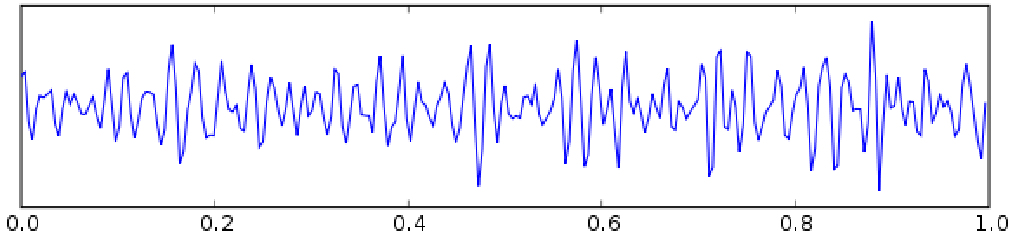

Figure 5.6 Gamma Waves of EEG [Online 3]

Figure 5.6 [Online 3] shows pattern of gamma eaves which are originated from somatosensory cortex. It is observed during short term memory matching of recognized objects, sounds or tactile sensation. Gamma waves relate to neural consciousness via the mechanism for conscious attention. These waves have direct impact on cognition. An increase in gamma activity indicates enhanced perception, improved memory, high level of information processing, high level of focus, boosted learning abilities.

Also, cross frequency coherence—the synchrony between alpha, beta and gamma—increases with higher cognitive load on a continuous mental arithmetic task. Cross frequency coherence is considered important for integrating anatomically distributed processing in the brain. There are also other rhythms introduced by researchers such as:

(a) Phi (ϕ) rhythm (less than 4 Hz) occurring within two seconds of eye closure. The phi rhythm was introduced by Daly [37].

(b) Kappa (κ) rhythm, which is an anterior temporal alpha-like rhythm. It is believed to be the result of discrete lateral oscillations of the eyeballs and is considered to be an artifact signal.

(c) The sleep spindles (also called the sigma (σ) activity) within the 11–15 Hz frequency range.

(d) Tau (τ) rhythm, which represents the alpha activity in the temporal region.

(e) Eyelid flutters with closed eyes, which gives rise to frontal artifacts in the alpha band.

(f) Chi (χ) rhythm is a mu-like activity believed to be a specific pattern in range of 11–17 Hz [38].

(g) Lambda (λ) waves are most prominent in waking patients, but are not very common. They are sharp transients occurring over the occipital region of the head of walking subjects during visual exploration. They are positive and time-locked to saccadic eye movement with varying amplitude, generally below 90 μV [39].

5.4 Commonly Used Methods for EEG Measurement

Electroencephalography (EEG): Electroencephalography (EEG) is the recording of electrical activity along the scalp produced by the firing of neurons within the brain. The greatest advantage of EEG is speed. Complex patterns of neural activity can be recorded occurring within fractions of a second after a stimulus has been administered. EEG provides less spatial resolution compared to MRI and PET. EEG can determine the relative strengths and positions of electrical activity in different brain regions.

Positron Emission Technique (PET): It is the imaging technique of brain giving information about glucose and oxygen structures in the brain, blood flow, and blood and volume in the brain. The main advantage of PET is that it can compare cross-sections of brain regions simultaneously.

Functional Magnetic Resonance Imaging (fMRI): It is also an imaging technique of anatomical structures, derived from magnetic imaging. It allows for measurement of blood oxygen concentration, blood flow, and blood volume. The main advantage of fMRI is that it can able to see ongoing changes as well as strong spatial resolution, and quick/effective data collection.

5.5 EEG Artifacts

Electrical signals detected along the scalp by an EEG machine, but which have non-cerebral origin, are called artifacts. Before the raw data can be given as input for further processing, it has to be preprocessed to correct it for EOGs and EMGs. Also noise from power line has to be eliminated. Artifacts affect the quality of the signal hence it makes it difficult for visualization. Artifacts can lead to wrong interpretation of data and it can change the basic characteristics of the signal.

Some of the commonly observed artifacts in the EEG recordings are

5.5.1 Electro Ocular Gram (EOG)

EEG basically reflects the activity of the brain. While recording the data sometimes the subjects might blink hence a false signal or an artifact called EOG is generated. The eye forms an electric dipole (Cornea being positive and retina being negative) any eye movement would produce an electric field around the eye which would traverse into the scalp and recorded as an artifact while acquiring the EEG [40]. The EOG is a high amplitude signal which masks the original signal recorded at the particular instance of blinking within it.

If uncorrected the high amplitude data recorded in the form of EOG can very well be misunderstood as the signal of interest and this would lead to faulty conclusions. Though EOG on its own can be a signal of use, it is considered an artifact when it is not needed. For example EOG recordings can be used to determine the gaze ions, but in classification purposes using EEG, EOG is hardly considered as a relevant data. The EOG can be eliminated by placing two electrodes on the eye lids and record the ocular signal. This ocular signal can be subtracted with the EEG signal recorded at that particular instance when the eye blinks. Other way to avoid EOG is to instruct the subject not to blink their eyes during the data acquisition. EOG can also be eliminated by designing adaptive filters [40].

5.5.2 Electromyogram (EMG)

EEG signals sometimes are intermingled with electrical activity of the muscle tissue overlaying the skull. Also the EMG produced by the muscles in other parts of the body propagates through the body and can also reach the skull. Muscle artifacts are usually observed in higher frequencies and can be easily identified due to their high values as comparing the local back ground activity [41].

5.5.3 Electrocardiogram (ECG)

ECGs represent the activity of the heart. Though the heart functions independent of the brain, the electrical activity produced by the heart in the form of ECGs are recorded by the EEG electrodes. Again an EEG wave form uncorrected for ECGs and EMGs would look distorted and would lead to faulty analysis of the recorded signal. The ECG artifact is not always observed.

5.5.4 Power Line Noise

Power Line signal is induced due to the power line to which the data acquisition system is connected to. The frequency associated with this noise is 50 Hz. The noise from the power line can be eliminated by designing a notch filter at 50 Hz which would remove the data at 50 Hz and thus eliminating the noise from the power line.

5.6 EEG Signal Recording Systems

For recording the EEG signal, small metal discs usually made of stainless steel, tin, gold or silver covered with a silver chloride coating, are placed on the scalp in special position. The scalp area is prepared by conductive gel or paste to reduce impedance. Impedance of the electrode is measure by ac excitation at a specified frequency. The impedance should be around 100 Ω or lesser.

International 10-20 system

The International 10-20 System of Electrode Placement is the most widely used method to describe the location of scalp electrodes. The 10-20 system is based on the relationship between the location of an electrode and the underlying area of cerebral cortex. Each site has a letter (to identify the lobe) and a number or another letter to identify the hemisphere location. The Figure 5.7 [Online 4] shows the different lobe in human brain and the labeling of electrodes in 10-20 system.

The letters used are: "F" - Frontal lobe, "T" - Temporal lobe, "C" - Central lobe, "P" - Parietal lobe, "O" - Occipital lobe. (Note: There is no central lobe in the cerebral cortex. "C" is just used for identification purposes only) .Even numbers (2, 4, 6, 8) refer to the right hemisphere and odd numbers (1, 3, 5, 7) refer to the left hemisphere. "Z" refers to an electrode placed on the mid line.

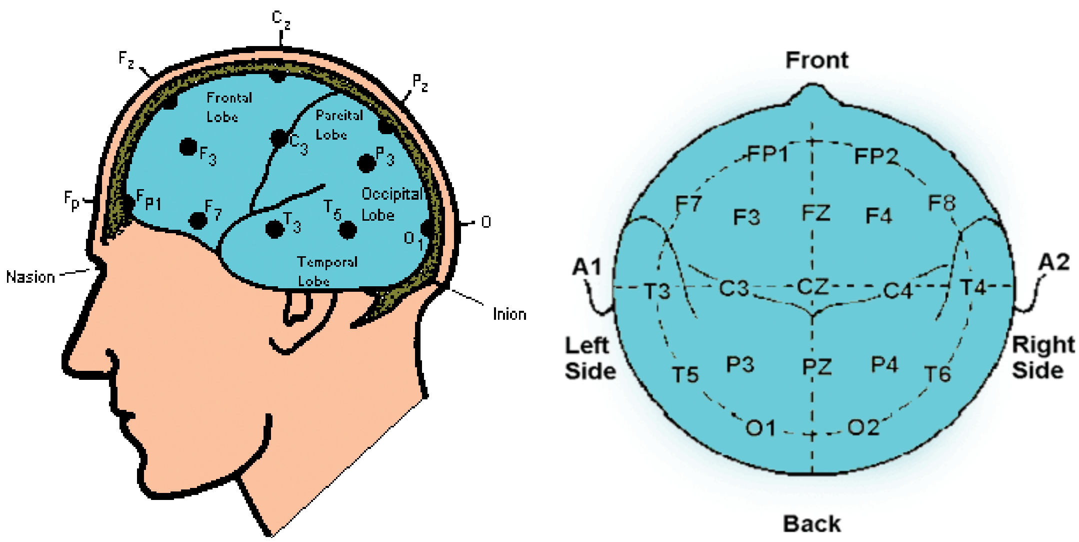

Figure 5.7 Different Lobes and Associated Labels of Points in 10-20 System [Online 4]

The positions are determined as follows: Reference points are nasion, which is point between the forehead and nose, and inion, which is the bony lump at the base of the skull on the midline at the back of the head. From these points, the skull perimeters are measured in the transverse and median planes. The Figure 5.8 [Online 4] shows the electrode placement from reference point. Electrode locations are determined by dividing these perimeters into 10% and 20% intervals. Thus "10" and "20" in 10-20 system refer to the 10% and 20% inter electrode distance.

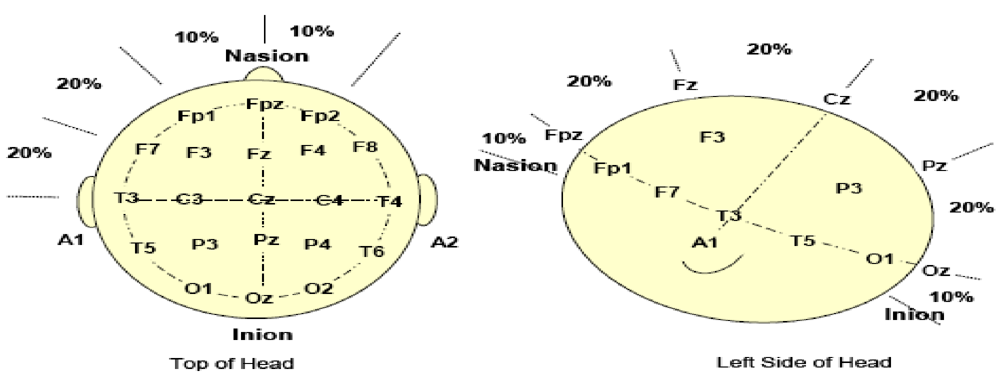

Figure 5.8 International 10-20 System for Electrode Placement [Online 4]

When recording a more detailed EEG with more electrodes, extra electrodes are added utilizing the spaces in-between the existing 10-20 system. This new electrode-naming-system is more complicated giving rise to the Modified Combinatorial Nomenclature (MCN). This MCN system uses 1, 3, 5, 7, and 9 for the left hemisphere which represents 10%, 20%, 30%, 40% and 50% of the inion-to-nasion distance respectively. 2, 4, 6, 8, 10 are used to represent the right hemisphere.

The signals from EEG electrode are taken with respect to some reference. Sometimes the average to two electrodes placed on the earlobes is taken as reference. These electrodes are marked as A1 and A2.

5.7 Signal Processing

The raw signal of EEG is amplified and processed in signal processing techniques. Signal processing of an EEG is done due to amplification and the recognition of some aspect of the EEG that correlates with the physiology and pharmacology of interest [41]. Figure 5.9 shows the block diagram of a typical EEG based task classification system.

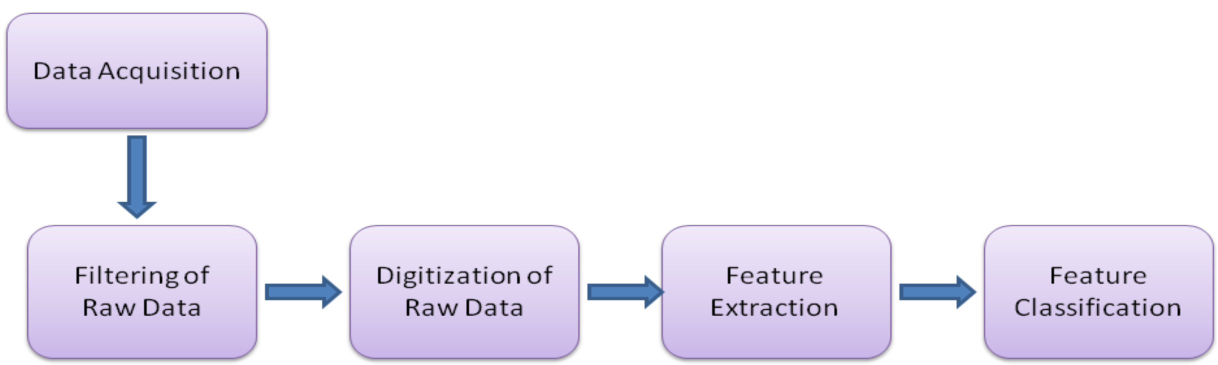

Fig 5.9 General Signal Processing Steps [41]

The signal processing consists of the following steps:

5.7.1 Filtering of raw data

The raw EEG is filtered for noise induced from the power lines, EMG and EOG etc. Though EMG and EOG might be useful in extracting some vital information most of the times they hinder in proper classification. The task of filtering is accomplished by implementing various filters like band pass filters, low pass filters, high pass filters, and adaptive filters and by visual inspection [42].

5.7.2 Digitization of raw data

Digitization of raw data is performed to convert the analog raw data into digital data. Analog signals are continuous and smooth. Analog signals are continuous in both time and signal. They can be measured or displayed with any degree of precision at any moment in time. Digital signals are fundamentally different because they represent discrete points in time and their values are quantities to a fixed resolution rather than continuous. The binary world of computers and digital signal processors operates on binary numbers, which are sets of bits. Digital signals are also quantized in time, unlike analog signals, which vary smoothly from moment to moment. When translation from analog to digital occurs, it occurs at specific points in time. The inverse of the separating of the time points which is constant is called sampling frequency and it is expressed in Hz. In latest EEG recording systems the acquired data is sometimes found digital, in this case this step is ignored.

5.7.3 Feature Extraction

Feature extraction involves extracting the relevant data from the digitized data by which proper classification can be done. Feature extraction is the most important aspect of any classification process. The extracted feature contains the discriminatory information hence the accuracy of feature extraction affects the accuracy of the classification. Feature extraction can be done in both time and frequency domain.

Some examples of time domain analysis are common spatial patters, auto regressive parameter estimation and basic probability and statistical analysis. Some examples of frequency domain analysis are Fourier spectrum analysis and power spectral density estimation. Data reduction can also be achieved in the feature extraction process as only the relevant data is selected for classification purposes and thus reducing the processing the time.

