DEVELOPMENT OF VIRTUAL REALITY ENVIRONMENT FOR COGNITIVE ENHANCEMENT

A DISSERTATION

Submitted in partial fulfilment of the requirement for the award of the degree

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In

ELECTRICAL ENGINEERING

(With the specialization in INSTRUMENTATION & SIGNAL PROCESSING)

By

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CANDIDATE'S DECLARATION

I hereby certify that this report which is being presented in the dissertation entitled "**DEVELOPMENT OF VIRTUAL REALITY ENVIRONMENT FOR COGNITIVE ENHANCEMENT**" in partial fulfilment of the requirement of award of Degree of **Master of Technology** with specialization in **Instrumentation and Signal Processing**, in the **Department of Electrical Engineering**, **Indian Institute of Technology, Roorkee** is an authentic record of the work carried out during a period from Jun 2015 to Jun 2016 under the guidance and supervision of **Dr.Vinod Kumar**, Department of Electrical Engineering, Indian Institute of Technology, Roorkee.

I have not submitted the matter embodied in this seminar report for the award of any other degree or diploma.

Date:

Place: Roorkee

(VISHAL V SINGH)
Lt Col

CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ACKNOWLEGEMENT

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I extend my gratitude to the Officers and Staff of the Roorkee Cantt, who have extended all the support for carrying out the study on the soldiers.

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Lt Col Vishal V Singh

ABSTRACT

Cognitive enhancement has received considerable attention during the last decade, both in the general public and in academic discourse. Cognitive Enhancement refers to use of any intervention directed at improving any of the cognitive functions such as memory, attention, concentration, learning, planning and reasoning abilities. The interventions can be of conventional or non- conventional types.

In this study, I decided to make use of Virtual Reality (VR) as the intervention for the cognitive enhancement. First part of the study involved the development of a VR environment (Virtual Battlefield) to be used as the intervention. VR can help user in reducing distress and at the same time can assist in improving the person's cognition and therefore has been widely used as a means of cognitive enhancement. Two groups of military persons were asked to take part in this study and multipronged analysis was carried out. The results from various tests were analysed to understand the effect of VR on cognitive enhancement of the subjects. The trends obtained from the tests indicate fair amount of enhancement in the cognitive functions of younger soldiers not involved in combat till date.

With the latest advanced technologies, the complex signals like EEG, EMG, EOG, ECG etc can be analysed in a suitable manner to establish its relationship with the psychological parameters like attention, stress, memory etc. The analysis was carried out by studying the effects of the VR on the individuals using the changes in various physiological parameters using the EEG and ECG signals. The psychological test conducted using Vienna Test Systems indicated a definite improvement on some of the cognitive functions for the subjects such as improved eye-hand coordination, attention and visual memory.

This study is aimed to be used as an aid to the various training institutes and units of the Armed Forces, to access the training pattern, evaluate the performance of the soldiers and take suitable corrective action.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

I am a scholar warrior of the Indian Army and commissioned into the Corps of Electronics and Mechanical Engineers. One of the responsibilities of my Corps is to develop ideas and innovations for enhancing the operational fitness of the entire Army. After getting the opportunity to pursue my Master of Technology from the prestigious IIT, Roorkee, I was keen to carry out my thesis work in an area by which I can contribute something to my corps and to the organisation as a whole.

Prior to joining IIT, Roorkee, I was on an important assignment of instructor for training officers of my corps in the advanced field of communications especially in Electronic Warfare. I expressed my desire to Dr Vinod Kumar to suggest me a field where I can contribute towards betterment of battlefield awareness of a soldier in a scientific way and he therefore, suggested me to work in the field of cognitive enhancement of the soldiers.

The study of cognitive enhancement finds a special relevance in the field of military. In the today's world of sustained conflict, the injury suffered by our soldiers is both physical as well as mental. The enhancement of a soldier's performance should therefore address both physical and cognitive aspects. Also, in military operations various cognitive tasks such as accumulation of information, its interpretation and making decision; operation of complex equipment demands better situational awareness which results from enhanced cognitive fitness apart from the physical fitness of the soldiers.