5.7.4 Feature Classification

Once the proper feature is extracted they must be classified or identified as a certain occurrence or class. Classification algorithms are available which are trained on the extracted features for classification purposes. Classification methods can be classified into

Linear Method of Classification

In this method of classification the classifier uses a simple decision boundary. The boundary line separates two classes based on which side of the boundary they belong to. The boundary is linear in nature. Linear boundaries are easy to design and implement. On the other hand the accuracy of classification is less comparing non linear classifiers. Linear Fisher Discriminant and Large Margin classification analysis are good examples of a linear classifier. Linear classifiers have lesser parameters to tune to hence they are less prone to over fitting. The Figure 5.10 shows the example of a linear classifier. This gives a stability and robustness to the classifier. Figure shows a typical linear classifier boundary [43, 44].

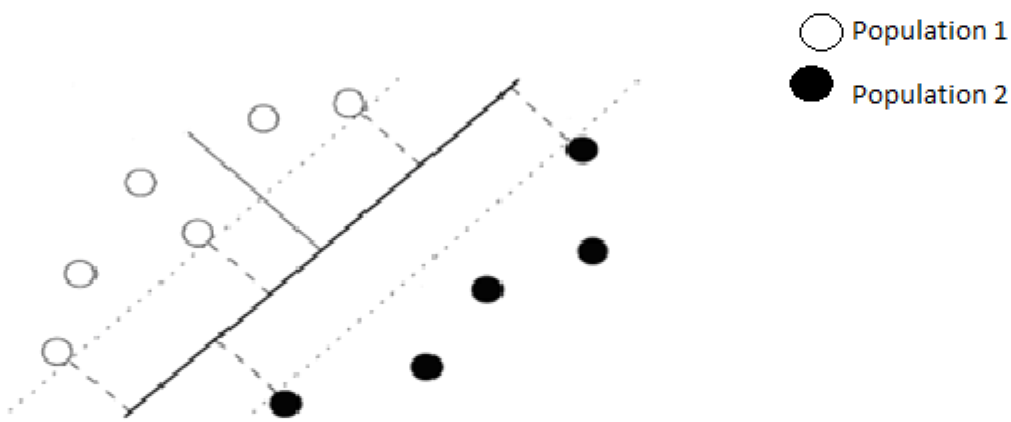

Figure 5.10 Example of Linear Classifier [43]

Non Linear Method of Classification

In this method of classification the classifier uses or creates boundaries based on the nature of the classes to be separated. The boundary surface can be irregular unlike a linear boundary. Non linear classifiers are difficult to design and implement. The accuracy of classification is high. Some examples of non linear classifiers are Support Vector Machines and Artificial Neural Networks and quadratic classifiers. The non-linear classifiers have more parameters associated with them to tune them hence they are prone to over fitting. Figure shows a typical non linear classifier boundary [43, 44].

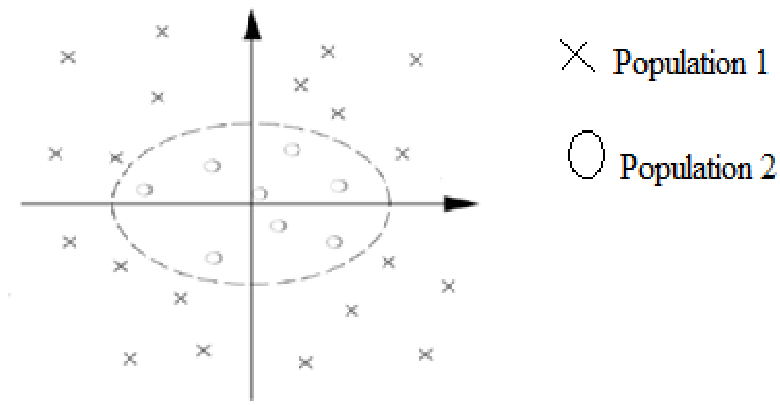

Figure 5.11Example of Two Dimensional Non linear Classifier [44]

The Figure 5.11 shows the example of a two dimensional non linear classifier. Its shows the non linearity in its classification.

Chapter-6
Description of Attention and Alertness

6.1 Attention

Attention is a concept often invoked by psychologists, but one that does not have a standard, universally accepted definition. Many psychologists are still debating what attention is, and what it does for our mental processes. However, most psychologists agree that the brain has some inherent limitations regarding the amount of information it can process.

Attention may be defined as the selective enhancement of some behavior at the expense of other behavior. Attention is one of the interesting aspects of cognitive psychology and it can be described as the process whereby a person concentrates on some parts of the environment while relatively excluding other things [45]. It is a cognitive process for selecting between the currently performed tasks [46]. For example, someone can concentrate on watching a movie on TV while ignoring the conversations in the room and only listening to those occurring in that movie. On the other hand, this is not the case all the time since attention can be divided between two or more tasks that need to be done at the same time such as talking on a cell phone while driving a car. The results of this process, i.e. divided attention, is one of the concepts of attention.

Attention is so important to human cognition because it places limits on what we think about at the same time that it helps determine what our thoughts, words, beliefs, and deeds are "about" at any given time. Concerning the issue of limits, consider a specific study involving visual attention.

6.2 Basic Categories of Attention

Basic categories of attention are

- Focused attention - It is defined as respond to specific stimuli which is given at task performing.
- Sustained attention ability to maintain consistent concentration on performing a task.
- Selective attention ability not to be distracted by interfering or competing stimuli.
- Alternating attention ability to alternate the focus of attention.

- Divided attention ability to respond to two or more kinds of stimuli simultaneously.
- Visual attention ability to respond on dynamic visual stimuli. The aim of this study is to find out the change in brain activity in visual attention and alertness, so we will mainly emphasize on visual attention.

6.3 Neuro Science in Visual Attention

The brain regions that participate in the deployment of visual attention include most of the early visual processing area [47]. A simplified overview of the main brain areas involved is shown in the Figure 6.1.

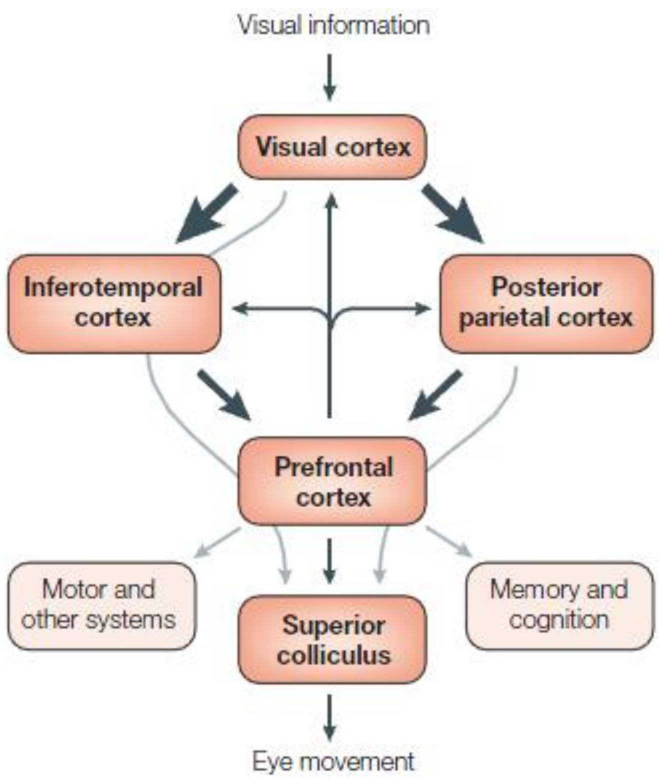

Figure 6.1 Neural Process during Visual Attention [47]

Visual information enters the primary visual cortex via the lateral geniculate nucleus (not shown), from there, visual information progresses along two parallel hierarchical streams. Cortical areas along the 'dorsal stream' (including the posterior parietal cortex; PPC) are primarily concerned with spatial localization and directing attention and gaze towards objects of interest in the scene. The control of attentional is mostly take place in the dorsal stream.

The Cortical areas along the 'ventral stream' (including the infer-temporal cortex; IT) are mainly concerned with the recognition and identification of visual stimuli. Although probably not directly concerned with the control of attention, these ventral stream areas have indeed been shown to receive attentional feedback modulation, and are involved in the representation of attended locations and objects (that is, in what passes through the attentional bottleneck). In addition, several higher-function areas are thought to contribute to attentional guidance, in that lesions in those areas can cause a condition of 'neglect' in which patients seem unaware of parts of their visual environment. From a computational viewpoint, the dorsal and ventral streams must interact, as scene understanding involves both recognition and spatial deployment of attention. One region where such interaction has been extensively studied is the prefrontal cortex (PFC). Areas within the PFC are bi-directionally connected to both the PPC and the IT [48], in addition to being responsible for planning action (such as the execution of eye movements through the superior colliculus (SC)), the PFC also has an important role in modulating, via feedback, the dorsal and ventral processing streams.

6.4 Alertness

An important attentional function is the ability to prepare and sustain alertness to process high priority signals. The relationship between the alert state and other aspects of information processing has been worked out in some detail for letter and word matching experiments [49].

The passive activation of internal units representing the physical form of a familiar letter, its name, and even its semantic classification (*e.g.* vowel) appears to take place at about the same rate, whether subjects are alert and expecting a target, or whether they are at a lower level of alertness because the target occurs without warning. The alert state produces more rapid responding, but this increase is accompanied by a higher error rate. It is as though the build-up of information about the classification of the target occurs at the same rate regardless of alertness, but in states of high alertness, the selection of a response occurs more quickly, based upon a lower quality of information, thus resulting in an increase in errors. These results led to the conclusion that alertness does not affect the build-up of information in the sensory or memory systems but does affect the rate at which attention can respond to that stimulus [49].

6.5 Neuro Science in Alertness

Anatomical evidence has accumulated on the nature of the systems producing a change in the alert state. One consistent finding is that the ability to develop and maintain the alert state depends heavily upon the integrity of the right cerebral hemisphere [50]. This finding fits very well with the clinical observation that patients with right-hemisphere lesions more often show signs of neglect, and it has sometimes led to the notion that all of spatial attention is controlled by the right hemisphere.

There is evidence that the maintenance of the alert state is dependent upon right-hemisphere mechanisms, and also that it is closely tied with attention. These two facts both suggest that the norepinephrine system arising in the locus coeruleus may play a crucial role in the alert state. Moreover, Robinson has shown in rats that lesions of the right cerebral hemisphere but not of the left hemisphere lead to depletion of norepinephrine on both sides, and that the effects are strongest with lesions near the frontal pole [51]. These findings are consistent with the idea that norepinephrine pathways course through frontal areas, dividing as they go backward toward posterior areas. Thus, an anterior lesion would have a larger effect.

In a nut shell alertness involves a specific subsystem of attention that acts on the posterior attention system to support visual orienting and probably also influences other attentional subsystems. Functionally, activation of norepinephrine works through the posterior attention system to increase the rate at which high priority visual information can be selected for further processing. This more rapid selection is often at the expense of lower quality information and produces a higher error rate.

Chapter-7
Material and Methodology

This chapter describes the Virtual park scenarios, EEG signal acquisition by Emotiv Head Set and its theory, MATLAB used for the analysis of EEG signal with the help of Wavelet Transform. EEG signals are very sensitive to the different kind of artifacts. For removing the artifacts the filters were used.

In the present research work, EEG signals were picked up with the help of Emotiv Head Set at F3, F4, O1 and O2 channels by giving visual stimulus in both two dimensional scenarios and desktop VR scenarios because these channels are mainly activated during the visual stimuli task.

7.1 Virtual Park Scenarios

Three different park scenarios were used as visual stimuli. The scenarios were in both two dimensional displays (2D) and three dimensional displays (3D). The first scenario has rich set of texture and fewer objects. The flying camera was situated at more height. The time period of this scenario was about 120 seconds. The second scenario has good amount of texture and objects. The time period of this scenario was 85 seconds. The flying camera was situated at less height as compare to first scenario. The third scenario has fair amount of texture and objects. The time period of this scenario was 80 seconds. This study is not depending on time period. The flying camera was situated at less height as compare to all scenarios. The stereoscopic goggle was used for three dimensional displays. The user can easily navigate into the environment by using the joystick. In this research work the user was navigated by flythrough camera function. The flythrough camera function was used for freely navigation without joystick.

7.1.1 Hardware and Software used

- Intel i5 processor (or equivalent)
- Microsoft Windows XP with Service Pack 2, Microsoft Windows Vista or Microsoft Windows 7
- 4GB RAM

- 200 MB available disk space.
- Joystick
- Stereoscopic goggles

7.2 Immersion Questionnaires

In this research questionnaire was a created to analyze the immersion *i.e.* Immersion Questionnaires. The Immersion Questionnaire (IQ) was based on fine details of the various scenarios. After each scenario the questionnaires were asked to the subject. The questionnaires were different in two dimensional scenarios and VRE.

7.3 Emotiv Neuro Headset

Emotiv Neuro Headset is a very efficient tool which is used to acquiring the EEG signals. It is very user friendly hardware and easy to use.

7.3.1 Hardware and Software used

- 2.4 GHz Intel Pentium 4 processor (or equivalent)
- Microsoft Windows XP with Service Pack 2, Microsoft Windows Vista or Microsoft Windows 7
- 1GB RAM
- 50 MB available disk space.
- One or two unused USB 2.0 ports

7.3.2 Items in the EPOC Headset Kit

The Figure 7.1 [Online 5] shows the headset kit of the Emotiv Head Set

- Headset Assembly with Rechargeable Lithium battery already installed
- USB Transceiver Dongle
- Hydration Sensor Pack with 16 Sensor Units
- Saline solution
- 50/60Hz 100-250 VAC Battery Charger (US customers) or USB charger (non-US customers)

- CD Installation Disk for Windows XP or Vista (for EPOC consumer headset. SDKs are delivered electronically

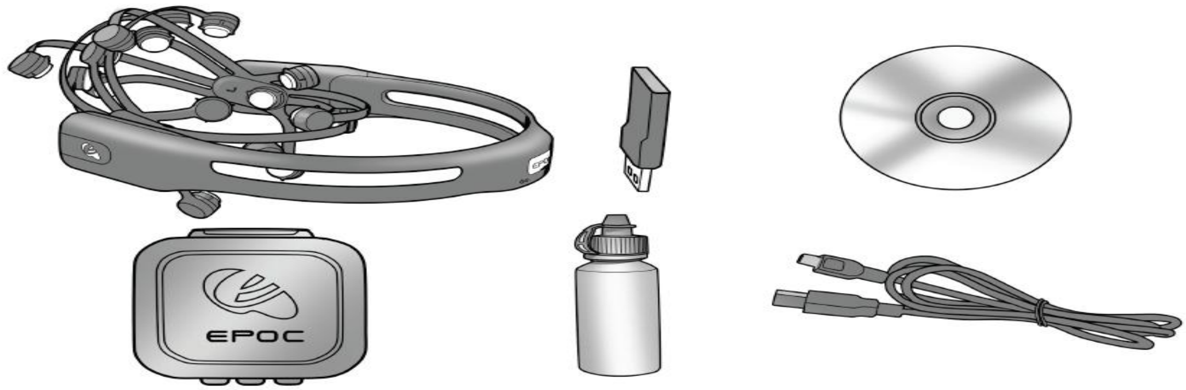

Figure 7.1 Items in Emotiv Pack [Online 5]

7.3.3 Hydrating the Sensors

The sensors are very sensitive to the moisture. The process of wetting the sensors showed in Figure7.2 [Online 5]. Open the Saline Hydration Sensor Pack with the white felt inserts inside. The inserts will eventually be mounted in the headset arms but must be properly wetted with saline solution first. Begin wetting each of the felt inserts with the supplied saline solution. The felts should be wet to the touch, but not soaking wet.

Add a few drops of saline to saturate the large white hydrator pad attached to the top cover of the hydrator, then close the cover and gently shake the hydrator pack. This will maintain the moisture of the felt pads when they are not in use. Open the pack and check that each of the pads had been wetted. If not fully wetted, then add a drop or two of saline to any pads not sufficiently wet using the dropper bottle. Be careful not to over-wet the pads. For any connection problems, add more saline to each felt pad.

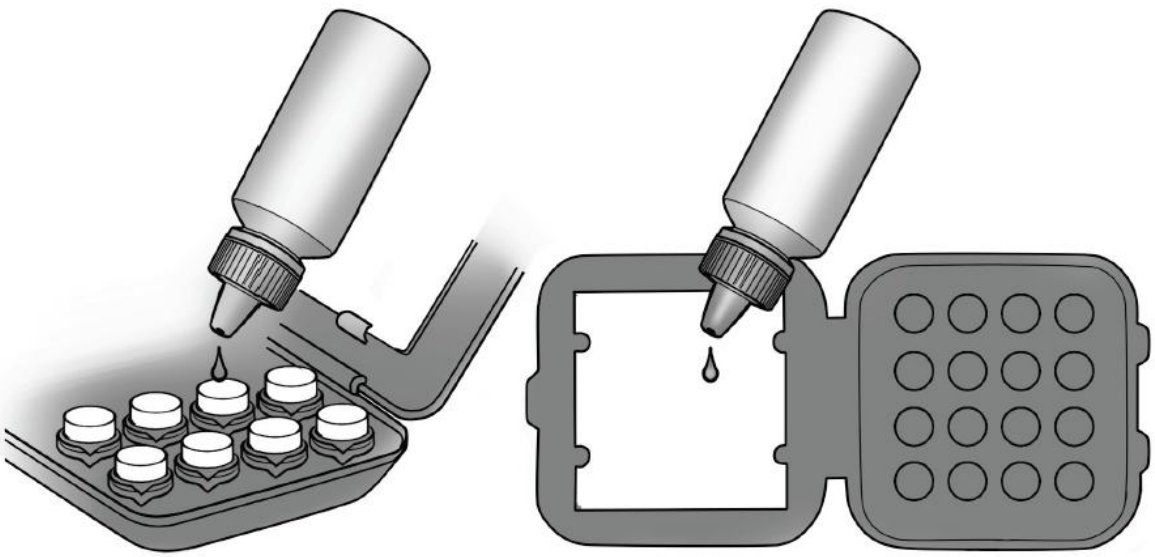

Figure 7.2 Electrode Hydration [Online 5]

7.3.4 Sensor Assembly

After the wetting process, remove the sensor units with their felt pads from the hydrator pack and insert each one into the black plastic headset arms, turning each one clockwise one-quarter turn until you feel a definite "click". The "click" indicates each sensor is correctly installed in a headset arm. The assembly of sensors showed in Figure 7.3 [Online 5].

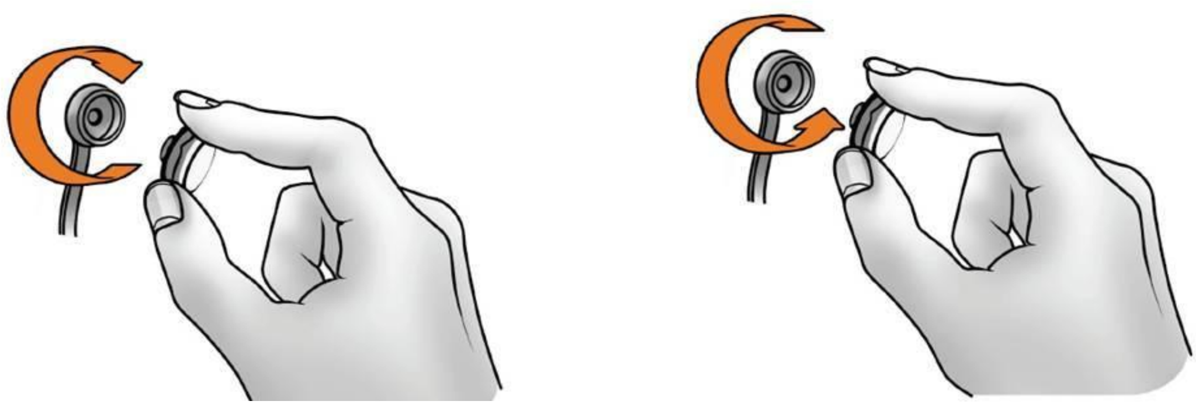

Figure 7.3 Sensor Assembly [Online 5]

When not in use, the sensor units should be removed from the headset arms and stored in the hydrator pack for subsequent use.

7.3.5 Pairing the Neuro Headset

The Figure 7.4 [Online 5] showed the pairing of neuro headset. Insert the supplied USB Transceiver Dongle into the computer's USB slots. Use a USB extension cable and position the Transceiver in a prominent location away from monitor and PC to improve poor reception.

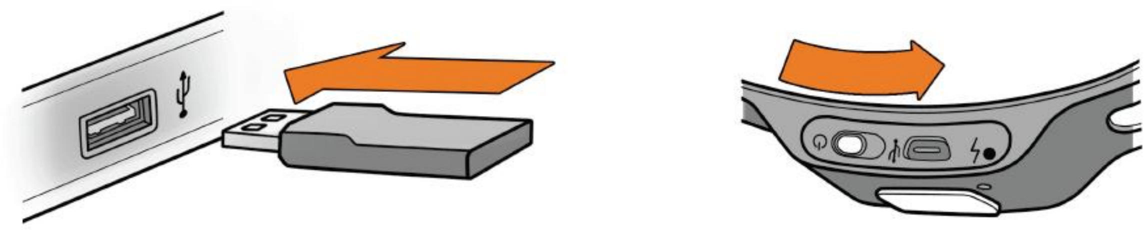

Figure 7.4 Connecting the Neuro Headset with PC [Online 5]

Then turn-on the headset using switch at the bottom end of headset, holding it close to the Transceiver.

7.3.6 Headset Placement

Using both hands, slide the headset down from the top of head. Place the arms approximately as depicted, being careful to place the sensors with the black rubber insert on the bone just behind each ear lobe. Correct placement of the rubber sensor is critical for correct operation. Figure 7.5 [Online 5] shows the Emotiv Head Set placing.

The signals can be easily captured when it is properly connected to the bone just behind the ear. The sensors are placed according to the channel.

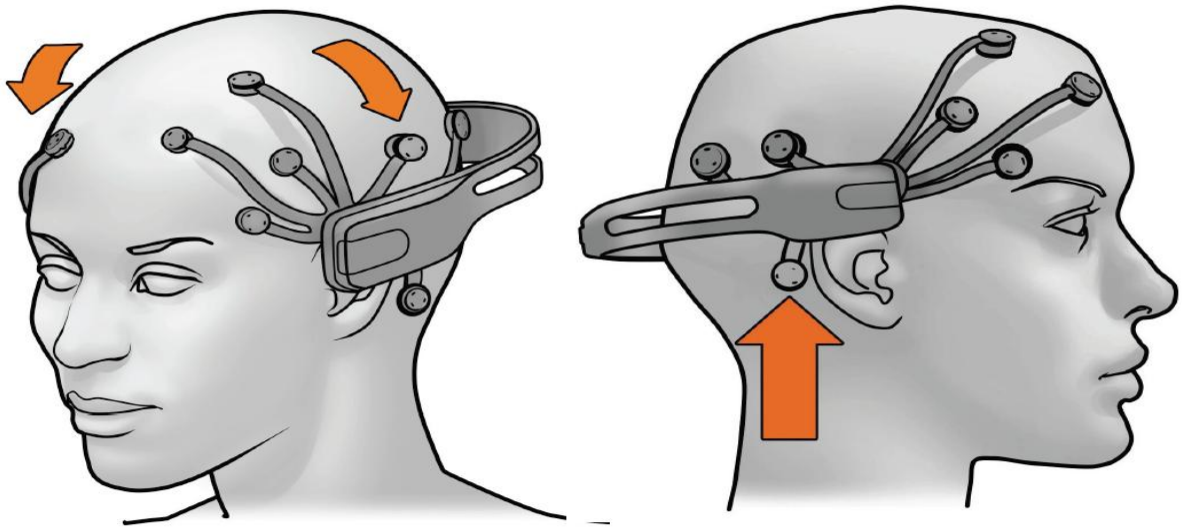

Figure 7.5 Adjusting the Hardware on Scalp [Online 5]

The 2 front sensors should be approximately at the hairline or about the width of 3 fingers above the eyebrows which is showed in Figure 7.6 [Online 5].

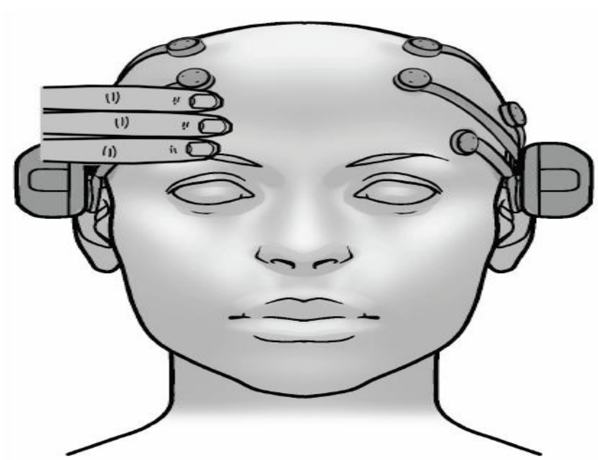

Figure 7.6 Finger Measure [Online 5]

After the headset is in position, press and hold 2 reference sensors (located just above and behind the ears) for about 5-10 seconds. Good contact of reference sensors is the key for a good signal. Check that the lights corresponding to these 2 reference sensors turn from red to green in the EPOC Control Panel Headset Setup screen. The Figure 7.7 [Online 5] shows the reference point placement.

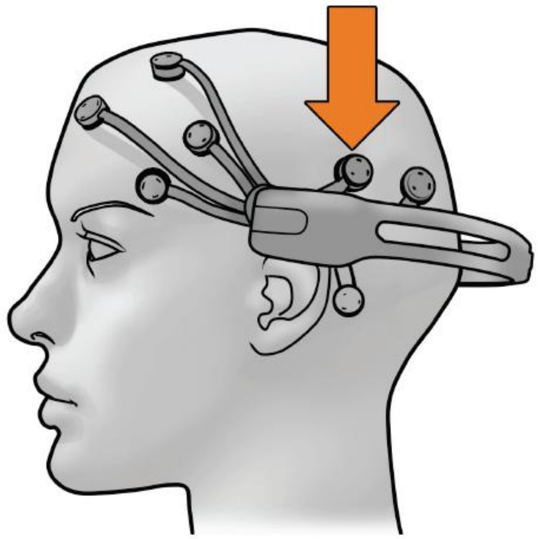

Figure 7.7 Reference Position [Online 5]

Gently press and hold each remaining sensor against the scalp until all the lights corresponding to those sensors turn to green in the EPOC Test Bench as shown in Figure 7.8 [Online 5].

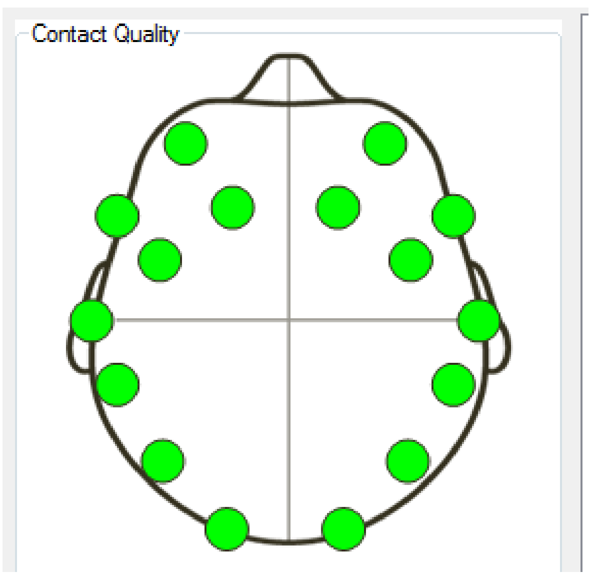

Figure 7.8 Sensor Contact Quality

7.3.7 Data Acquisition

Emotiv is a fourteen channel data acquisition system. The sampling rate is 128 samples per second. The channels are AF3,F7,F3,FC5,T7,P7,O1,O2,P8,T8,FC6,F4,F8,AF4. After placing the Emotiv cap, the positions of markers will set according to requirement in different condition. The marker is the main feature of emotive. The position of marker gives the EEG data at that time duration. Emotive can analyze the FFT by different windowing functions. The snapshot of Emotiv test bench is shown in Figure 7.9.