Realising the importance of cognitive fitness in military environment, I was extremely motivated to carry out real time assessment of the cognitive enhancement of our soldiers due to exposure to a virtual battlefield environment.

1.2 Cognitive Enhancement

Cognition is group of mental processes that include memory, attention, learning, reasoning, problem solving and decision making. Cognition hence can be defined as the processes used to organise information, including perception (acquiring information), attention (selecting), understanding (representing) and memory (retaining) information and using it to reasoning and coordination of motor outputs (guide behaviour) [3, 4].

Cognitive Enhancement then, refers to the use of any intervention aimed at improving any of these functions. The improvement can be achieved by various means which can be natural or artificial. Cognitive enhancement can result from convention means such as education, mental techniques and meditation to less conventional means such as drug, implants and genetic manipulation [2, 3].

The cognitive performance of human beings have been analysed by using questionnaires i.e. by means of a qualitative approach. Early studies for human performance evaluation were subjective and qualitative to measure the workload. But the latest studies are using various physiological parameters for quantitative and objective performance measurement. The physiological parameters that are widely studied are EEG (Electroencephalogram), ECG (Electrocardiogram), EOG (Electro-oculogram), Heart Rate and Heart Rate Variability (HRV).

1.3 Literature Review

A review of the available literature reveals the abundance of research being carried out the world over in the field of cognitive enhancement and cognition assessment. Few of the areas with researches include enhancement using non-conventional methods like genetic modification, using implants such as brain computer interface and using medicines and drugs; and conventional methods of cognitive enhancement like using meditation, education, environmental enrichment and use of virtual environment [2, 3].

Cognitive enhancement has also been extensively used and researched for cognitive behaviour therapy (CBT), specially for the treatment of depression and hypertension, post-traumatic stress disorder (PTSD), heart disease and stress disorder. Research have also been carried out in the field of cognitive studies in decision making processes, intelligence analysis, field of medicine and education [4].

Extensive researches have also been carried out in the field of military psychology but are restricted especially within the developed countries. For example U.S has dedicated laboratories to perform medical research towards improving cognitive performance such as Walter Reed Army Institute of Research assesses human alertness, attention and cognition. Similarly few other world military like U.K and France have a dedicated research wings or organisations for cognitive enhancement of soldiers. In the Indian context, Defence Institute of Psychological Research (DIPR) have carried out number of researches in the field of military psychology. However, these researches have mostly been confined to the personnel selection, motivation, human adjustments and tactical requirement and less toward the important aspects of cognitive enhancement [1].

From the review of various literatures, it was found that maximum use of Virtual Reality(VR) was made or being made to treat patients with various psychological diseases or with various phobias such as fear of heights or fear of public speaking etc. In the field of military the interventions utilising the VR were restricted to basically treat soldiers with Post Traumatic Stress Disorder (PTSD) or with Traumatic Brain Injury (TBI). The areas of cognitive enhancement due to VR especially in the parlance of Indian Military have been less researched.

Therefore, we decided to carry out the study in field of cognitive enhancement using virtual battlefield. We intend to study and monitor the changes in cognitive behaviour of the military personnel due to their immersion in a basic virtual battlefield and study the cognitive enhancement post the exposure.

1.4 Aim of Dissertation Work

The main objectives of this dissertation work are:-

(a) Develop a virtual battlefield using various 3D applications and use it on the subjects.

(b) Carry out on-field recording of various Physiological parameters viz EEG and ECG and certain Psychological tests viz two hand coordination, attention/concentration and short term working memory; of the soldiers prior to their exposure to the VR environment.

(c) Carry out analysis of these parameters and test results.

(d) Carry out comparative analysis of the two sets of recordings viz prior and post VR battlefield exposure and ascertain their efficacy towards cognitive enhancement of the soldiers.

(e) Make suggestions to the military regarding the use of VR environments of various situations as per the positive or negative outcome of the test results.

1.5 Layout of Dissertation Work

The dissertation has been sub divided into various chapters as elucidated below:-

(a) Chapter 1 discusses the basics about cognition and cognitive enhancement. It also covers the literature review.