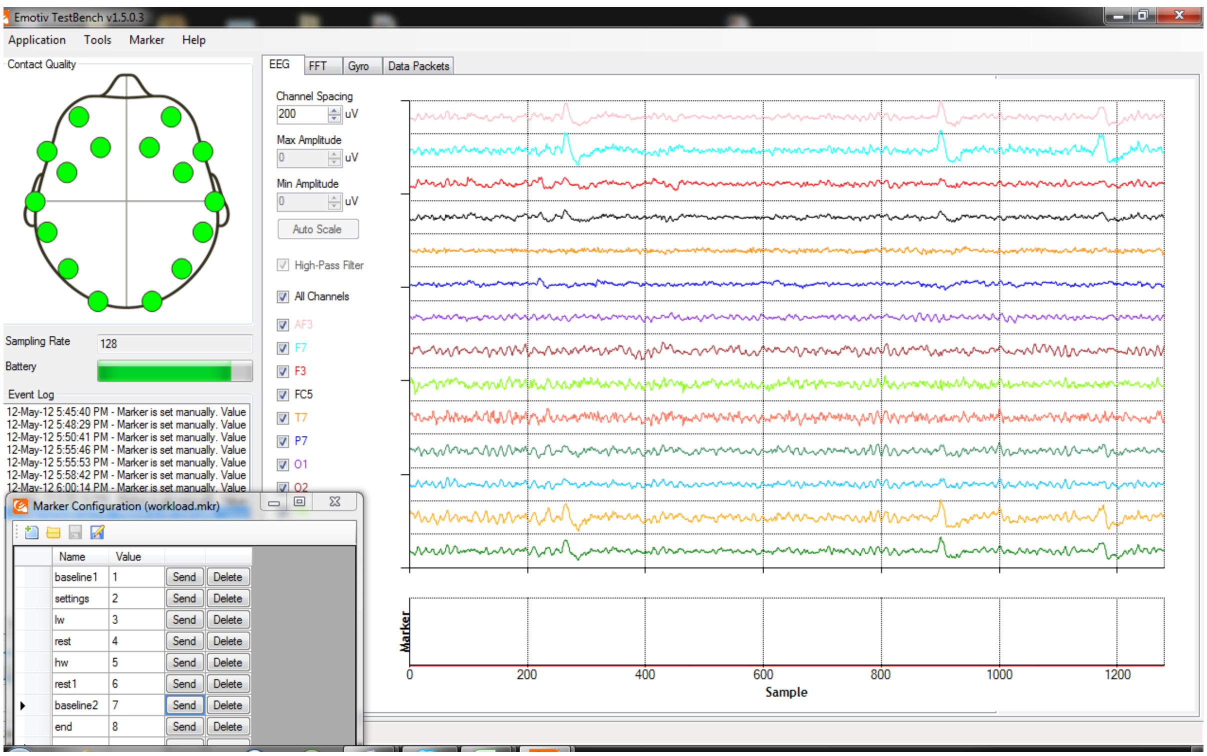

Figure 7.9 Data Acquisition

7.4 MATLAB Software

The name MATLAB stands for MATrix LABoratory. MATLAB was written originally to provide easy access to matrix software developed by the LINPACK (linear system package) and EISPACK (Eigen system package) projects.

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming environment. Furthermore, MATLAB is a modern programming language environment: it has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming. These factors make MATLAB an excellent tool for teaching and research.

MATLAB has many advantages compared to conventional computer languages (*e.g.*, C, FORTRAN) for solving technical problems. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. The software package has been commercially available since 1984 and is now considered as a standard tool at most universities and industries worldwide.

It has powerful built-in routines that enable a very wide variety of computations. It also has easy to use graphics commands that make the visualization of results immediately available. Specific applications are collected in packages referred to as toolbox. There are toolboxes for signal processing, symbolic computation, control theory, simulation, optimization, and several other fields of applied science and engineering.

7.4.1 MATLAB Windows

In almost all systems, MATLAB works through three basic windows, which are discussed below.

MATLAB Desktop

This is where MATLAB puts us when it launch (see Figure 7.10). The MATLAB desktop, by default, consists of the following sub windows.

Command Window

This is the main window. It is characterized by the MATLAB command prompt (>>), when launching the application program, MATLAB puts us in this window. All commands, including those for running user-written programs, are typed in this window at the MATLAB prompt. In MATLAB 7 version, this window is a part of the MATLAB window (see Figure 7.10) that contains three other smaller windows.

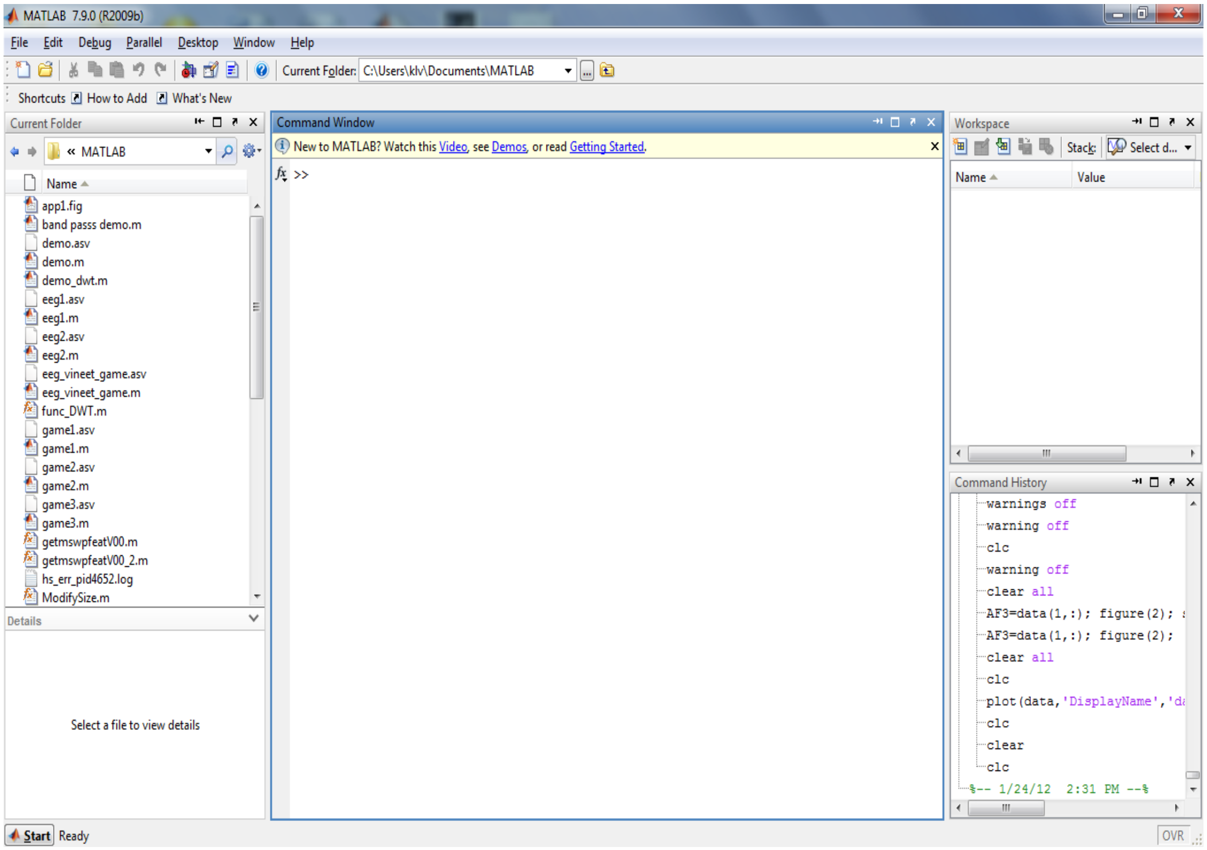

Figure 7.10 MATLAB Window

Current Directory

This is where all files from the current directory are listed. It can do file navigation here. It has several options to select (with a mouse click). To see the options, click the right button of the mouse after selecting a file. It can run M-files, rename them, delete them, etc.

Workspace

This sub window lists all variables that was generated and shows their type and size. It can do various things with these variables, such as plotting, by clicking on a variable and then and then using the right button on the mouse to select the option.

Command History

All command types on the MATLAB prompt in the command window get recorded even across multiple sessions, in this window. This can select a command from this window with the mouse and execute it in the command window by clicking on it. It can also select a set of commands from this window and create an M-file with the right click of the mouse.

7.4.2 MATLAB Tool-Boxes

MATLAB features a family of add-on application specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow us to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include

- Signal processing
- Wavelet
- Neural Network
- Fuzzy logic
- Data Acquisition
- Bioinformatics
- Control system
- Communication
- Image processing
- Simulation
- Parallel Computing

Also, there are many toolboxes in MATLAB used for different applications. In the analysis of biomedical signals Signal processing, Wavelet, Neural network toolboxes are very useful. MATLAB is very user friendly, high level language, easy to use and very nice software. It makes analysis process very easy and widely used in the Research and Development sector.

7.5 Filters

The filters were designed with the help of MATLAB software. Filtering process used for removing the artifacts from the EEG data.

7.5.1 Notch filter

In signal processing, a band-stop filter or band-rejection filter is a filter that passes most frequencies unaltered, but attenuates those in a specific range to very low levels. It is the opposite of a band-pass filter. A notch filter is a band-stop filter with a narrow stop band with high Q factor. A Notch filter is a filter that passes all frequencies except those in a stop band centered on a center frequency. Figure 7.11 [Online 6] shows the magnitude and frequency of notch filter.

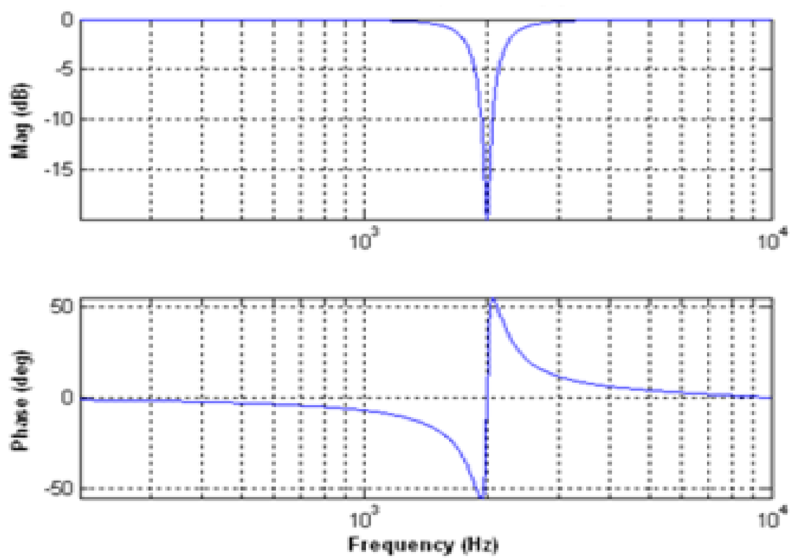

Figure 7.11 Magnitude and Phase Response of Notch Filter

The artifact caused due to interference of 50 Hz line frequency in the EEG data set is removed by applying notch filter. The strong signals generated due to a/c power supplies kept very close to the EEG data acquisition amplifiers cause the 50 Hz line frequency to interfere with the EEG data. This artifact can contaminate a single electrode or all electrodes. The contamination of the dataset due to this artifact depends on the source of the problem. This artifact can be easily filtered out using a simple notch filter. Normally, the notch filter cut-off frequency is set to 50 ± 2 Hz.

7.5.2 Band Pass Filter

The low pass filter that only pass signals of a low frequency range or a high pass filter which pass signals of a higher frequency range, a Band Pass filters passes signals within a certain "band" or "spread" of frequencies without distorting the input signal or introducing extra noise that are 3dB below the maximum centre or resonant peak while attenuating or weakening the others outside that range. Figure 7.12 [Online 6] shows the band pass filter. It is the combination of low pass and high pass filter where low pass filter is followed by the high pass filter. The "ideal" Band Pass Filter can also be used to isolate or filter out certain frequencies that lie within a particular band of frequencies, for example, noise cancellation. Q factor plays an important role in band pass filtering. A high-Q filter will have a narrow pass band and a low-Q filter will have a wide pass band. These are respectively referred to as narrow-band and wide-band filters. An ideal band pass filter would have a completely flat pass band (*e.g.* with no gain/attenuation throughout) and would completely attenuate all frequencies outside the pass band.

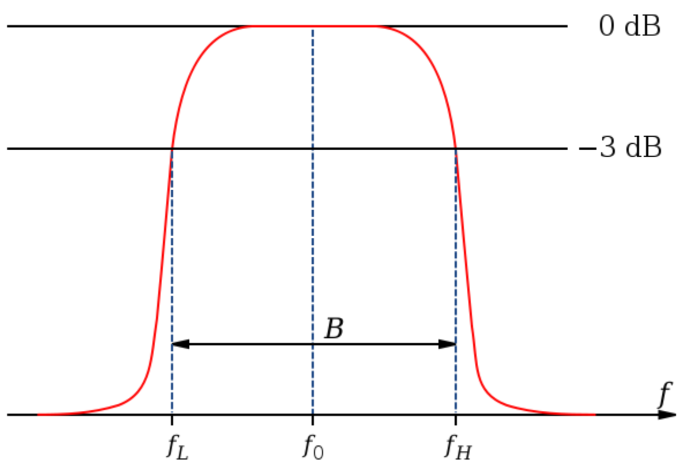

Figure 7.12 Band Pass Filter Magnitude Transfer Function

7.6 Wavelet Transform

Traditional spectral analysis tools are not the best options to quantify the different oscillatory activities in the EEG, since the neural processes that generate the EEG are intrinsically dynamic. Indeed, there are transient changes in the power or peak frequency of EEG waves which can provide information of primary interest. The non-stationary nature of the EEG signals makes it necessary to use methods which are able to quantify their spectral content as a function of time. Time-Frequency Representation (TFR) methods are well suited as tools for the study of spontaneous and induced changes in oscillatory states.

EEG signal is non stationary that means its spectrum changes with time; such a signal can be approximated as piecewise stationary, a sequence of independent stationary signal segments [53]. Although the field of spectral analysis has been dominated by use of the Fourier transform. The Fourier functions do not adequately represent non stationary signals. In order to extract the individual EEG sub-bands a wavelet filter is employed instead of the traditional Fourier transform because the wavelet transform has the advantages of time frequency localization, multi-rate filtering, and scale-space analysis [54-55]. Wavelet transform uses a variable window size over the length of the signal, which allows the wavelet to be stretched or compressed depending on the frequency of the signal [55-56].

7.6.1 Basic Idea

Wavelet transform is a spectral estimation technique in which any general function can be expressed as an infinite series of wavelets. The basic idea underlying wavelet analysis consists of expressing a signal as a linear combination of a particular set of functions, obtained by shifting and dilating one single function called a mother wavelet. The decomposition of the signal leads to a set of coefficients called wavelet coefficients. Therefore the signal can be reconstructed as a linear combination of the wavelet functions weighted by the wavelet coefficients. In order to obtain an exact reconstruction of the signal, adequate number of coefficients must be computed. The key feature of wavelets is the time-frequency localization. It means that most of the energy of the wavelet is restricted to a finite time interval. Frequency localization means that the Fourier transform is band limited. When compared to Short Time Fourier Transform(STFT), the advantage of time-frequency localization is that wavelet analysis varies the time-frequency aspect ratio, producing good frequency localization at low frequencies (long time windows), and good time localization at high frequencies (short time windows). This produces a segmentation, or tiling of the time-frequency plane that is appropriate for most physical signals, especially those of a transient nature. The wavelet technique applied to the EEG signal will reveal features related to the transient nature of the signal, which are not obvious by the Fourier, transform. In general, it must be said that no time-frequency regions but rather time-scale regions are defined [57-58].

7.6.2 Wavelet

A wavelet is a waveform of effectively limited duration that has an average value of zero. It starts out at zero, increases, and then decreases back to zero. They have advantages over traditional Fourier methods in analyzing physical situations where the signal contains discontinuities and sharp spikes. Wavelets were developed independently in the fields of mathematics, quantum physics, electrical engineering, and seismic geology. Interchanges between these fields during the last ten years have led to many new wavelet applications such as image compression, turbulence, human vision, radar and earthquake prediction.

Wavelets can be combined, using a "shift, multiply and sum" technique called convolution, with portions of an unknown signal to extract information from the unknown signal. More technically, a wavelet is a mathematical function used to divide a given function or continuous-time signal into different scale components. Usually one can assign a frequency range to each scale component. Each scale component can then be studied with a resolution that matches its scale. A wavelet transform is the representation of a function by wavelets. The wavelets are scaled and translated copies (known as "daughter wavelets") of a finite-length or fast-decaying oscillating waveform (known as the "mother wavelet").

The wavelet transform of a signal *f(t)* at the scale *s* and position τ is computed by correlating *f*(*t*) with a wavelet atom in eq.(1):

$$w_f(\tau,s)=\int_{-\infty}^{\infty} f(t)\varphi^{*}_{\tau,s}(t)dt \text{---(1)}$$

Where, $\varphi^{*}_{\tau,s} = \frac{1}{\sqrt{s}}\varphi\left(\frac{t-\tau}{s}\right)$

Where s is positive and defines the scale (1/frequency) and τ is any real number and defines the translation (shift).

All the windows that are used are the dilated (or compressed) and shifted versions of the mother wavelet One major advantage afforded by wavelets is the ability to perform local analysis — that is, to analyze a localized area of a larger signal. Wavelet transform is applicable to non-stationary signals i.e. signal whose frequencies vary with time. Wavelet's feature extraction and representation properties can be used to analyze various transient events in biological signals. The WT makes use of multi-resolution signal analysis technique to decompose EEG signals into a number of frequency bands. Wavelet transforms are classified into discrete wavelet transforms, continuous wavelet transforms, fast wavelet transform, wavelet packet decomposition. Almost all practically useful discrete wavelet transforms use discrete-time filter banks. These filter banks are called the wavelet and scaling coefficients in wavelets nomenclature. These filter banks may contain either Finite Impulse Response (FIR) or Infinite Impulse Response (IIR) filters.

7.6.3 Continuous Wavelet Transforms

Continuous Wavelet Transform (CWT) is defined as the sum over all time of the signal multiplied by scaled, shifted versions of the wavelet function φ. The results of the CWT are many wavelet coefficients C, which are a function of scale and position. Multiplying each coefficient by the appropriately scaled and shifted wavelet yields the constituent wavelets of the original signal. Unlike the discrete wavelet transform, the CWT can operate at every scale, from that of the original signal up to some maximum scale which is determine for detailed analysis. The CWT is also continuous in terms of shifting: during computation, the analyzing wavelet is shifted smoothly over the full domain of the analyzed function. CWT is resistant to the noise in the signal. Different kinds of continuous wavelets used are morlet wavelet, Mexican hat wavelet, Shannon wavelet *etc.*

7.6.4 Discrete Wavelet Transform

When the scales and positions are chosen based on powers of two — so-called dyadic scales and positions then the analysis will be much more efficient and just as accurate, the transform obtained is named as Discrete Wavelet Transform (DWT). The DWT of a signal x is calculated by passing it through a series of filters. First the samples are passed through a low pass filter with impulse response g resulting in a convolution of the two signals which is shown in eq.(2).

$$y[n] = (x*g)[n] = \sum_{k=-\infty}^{\infty} x[k]g[n-k] \text{---------------------------------(2)}$$

The signal is also decomposed simultaneously using a high-pass filter h. The outputs give the detail coefficients (from the high-pass filter) and approximation coefficients (from the low-pass). It is important that the two filters are related to each other and they are known as a quadrature mirror filter. However, since half the frequencies of the signal have now been removed, half the samples can be discarded according to Nyquist‘s rule. The filter outputs are then sub sampled by 2.

7.6.5 The Fast Wavelet Transform

The DWT matrix is not sparse in general, the same complexity issues that had previously faced for the Discrete Fourier Transform. It can be solve for the FFT, by factoring the DWT into a product of a few sparse matrices using self-similarity properties. The result is an algorithm that requires only order n operations to transform an n-sample vector. This is the "fast" DWT of Mallat and Daubechies.

7.6.6 Wavelet Packet Decomposition

As it is well known, wavelet analysis provides a timescale description of any finite energy signal. Essentially, it is a successive decomposition of the signal in different scales. At each step, the corresponding details are separated, providing useful information for detecting and characterizing short time phenomena or abrupt changes of energy.

However, since wavelets do not possess a well defined average in frequency, they are not well suited to describe and characterize stationary phenomena or to detect time frequency structures. This is an important limitation, because significant events often involve joint variations of time and frequency [59]. To overcome this problem, wavelet packet analysis appears as a natural extension of wavelet analysis. Moreover, this technique allows a time-scale-frequency description of the signals. A family of wavelet packets is a collection of elemental signals obtained from appropriate linear combination of wavelets.

The main advantage of using wavelet packets is that standard wavelet analysis can be extended with a flexible strategy. Thus, the description of the given signal can be well adapted according to the significant structures. The classification of EEG signals in this research was based on wavelet packet transform.

The wavelet transform is actually a subset of a far more versatile transform i.e. wavelet packet transform. They form bases which retain many of the orthogonality, smoothness, and localization properties of their parent wavelets. The coefficients in the linear combinations are computed by a recursive algorithm making each newly computed wavelet packet coefficient sequence the root of its own analysis tree.

The wavelet packet method is a generalization of wavelet decomposition that offers a richer range of possibilities for signal analysis. Wavelet packet atoms are waveforms indexed by three naturally interpreted parameters: position and scale as in wavelet decomposition, and frequency. In wavelet analysis, a signal is split into an approximation and a detail. The approximation is then itself split into a second-level approximation and detail, and the process is repeated. For n-level decomposition, there are n+1 possible ways to decompose or encode the signal. In wavelet packet analysis, the details as well as the approximations can be split. This yields 2n different ways to encode the signal. This is the wavelet packet decomposition tree.

From the point of view of compression, the standard wavelet transform may not produce the best result, since it is limited to wavelet bases that increase by a power of two towards the low frequencies. It could be that another combination of bases produces a more desirable representation for a particular signal.

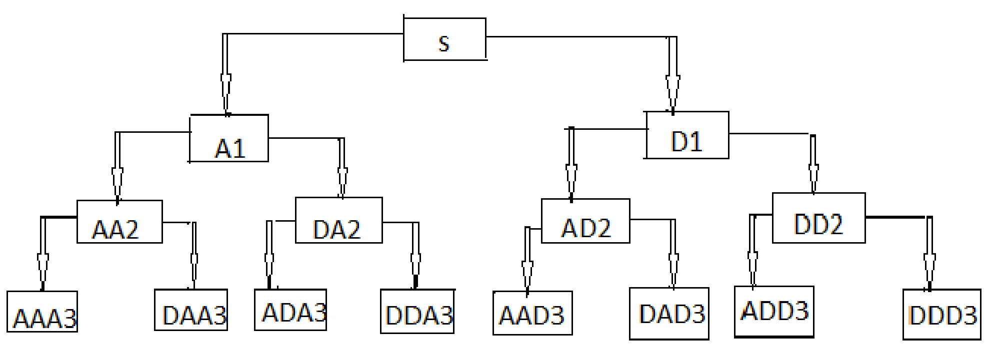

Figure 7.13 Wavelet Packet Tree at Level 3

Figure 7.13 shows the wavelet packet decomposition at level 3. The approximation and detail components are also decomposed. In the corresponding wavelet packets situation, each detail coefficient vector is also decomposed into two parts using the same approach as in approximation vector splitting. This offers the richest analysis: the complete binary tree is produced in the one-dimensional case or a quaternary tree in the two-dimensional case. Simple and efficient algorithms exist for both wavelet packet decomposition and optimal decomposition selection. This toolbox uses an adaptive filtering algorithm, based on work by Coifman and Wickerhauser, with direct applications in optimal signal coding and data compression. Such algorithms allow the Wavelet Packet 1-D and Wavelet Packet 2-D tools to include "Best Level" and "Best Tree" features that optimize the decomposition both globally and with respect to each node.

7.6.7 Introduction to Wavelet Families

(1) Haar

Any discussion of wavelets begins with Haar, the first and simplest. Haar is discontinuous, and resembles a step function which is shown in Figure 7.14. It represents the same wavelet as Daubechies db1.

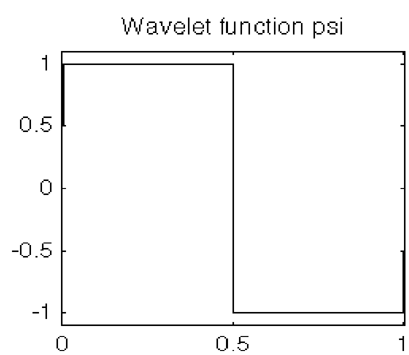

Figure7.14: Haar wavelet[Online 7]

(2) Daubechies

Ingrid Daubechies invented compactly-supported orthonormal wavelets, making discrete wavelet analysis practicable. The names of the Daubechies family wavelets are written dbN, where N is the order, and db the "surname" of the wavelet. The various Daubechies family showed in Figure 7.15. The db1 wavelet, as mentioned above, is the same as Haar.

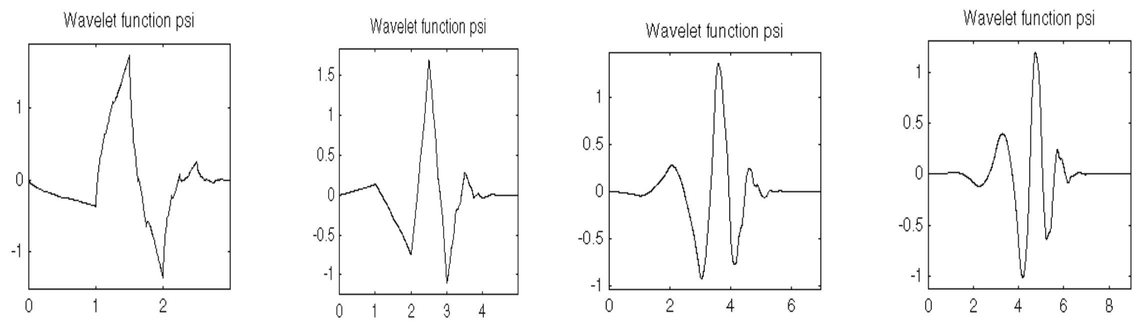

Figure 7.15 Various Daubechies Families (db2 to db5) [Online 7]

7.6.8 Wavelet vs. Fourier Transform

- In Fourier Transform (FT) represents a signal in terms of sinusoids. FT provides a signal which is localized only in the frequency domain. It does not give any information of the signal in the time domain.

- Basic functions of the Wavelet Transform (WT) are small waves located in different times. They are obtained using scaling and translation of a scaling function and wavelet function. Therefore, the WT is localized in both time and frequency.

- If a signal has a discontinuity, FT produces many coefficients with large magnitude (significant coefficients). But WT generates a few significant coefficients around the discontinuity. Nonlinear approximation is a method to benchmark the approximation power of a transform.

- In addition, the WT has a property of multi resolution. Multi resolution is useful in several applications. For instance, image communications and image data base are such applications.

- In nonlinear approximation it keeps only a few significant coefficients of a signal and set the rest to zero. Then reconstruct the signal using the significant coefficients. WT produces a few significant coefficients for the signals with discontinuities. Thus, the WT for nonlinear approximation has better results when compared with the FT.

7.6.9 Wavelet Denoising

Signal de-noising actually inhibits the useless part and restores the useful part. It can remove the corresponding high-frequency of noise and low-frequency approximation of the relevant part of signal and then reconstruct to form the filtered signal. The Daubechies wavelet function was used. Daubechies wavelet is a compactly supported wavelets, the majority does not have symmetry.

If the received signal is X (t), which generally contains two components: one is a useful signal S (t) and the other is the noise N (t), which has intensity spectrum distributing in the frequency axis, it is hindered to understand and master the S (t).

To illustrate the extent of the problem, expressed as the limited noise signal in equation (3).

$$X_i(t) = S_i(t) + N_i(t) \qquad \text{--} \; (3)$$

Where i=1, 2, 3…..

The basic purpose of signal processing is making the maximum extent possibility to recover the effective signal from the contaminated signal X_i (t), maximum suppression or elimination of noise N_i (t). If is expressed as signal, which is processed after de-noising, TH is Threshold value, wavelet transformation of X and S are expressed as $X_i(t)$ and $S_i(t)$ respectively, so the nonlinear threshold described as follows:

After wavelet transformation, signal $X_i(t)$ obtained as X;

1. In the wavelet transformation domain, threshold is processed in wavelet coefficients.

   Hard threshold value method:

   $$S = x \text{ if } |x| >= t$$
   $$= 0 \text{ if } |x| < t$$

   On the other hand soft threshold value method:

   $$S = \text{sign}(x)\,|(x)–t| \quad \text{if } |x| >= t$$
   $$= 0 \;\; \text{if } |x| < t$$

2. Wavelet inverse transformation calculation is obtained $s_i*(t)$ (* in order to distinguish it from $s_i(t)$).

It can be seen that different threshold values are set at all scales, then the wavelet transformation coefficients compared with the threshold values, if less than this threshold, the noise generated and set to zero, if more than, to retain its value, thus achieving the purpose of de-noising. Clearly, the crucial point is how to choose threshold value between preserving signal details and selecting the de-noising capacity, to some extent; it is directly related to the quality of the signal de-noising.

Generally, Th is taken as: Th $=\sigma \sqrt{2 \log n}$ also in the resolution of the wavelet transformation coefficients, taking a percentage of maximum value or absolute value as threshold. Basically denoising involves three steps as follows,

i) **Decompose**- Choose a wavelet, choose a level N. Compute the wavelet decomposition of the signal y at level N.

ii) **Threshold Detail Coefficients**- For each level from 1 to N, select a threshold and apply soft thresholding to the detail coefficients. There are two ways: Soft and hard thresholding. Soft thresholding is an extension of hard thresholding, first setting to zero the elements whose absolute values are lower than the threshold, and then shrinking the nonzero coefficients towards 0. The hard procedure creates discontinuities at $x = \pm t$, while the soft procedure does not.

iii) **Reconstruct**- Compute wavelet reconstruction using the original approximation coefficients of level N and the modified detail coefficients of levels from 1 to N. It is also possible to reconstruct the approximations and details themselves from their coefficient vectors.

The reconstructed details and approximations are true constituents of the original signal. By combine them

$$A1 + D1 = S$$

7.6.10 Applications of Wavelet Transform

Image compression: JPEG 2000

Edge and Corner Detection

Pattern recognition

Filter design

Research area

7.7 Protocol

Eight healthy subjects aged 22-26 years were participated in this study and no subject had any medical illness, brain injury, psychiatric or cardiac history or were taking prescription drugs. There were three different scenarios of a park which has different time duration. The subjects have to navigate into the entire scenarios in order of two dimensional and VR environment respectively. Simultaneously EEG signals were acquired for each scenario. After watching the scenarios the immersion questionnaires were asked for analysis of alertness for the comparative study of two dimensional environment and VR environment.