(b) Chapter 2 lists out various conventional and non-conventional interventions for cognitive enhancement.

(c) Chapter 3 brings out the nuances of VR as and an intervention and selection of subjects for the study.

(d) Chapter 4 discusses various methods for evaluation of cognitive enhancement both physiological and psychological.

(e) Chapter 5 describes the selected methodologies and their various tests in detail.

(f) Chapter 6 discusses the methods for data collection and usage of the systems involved.

(g) Chapter 7 describes in detail how the virtual reality environment was developed for this study.

(h) Chapter 8 – Results and Discussion

(i) Chapter 9 - Conclusion

CHAPTER 2

INTERVENTIONS OF COGNITIVE ENHANCEMENT

There are various methods that are used as interventions for the cognitive enhancement. These are shown below and explained in successive paragraphs.

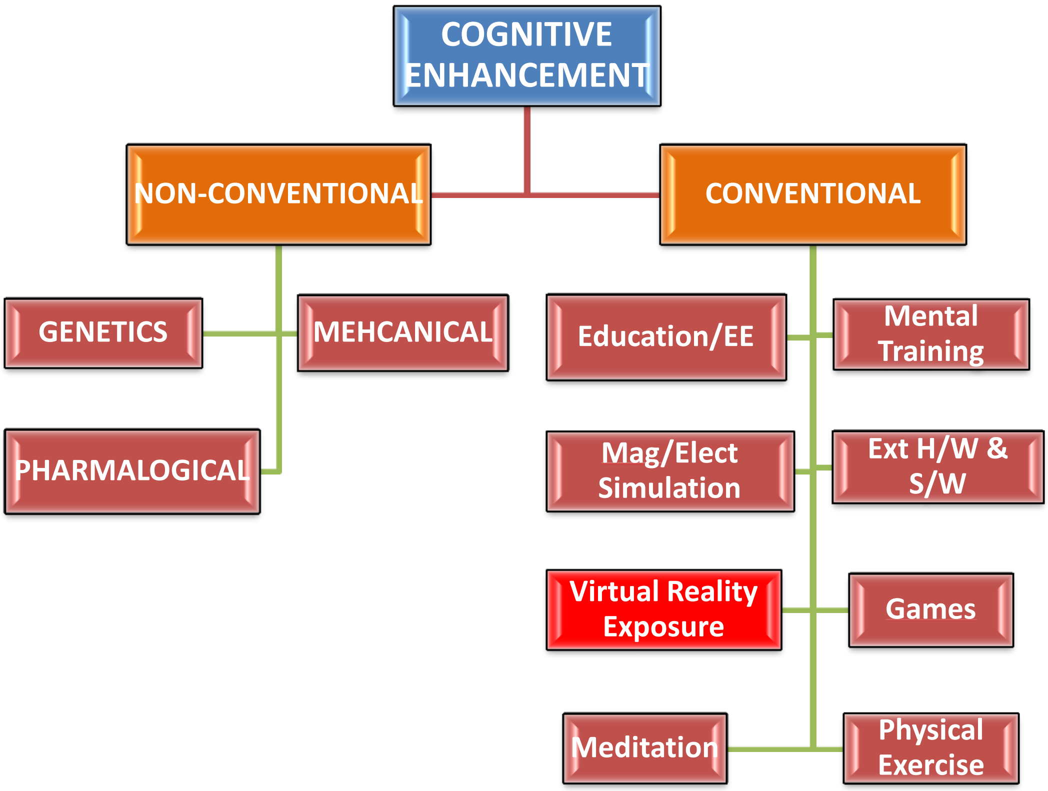


Fig 2.1: Cognitive Tree Showing Different Interventions for Cognitive Enhancement.