7.8 EEG Data Acquisitions

The EEG signals of each subject were recorded by Emotiv system using electrodes. The four channels were analyzed for this research work. They were F3, F4, O1 and O2 and they were placed according to the 10-20 international system. These channels were used because the visual information carried by occipital lobe, the frontal lobe processes this visual information [25]. Each time sampling frequency was kept at 128 Hz. During recording session all metallic objects and mobile phones were kept away from the subject as well as administrator to minimize the external noise. Subjects were asked to minimize muscle movements.

7.9 EEG Signal Processing

Preprocessing of EEG raw signal includes segmentation, noise removal and frequency division.

7.9.1 Noise Removal

The EEG signal is small compared to the amplitude of common artifacts (muscle, mains power frequency radiation). Clean signals are dependent on low scalp/electrode impedance, differential amplifiers, and filtering. There are several noises exist. These noises arise due 50 Hz power line interference, movement or breathing by the subject, electrode noise. So to obtain a better result from acquired signal first these noises have to be removed. Following techniques were used to remove noise.

- Normalization was done by subtracting the mean value of signal to the raw signals. It reduces the effects of individual differences due to their fundamental frequency rhythms and to reduce the computational complexity [60].
- A 50 Hz notch filter was used to remove power line interference from the acquired signals.
- Wavelet soft de-noising is used to de-noise the signal, Each EEG signal is decomposed into levels using db4 and 'sqtwolog'is used to calculate the threshold.

7.9.2 Frequency Division

The object of wavelet analysis is to decompose signals into several frequency bands. Selection of appropriate wavelet and the number of decomposition levels are very important for the analysis of signals using WPT. Daubechies wavelet'db4' was used because the wavelet functions have near optimal time-frequency localization properties. Moreover, their waveforms are similar to the waveforms to be detected in the EEG signal [60]. Its smoothing feature was suitable for detecting changes of the EEG signals. The frequency band contains [$f_m/2$: $f_m/2$] of each detail and approximation scale of the WPT is directly related to the sampling rate of the original signal (f_m), which is given by $f_m = f_s/2^{l+1}$, where f_s is the sampling frequency, and l is the level of decomposition. Based on the Nyquist' theorem, the highest frequency that the signal could contain would be $f_s/2$ [61]. The 4 levels of decomposition were chosen based on the dominant frequency components of the signal. From the wavelet packet co-efficient reconstruction, different frequency bands of EEG are reconstructed. The wavelet packet decomposition is efficient method for EEG signal analysis.

7.9.3 Frequency Bands

The various frequency bands of EEG signals were finding out by wavelet packet coefficients reconstruction at their particular level. The sampling frequency was 128 Hz. It's decomposed using WPT. The table (2) shows the frequency bands and its coefficient.

Table 2

Frequency Band and Decomposition Level

Frequency Band	Decomposition Coefficient
Delta	[4,0]
Theta	[4,1]
Alpha	[4,2]
Beta	[4,3], [3,2], [3,3]
Gamma	[1,1]

In this research work, the spectra of alpha and gamma frequency bands were used for the study attention and alertness.

7.9.4 Feature Extraction

(1) Energy

Wavelet packet node energy is more robust in representing a signal than using the wavelet packet coefficients directly. According to Parseval's theorem, the energy of the distorted signal can be partitioned at different resolution levels. Total signal energy can be defined in equation (4).

$$E_i=\sum_{j=1}^{N}\left|C_{ij}\right|^2 \text{--} (4)$$

i=1,2……l

Where i =1,2……l is the wavelet decomposition level from level 1 to level l. N is the number of the coefficients of detail or approximate at each decomposition level. In order to analyze specific frequency region, suitable tree structure should be chosen, which represent the wavelet packet energy distribution in that tree.

(2) Power Spectral Density (PSD)

Power Spectral Density (PSD) is a positive real function of a frequency variable associated with a stationary stochastic process, or a deterministic function of time, which has dimensions of power per Hz (watts per hertz (W/Hz) or dB/Hz). It is often called simply the spectrum of the signal. Intuitively, the spectral density captures the frequency content of a stochastic process and helps identify periodicities.

Power spectral density function shows the strength of the variations (energy) as a function of frequency. In other words, it shows at which frequencies variations are strong and at which frequencies variations are weak.

The power is calculated using PSD concept. The estimated PSD provides a lot of information about the signal which will be considered for modeling and prediction of signal characteristics. The PSD of a signal provides lots of information about the signal including signal characteristics.

For a finite length signal x_l (n) of length l the PSD is calculated by, multiplying the Fourier transform of the filtered signal with the conjugate of that filtered signal and is given by equation (5).

$$F[r_{xx}(1)] = I_l(w) = \frac{1}{l}\{F[x_l\,(1) * x_l^*(-1)]\} \text{-----------------------------(5)}$$

Where r_{xx} (1) is the biased autocorrelation estimate and I_l (w) is known as period-gram and is given by,

$$I_l\,(w) = \frac{1}{l} \mid x_l\,(e^{-jw})^2 \mid$$

Feature classification can't be done because the no. of data set is less.

7.10 Statistical Analysis

7.10.1 Mean

It's the average value of all the measurements. It is mainly use for comparing two different data sets. The mean is the sum of the values divided by the number of values.

The equation (6) shows the mean. Here x_i is sum of all the samples and n is no. of samples.

$$\bar{x} = \frac{1}{n} \cdot \sum_{i=1}^{n} x_i$$ -- (6)

7.10.2 Standard Deviation

Standard deviation is widely used measurement of variability or diversity used in statistics and probability theory. It shows variation or dispersion from the average (mean, or expected value). A low standard deviation indicates that the data points tend to be very close to the mean whereas high standard deviation indicates that the data are spread out over a large range of values. Here equation (7) shows the basic formula of standard deviation (σ). Here μ shows the mean of the samples.

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (x_i - \mu)^2}, \quad \text{where} \quad \mu = \frac{1}{N} \sum_{i=1}^{N} x_i.$$ ------------------------- (7)

N shows the total no. of samples.

Chapter-8
Results and Discussion

The effect of desktop virtual reality environment and two dimensional environments on attention and alertness was carried out to investigate the change in brain signals while applying visual stimulus. In this analysis the spontaneous alpha and gamma band activities of brain were studied as these bands play an important role for attention. The mean and standard Deviation values of energy and PSD of alpha and gamma band were calculated corresponding to two dimensional environment and desktop VR environment. The objective score of questionnaires in 2D and virtual environment shows the amount of alertness. The high score of desktop virtual reality interpret that it has much more immersion and provide more information as compare to 2D display. This shows the alertness increases in desktop virtual reality.

For statistical analysis of EEG data the multivariate analysis was used. It's a tool box of Statistical Package for the Social Sciences (SPSS) software. The multivariate analysis correlates all the parameter to each other and gives the mean and standard deviation values. Here the channel 1 denotes F3, channel 2 denotes F4, channel 3 denotes O1 and channel 4 denote O2.

The tables [3-6] shows the mean values and standard deviation of energy and power spectral density in alpha and gamma band at channels F3, F4, O1, O2 for all the three scenarios of desktop VR environment as well as 2D environment. Some of the values in the tables are insignificant which is shown by dash mark.

8.1 Descriptive Statistics of Energy

8.1.1 Alpha Band

Table 3

Descriptive Statistics of Energy in Alpha Band

Descriptive Statistics					
	Channel	Scene	2D/3D	Mean	Std. Deviation
Alpha	F3	1	2D	33.106	27.58393424
			3D	24.161	43.03525923
			Total	27.99457143	34.67711218
		2	2D	11.4582	21.98357884
			3D	8.6905	15.80737361
			Total	10.22811111	18.37033179
		3	2D	5.463666667	8.836769338
			3D	3.865	6.415777233
			Total	4.4645	6.820324437
		Total	2D	15.72727273	22.19063996
			3D	11.59469231	24.89058555
			Total	13.48879167	23.27575501
Alpha	F4	1	2D	3.7355	5.240368355
			3D	3.912	6.227861966
			Total	3.853166667	5.363987152
		2	2D	0.8564	0.74532295
			3D	6.38475	10.69637722
			Total	3.313444444	7.188328128
		3	2D	5.698166667	12.19329443
			3D	15.2115	28.15623936
			Total	9.5035	19.26110651
		Total	2D	3.534	8.352126715
			3D	8.50275	16.84202169
			Total	5.919	13.08839018
Alpha	O1	1	2D	0.195	-
			3D	3.7394	7.125760647
			Total	3.148666667	6.535668831
		2	2D	6.831428571	11.04721041
			3D	0.561	0.586635037
			Total	4.551272727	9.128857816
		3	2D	3.0205	5.782268854
			3D	1.278625	1.953849237
			Total	2.025142857	3.964249659

		Total	2D	4.724142857	8.631028166
			3D	1.833529412	4.015309439
			Total	3.138967742	6.558819942
Alpha	O2	1	2D	0.713333333	0.336054063
			3D	4.0866	4.013748348
			Total	2.821625	3.505140264
		2	2D	0.856	0.642722854
			3D	1.637	0.039
			Total	1.190714286	0.617517534
		3	2D	1.940166667	2.193115721
			3D	13.74983333	16.88636196
			Total	7.845	13.03212661
		Total	2D	1.323461538	1.575508575
			3D	7.703071429	12.04273103
			Total	4.631407407	9.176656842
	Total	1	2D	12.12488889	21.04700689
			3D	8.412333333	20.60245752
			Total	9.649851852	20.42090911
		2	2D	5.372238095	12.35408094
			3D	4.497066667	9.505620348
			Total	5.007583333	11.11519374
		3	2D	3.825904762	7.566664284
			3D	7.517347826	14.83756552
			Total	5.755522727	11.94760504
		Total	2D	5.927156863	12.79551525
			3D	6.996017857	15.64390094
			Total	6.486560748	14.3003479

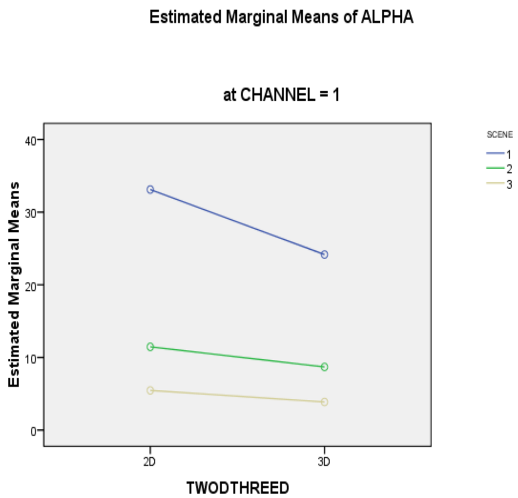

Figure 8.1(a) Estimated Marginal Mean of Alpha at F3

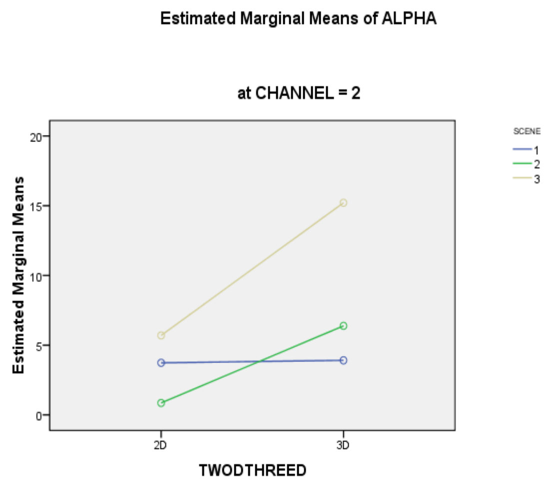

Figure 8.1(b) Estimated Marginal Mean of Alpha at F4

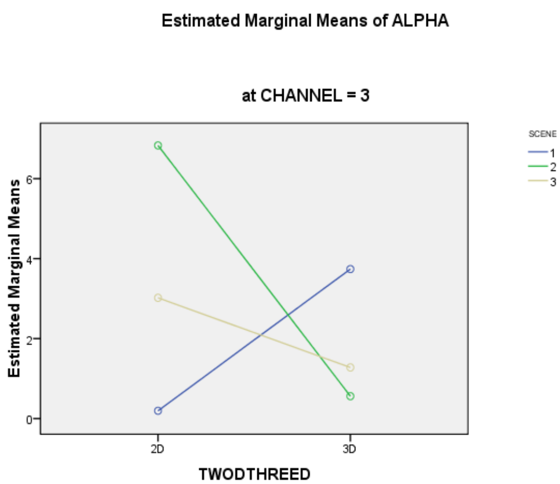

Figure 8.1(c) Estimated Marginal Mean of Alpha at O1

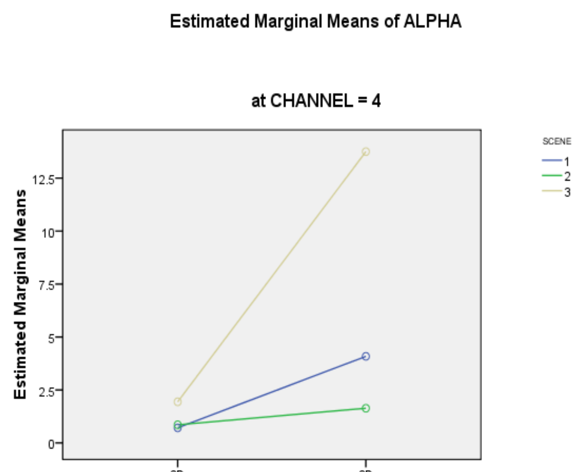

Figure 8.1(d) Estimated Marginal Mean of Alpha at O2

The mean value of energy in alpha band decreases at channel F3 in desktop virtual environment as compare to 2D environment which is shown in Figure 8.1(a). The Table (3) shows the mean and standard deviation values of energy at alpha band decreases in desktop VR. The Figure 8.1(b) shows the alpha band constant in channel F4 in scene1. Figure 8.1(c) shows the mean energy of alpha band decreases in channel O1 in scene 2. The alpha band decreases its oscillations in frontal lobe. Chanel O2 gives the increase in alpha band in Figure 8.1(d). The decrease in alpha band shows the subject is in alerting state by any mechanism (thinking, calculating).The alpha band is blocked or attenuated by attention (especially visual) and by mental effort.

8.1.2 Gamma Band

Table 4

Descriptive Statistics of Mean of Energy in Gamma Band

Descriptive Statistics					
	Channel	Scene	2D/3D	Mean	Std. Deviation
Gamma	F3	1	2D	50.90933333	41.58377858
			3D	16.067	13.23140794
			Total	30.99942857	31.7929614
		2	2D	10.7962	16.48176995
			3D	10.3925	15.60018458
			Total	10.61677778	15.07089249
		3	2D	12.42466667	19.30575785
			3D	20.3368	37.68726405
			Total	17.36975	30.57571991
		Total	2D	22.18027273	29.4957941
			3D	15.96323077	24.42069308
			Total	18.81270833	26.4466328
Gamma	F4	1	2D	18.8155	22.18123262
			3D	8.313	11.70912092
			Total	11.81383333	14.49405138
		2	2D	41.5862	41.22714716
			3D	1.33925	0.863121612
			Total	23.69866667	36.05644687
		3	2D	16.6	19.0077676
			3D	3.01725	1.769953366
			Total	11.1669	15.84176262
		Total	2D	26.55092308	30.19559902
			3D	4.223166667	6.934337929
			Total	15.8336	24.64839836
Gamma	O1	1	2D	7.212	-
			3D	9.672	10.46683116
			Total	9.262	9.41553204
		2	2D	17.57971429	20.29818428
			3D	9.43925	3.656079629
			Total	14.61954545	16.37338849
		3	2D	4.845	3.870780541

			3D	11.399875	12.9676667
			Total	8.590642857	10.37508366
		Total	2D	11.38142857	15.41646764
			3D	10.43035294	10.21569274
			Total	10.85987097	12.60474486
Gamma	O2	1	2D	5.656333333	8.014767765
			3D	29.2572	32.07816126
			Total	20.406875	27.48735664
		2	2D	24.9355	45.70546397
			3D	4.229333333	5.957983747
			Total	16.06142857	34.33403428
		3	2D	5.956166667	9.895785071
			3D	4.713	4.74697748
			Total	5.334583333	7.428068248
		Total	2D	11.72676923	25.6471345
			3D	13.37514286	21.94754295
			Total	12.58148148	23.34824318
	Total	1	2D	23.83777778	30.81409282
			3D	16.23144444	20.00760334
			Total	18.76688889	23.8169103
		2	2D	23.08152381	31.07794315
			3D	6.491466667	8.703821606
			Total	16.169	25.51505137
		3	2D	9.603857143	13.50871835
			3D	10.14043478	18.9409723
			Total	9.884340909	16.38604018
		Total	2D	17.66535294	25.64613479
			3D	11.12085714	17.35835918
			Total	14.24019626	21.84888461

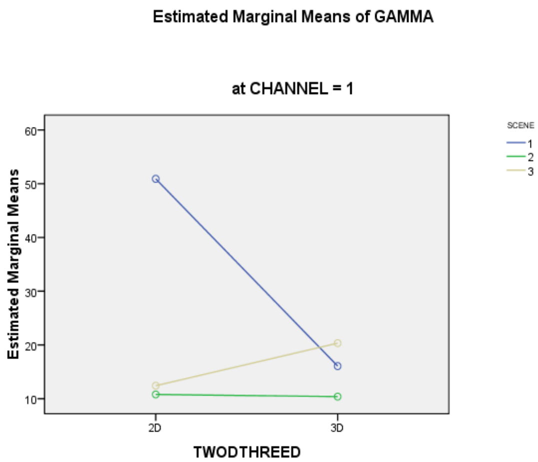

Figure 8.2(a) Estimated Marginal Mean of Gamma at F3

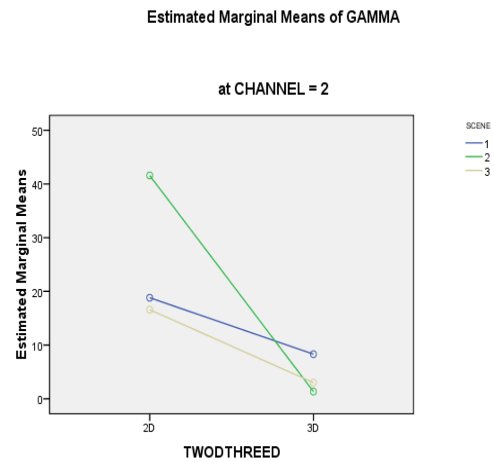

Figure 8.2(b) Estimated Marginal Mean of Gamma at F4

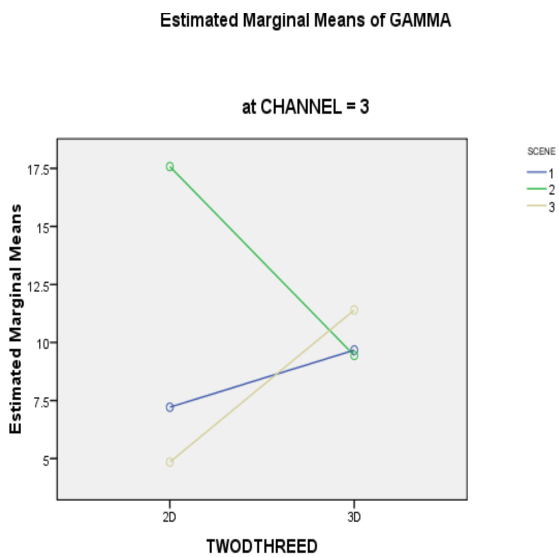

Figure 8.2(c) Estimated Marginal Mean of Gamma at O1

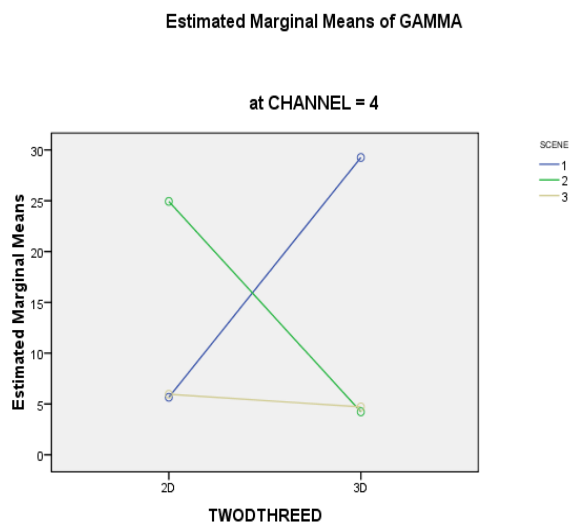

Figure 8.2(d) Estimated Marginal Mean of Gamma at O2

The Table (4) shows the increase in mean and standard deviations in gamma band in desktop VR. Figure 8.2(a) shows the increase in gamma band in desktop VR at F3 in scene 2 and scene 3. Figure8.2 (c) shows increase in gamma band in desktop VR at O1 in scene 1 and scene 3. Figure 8.2 (d) shows the increase in gamma band in scene 2 in desktop VR. It depicts the subject is in some attentive state by processing the visual stimuli.

8.2 Descriptive Statistics of Power Spectral Density

8.2.1 Alpha Band

Table 5

Descriptive Statistics of Mean of PSD in Alpha Band

Descriptive Statistics					
	Channel	Scene	2D/3D	Mean	Std. Deviation
PSD Alpha	F3	1	2D	0.004062067	0.006040014
			3D	2.905310675	5.777039157
			Total	1.661918414	4.369442708
		2	2D	0.003963542	0.00885285
			3D	0.002917558	0.005456586
			Total	0.00349866	0.007117286
		3	2D	0.042333033	0.050707306
			3D	0.010239282	0.019564692
			Total	0.022274439	0.035060839
		Total	2D	0.014454819	0.029554803
			3D	0.898777642	3.206589923
			Total	0.493463015	2.359577511
PSD Alpha	F4	1	2D	9.8776735	13.96911296
			3D	0.351240675	0.618809526
			Total	3.526718283	7.966037773
		2	2D	0.000009154	4.95964E-06
			3D	0.002087548	0.004088617
			Total	0.000932884	0.002732898
		3	2D	0.203250437	0.493218305
			3D	0.006355388	0.012629768
			Total	0.124492417	0.381494488
		Total	2D	1.613453492	5.461189981
			3D	0.119894537	0.365621142
			Total	0.896545193	3.943799467
PSD Alpha	O1	1	2D	0.0349036	-
			3D	0.59212484	1.177883278
			Total	0.499254633	1.07781096
		2	2D	0.001973286	0.003466456
			3D	2.07625E-05	3.29214E-05
			Total	0.001263277	0.002860163
		3	2D	0.000690935	0.001673249

			3D	0.000251548	0.000505097
			Total	0.000439857	0.001124777
		Total	2D	0.003775872	0.009343358
			3D	0.174277625	0.651266159
			Total	0.097276834	0.483414443
PSD Alpha	O2	1	2D	0.186102733	0.209438478
			3D	9.683251916	20.00889927
			Total	6.121820973	15.90430819
		2	2D	0.00000438	2.68101E-06
			3D	9.85633E-05	0.00015721
			Total	4.47443E-05	0.000103809
		3	2D	0.000241827	0.000518351
			3D	0.003375698	0.006690413
			Total	0.001808763	0.004811114
		Total	2D	0.043059745	0.11815579
			3D	3.459772104	12.09790512
			Total	1.814688376	8.729986846
	Total	1	2D	2.262305	6.561285521
			3D	3.577949399	10.79937596
			Total	3.139401266	9.48164243
		2	2D	0.001604476	0.004676186
			3D	0.001359944	0.003415251
			Total	0.001502588	0.004144369
		3	2D	0.064385633	0.263407241
			3D	0.004299327	0.010797212
			Total	0.032976882	0.182353108
		Total	2D	0.426402692	2.766472083
			3D	1.15218523	6.235883418
			Total	0.806251497	4.890761187

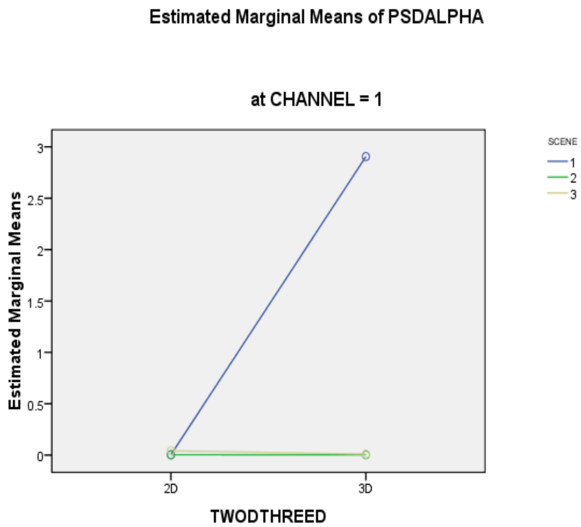

Figure 8.3(a) Estimated Marginal Mean of Alpha at F3

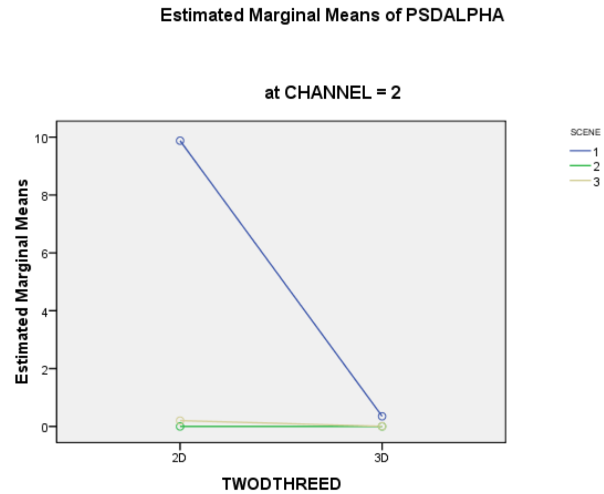

Figure 8.3(b) Estimated Marginal Mean of Alpha at F4

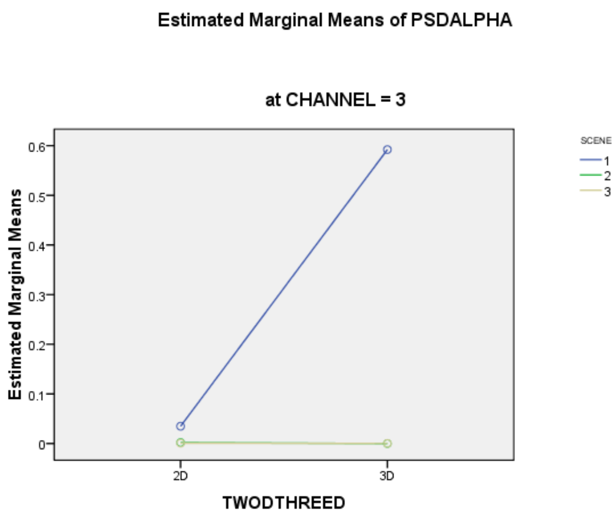

Figure 8.3(c) Estimated Marginal Mean of Alpha at O1

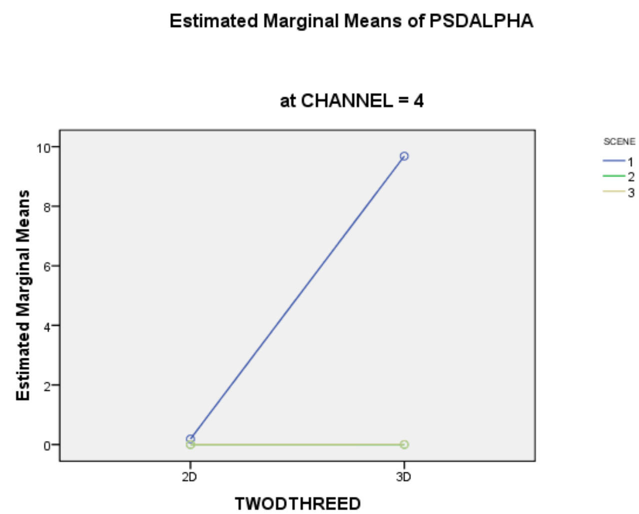

Figure 8.3(d) Estimated Marginal Mean of Alpha at O2

The Table (5) shows the mean and standard values of PSD of alpha band. Figure 8.3(a) shows the PSD of alpha band decreases at channel F3 in scene 2 and scene 3. Figure 8.3(b) shows the PSD of alpha band decreases at Channel F4 in all VR scenarios. The decrease in PSD of alpha is also shown in Figures 8.3(c) and 8.3 (d) marginally in scene 3.

8.2.2 Gamma Band

Table 6

Descriptive Statistics of Mean of PSD in Gamma Band

Descriptive Statistics					
	Channel	Scene	2D/3D	Mean	Std. Deviation
PSD Gamma	F3	1	2D	0.1219106	0.205765442
			3D	0.06153785	0.091676252
			Total	0.087411886	0.139128709
		2	2D	0.00118234	0.00186657
			3D	0.0018427	0.002745119
			Total	0.001475833	0.002165422
		3	2D	0.009952767	0.007001636
			3D	0.0019026	0.003025674
			Total	0.004921413	0.006049491
		Total	2D	0.036500164	0.107250492
			3D	0.020233477	0.054106395
			Total	0.027689042	0.081222537
PSD Gamma	F4	1	2D	1.08665	1.461377585
			3D	0.04537205	0.088091846
			Total	0.3924647	0.849068273
		2	2D	0.0049337	0.004923628
			3D	0.0002555	0.000129945
			Total	0.0028545	0.004266932
		3	2D	0.0043821	0.004575537
			3D	0.01968525	0.038476689
			Total	0.01050336	0.023823639
		Total	2D	0.171097008	0.585741342
			3D	0.021770933	0.053783272
			Total	0.099420492	0.422693512
PSD Gamma	O1	1	2D	0.000676	.
			3D	0.05340256	0.106517043
			Total	0.0446148	0.097673193
		2	2D	0.002400814	0.00322874
			3D	0.00134505	0.000599518
			Total	0.0020169	0.002578063
		3	2D	0.000732333	0.000760569
			3D	0.00144795	0.001307716

			Total	0.001141257	0.001130656
		Total	2D	0.00156255	0.002406422
			3D	0.016704506	0.058596106
			Total	0.009866203	0.043501574
PSD Gamma	O2	1	2D	0.1181911	0.163719454
			3D	0.89892806	1.874495803
			Total	0.6061517	1.476068756
		2	2D	0.002540225	0.004297904
			3D	0.000750133	0.001046912
			Total	0.001773043	0.003242974
		3	2D	0.0010781	0.001789567
			3D	0.002803867	0.005021337
			Total	0.001940983	0.003705238
		Total	2D	0.028554062	0.084172637
			3D	0.322408136	1.131378172
			Total	0.180922841	0.815883198
	Total	1	2D	0.321586789	0.688409374
			3D	0.288294039	0.992049961
			Total	0.299391622	0.888574556
		2	2D	0.002740324	0.003647104
			3D	0.001068227	0.00150189
			Total	0.002043617	0.003033485
		3	2D	0.003191119	0.004638759
			3D	0.005072209	0.016034587
			Total	0.004174416	0.011935467
		Total	2D	0.059192969	0.301476236
			3D	0.095035302	0.56772811
			Total	0.077951573	0.458731047

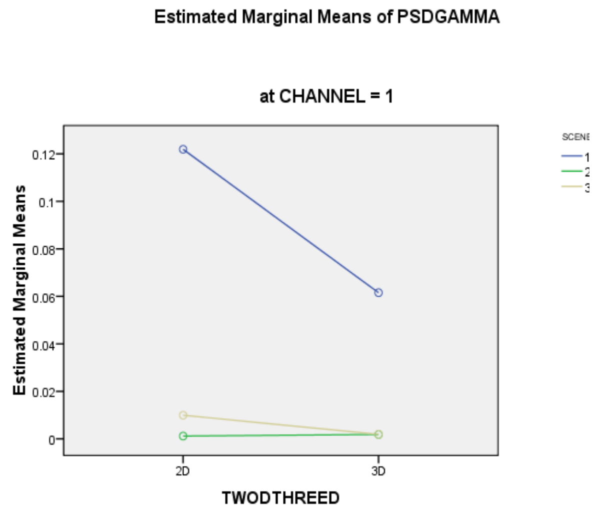

Figure 8.4(a) Estimated Marginal Mean of Gamma at F3

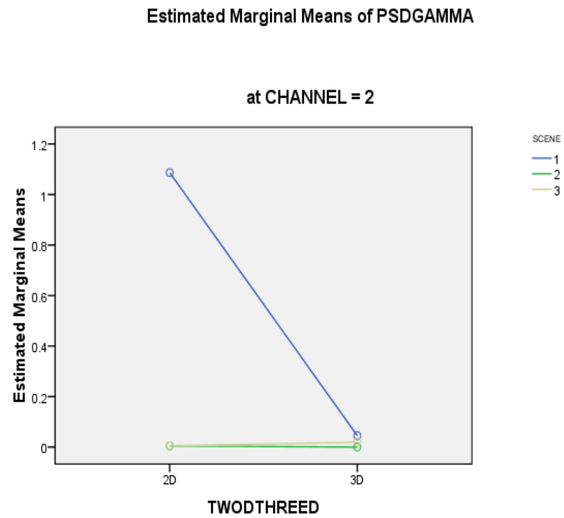

Figure 8.4(b) Estimated Marginal Mean of Gamma at F4

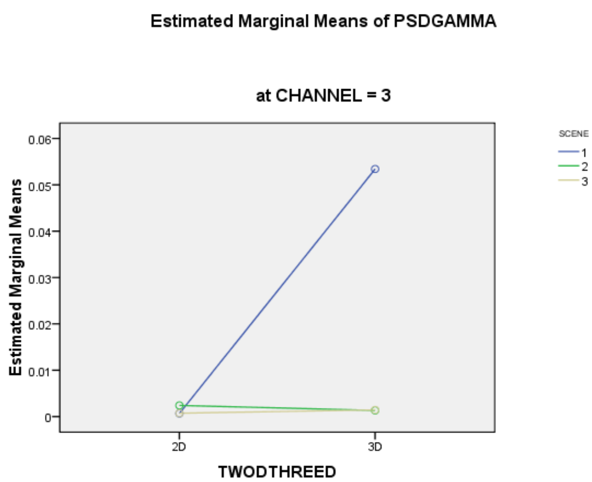

Figure 8.4(c) Estimated Marginal Mean of Gamma at O1

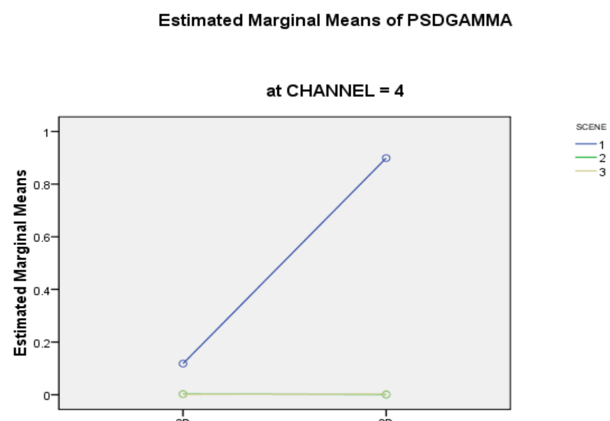

Figure 8.4(d) Estimated marginal Mean of Gamma at O2

The Table 6 shows the PSD is increases in gamma band in influence of desktop VR. The mean of PSD Gamma has increased at channel O1 and O2 in desktop VR as compare to 2D which is shown in Figures 8.4 (c) and 8.4 (d).The Figures 8.4(a) and 8.4 (b) shows the PSD gamma has also increased at channel F3 in scene 2 and channel F4 in scene 2 and scene 3. The increase in PSD in gamma band indicate the subject feeling immerse in desktop VR and started to analyze the scenario's information.

8.3 Score of Immersion Questionnaires

The following table shows the desktop virtual reality environment gained much more score as compare to conventional two dimensional scenarios.

Table 7

Score Table of each subject

Subject ID	Scene 1		Scene 2		Scene3	
	2D Environment	Desktop VR	2D Environment	Desktop VR	2D Environment	Desktop VR
Subject 1	3	5	3	4	5	4
Subject 2	2	2	1	0	4	5
Subject 3	3	2	3	1	4	3
Subject 4	2	3	1	3	4	3
Subject 5	4	2	3	3	5	3
Subject 6	3	3	3	2	4	2
Subject 7	2	5	2	3	3	3
Subject 8	3	2	1	4	5	3
Total Score	**22**	**24**	**17**	**20**	**34**	**26**

The Table 7 shows the performance of the subject was more in desktop VR in sceneario1 and scenario 2. Figure 8.5 shows the graph of each subject of scenario1 and scenario 2.

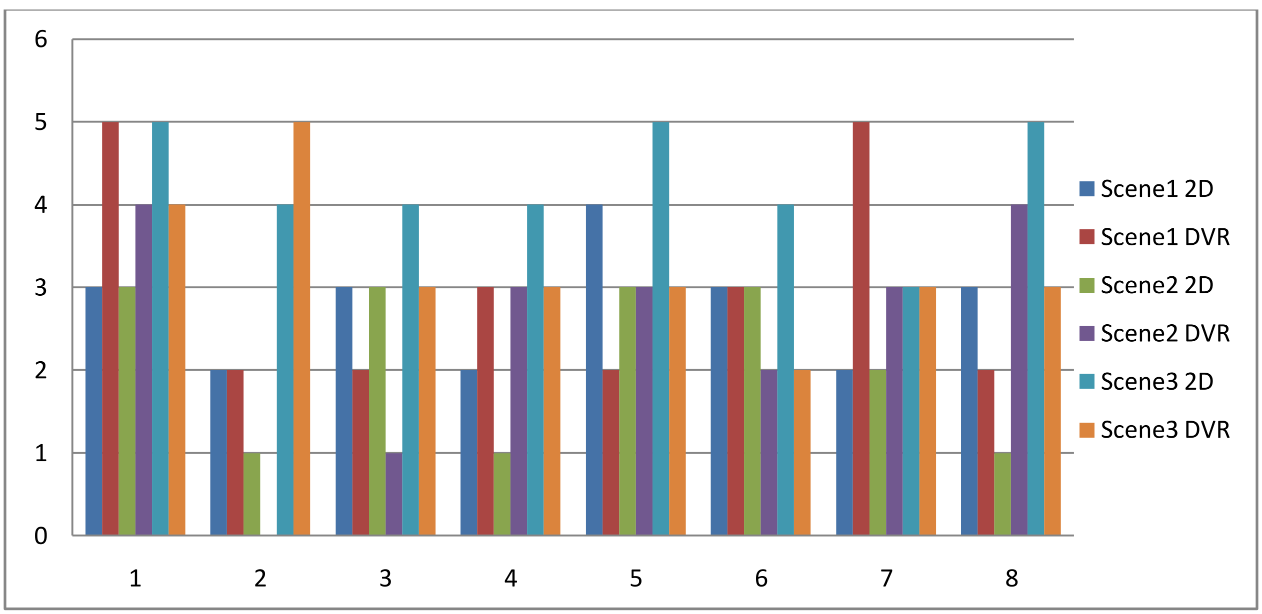

Figure 8.5 Score Graph of Immersion Questionnaire

8.4 Discussion

The results give evidence of visual attentional activity and alertness increases during the subject's interaction with the desktop virtual reality environments. The decrease in alpha band shows an increase in attentional activity with the desktop VR environment means the subjects were transit to wake-up state. The increase in gamma band shows the subjects were in thinking or in reasoning state and analyze the scenario's information. The statistical results were less significant due to the less effectiveness of immersion in desktop VR. The quality of immersion is much better in head mounted display. The results show the decrease oscillation in alpha band and increase in gamma band. The scene realism and information consistent with the virtual reality that is involved in the environment richness and visual attention cause the observed alpha wave decrease in the frontal and occipital lobes.

The results of Immersion questionnaires prove the desktop virtual reality has more alertness activity in scenario 1 and scenario 2. The scenario 3 has more significant in 2D because it has less solid object which is easily recognizable in 2D as compare to VR. The capacity of VR is to create dynamic, immersive three dimensional stimulus environments, in which all behavioral responding can be recorded. It offers assessment and manipulation options that are not available using traditional assessment methods.

Chapter-9
Conclusion

The desktop VR environment increases human cognition parameters. In the present study eight subjects were allowed to navigate into three different scenarios of a park which were in both two dimensional environment and desktop virtual reality environment. The aim was to detect sensory and realism factors in desktop VR which changes the electric brain activity and enhance the human cognition parameters like visual attention and alertness. The immersion questionnaires scores proves the performance of the participants in two dimensional environment were lower than the desktop virtual reality environment. The desktop virtual reality giving an enhanced sense of "being there". The decrease in alpha band shows an increase in attention in desktop VR. Alpha band activity is sometimes referred as 'idling' activity and the reduction in alpha band activity indicate more attentional activity which is referred as 'alpha blocking'.

The gamma band increase as a complement on alpha decreases in desktop VR. It seems that electric brain activity could be considered as an objective measure for being there that gives results on the various factors related with the feel of immersion in desktop virtual environments.

9.1 Future Recommendation

The objective of this work is real time monitoring of attention and alertness by giving the visual stimuli. This will lead to acceptance of virtual reality in assessment of attention and alertness level in driving condition and the recruitment process of the soldiers. The motivation behind the usage of VR for enhance the human cognition level and use its applications for examining cognitive states for some cases that are difficult to handle in real world environments. Study the new perspective that the results of cognition experiments bring into the advancement in development of VR technology. This technique is also useful in clinical applications.

Performance measurement in VR Environments has the ability to provide a simultaneous view of the user's actions in the real-world virtual environment interface [62]. In future visual attention and alertness level can be enhanced by projector based virtual environment or head mounted display system. It can be used as simulator for assessment of various cognitive parameters without violating the important properties of measurement such as reliability, validity and sensitivity.

Experimentation in psychology requires a tradeoff between experimental control and ecological validity. VR displays afford less of a tradeoff than traditional approaches to psychological experimentation (see Figure 9.1)

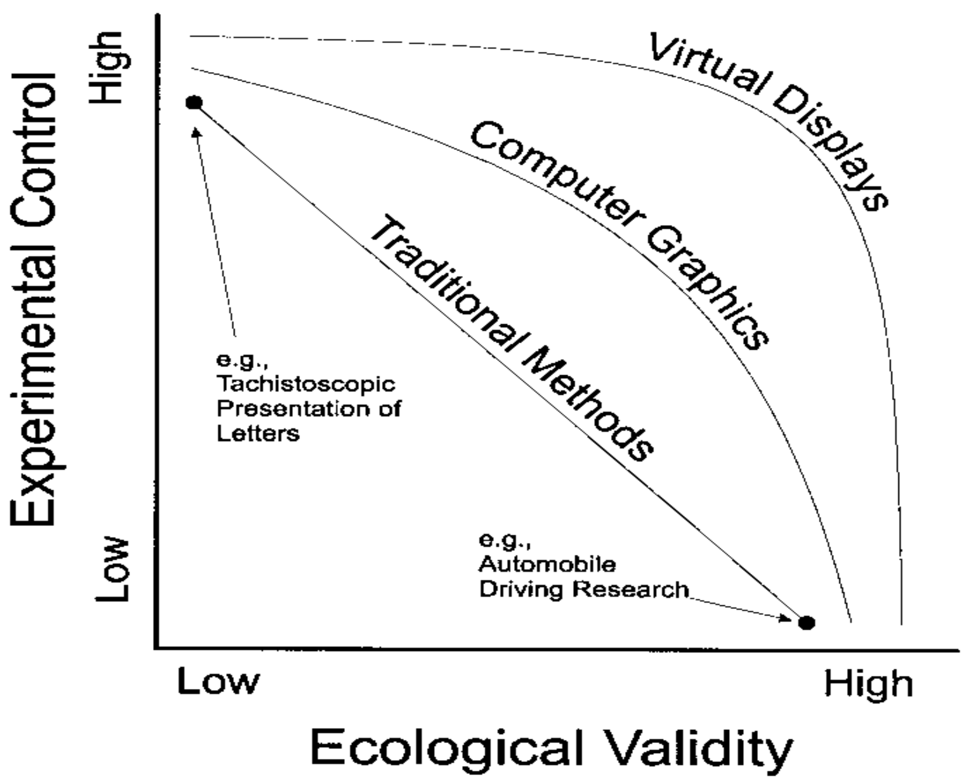

Figure 9.1 Tradeoff Between Experimental Control and Ecological Validity [63]

Furthermore, especially immersive virtual displays provide us with ecologically valid experiments, where the experimenter has the chance to maintain complete control of the virtual world around the subject [63]. In future work the differences between the virtual and the real world can be studied by modeling a real scene by using immersive virtual reality environments.

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