2.1 Non-Conventional Methods of Cognitive Enhancement

2.1.1 Enhancing Cognition via Genetics

It involves manipulation of genes involved in any of the cognitive process for cognitive enhancement. Genetic cognitive enhancement is a more direct means to enhance ourselves. For example, a gene encoding of particular dopamine receptor could be inserted into the brain directly to enhance alertness, attentiveness; yielding effects similar to those indicated with Ritalin use. This genetic manipulation would simply provide a more permanent and deliberate means of altering brain chemistry. [2]

2.1.2 Enhancing Cognition via Mechanical Means

Mechanical Cognitive Enhancement entails the integration of brain with technology. These include devices that contain sensors or actuator implanted in or communicating with brain to replace neural and sensory functions. The most common example includes brain pacemakers, cochlear implants intended to correct hearing impairments and retinal implants to correct vision impairment.[2]

2.1.3 Enhancing Cognition via Pharmacology

This involves use of drugs and chemicals for the purposes of cognitive enhancement. For example, the dopamine stimulants demonstrated effects of modulating working memory. Some of the most commonly used drugs and chemicals are caffeine, modafinil, creatine, methlphenidate etc.[2, 3]

2.2 Conventional Means of Cognitive Enhancement

2.2.1 Education and Enriched Environments

Education: The education received helps re-organising the neural networks in building concepts, learning language, understanding, problems solving, improving IQ and memory. Environment Enrichment (EE) or stimulation have found to increase the dendrites absorption and produce synaptic changes to improve or decline the cognitive functioning.

2.2.2 Virtual Reality Technology (VRT)

VRT provides various stimuli to remove distractions and provide environments to enhance attention and ability to concentrate. Virtual Reality is very interesting, interactive, immersed and imaginal and therefore can bind a subject's attention and concentration for a longer duration as compared to any other methods. Many kinds of VRT systems like systems for aircraft take-off phobia, phobia of public speaking, height phobia etc are widespread developed, clinically tested and used for the cognitive behaviour therapy(CBT).[5]

2.2.3 Meditation

Meditation is sustained, real-time metacognition or simply cognition about cognition, i.e., higher-order thought. A number of meditation researchers justify the enhancement in cognitive abilities through meditation.

2.3 Conclusion

It is currently estimated that in the near future the current workforce will consist of 80% cerebral and 20% manual jobs, and therefore definition of fitness in near future will encompass more of cognitive fitness then physical fitness. To enhance the cognitive performance, number of interventions are used, these interventions can range from widely practiced conventional means of cognitive enhancement, such as education, mental techniques, neurological health, and external systems; to less practiced methods like genetic implants, mechanical implants, brain-computer interfaces etc.

CHAPTER 3

SELECTION OF INTERVENTIONS AND SUBJECTS

In the previous chapter various conventional and non-conventional interventions of cognitive enhancement were discussed. The intervention and subjects planned for the thesis work is slightly different from those discussed and have been less practiced. As discussed in first chapter the motivation for me is to work in a field which helps me to contribute to my organisation. And therefore, I have planned to undertake analysis of cognitive enhancement of the soldiers with VR environment being a virtual battlefield as the intervention. This would help me to evaluate the cognitive enhancement in the soldiers in more scientific way and at the same time also pave way for the applicability of some other conventional VR interventions like moving in a military convoy, urban insurgency etc.

3.1 Selection of Intervention: Virtual Reality Environment

Virtual reality (VR) is a computer interface that allows a soldier to become immersed within a computer created and controlled setting. The use of VR in the assessment and training of cognitive processes in soldiers is being acknowledged as the need for assessments that are precisely designed for military personnel increases and as the VR technology advances. As the virtual environments (VEs) allow for exact reproduction and control of dynamic perceptual stimuli (visual, auditory, olfactory, ambulatory, and haptic conditions), hence they can provide assessments that combine the control and precision of laboratory measures with a task similarity that nearly approximates real life situations.[8]

The complexity and lethality of modern warfare places great demands on military personnel's neurocognitive resources. At various threat levels, a soldier must be able to exercise control of his cognitive functions. It is difficult to interpret the results of traditional cognitive assessment techniques to answer questions that are military related. There are varying levels of response to a situation involving stress. How well a performance during a software controlled cognitive assessment can predict performance during the uncertainties and stresses of war? Post a mild brain injury, how can we assess the functional deficiency of soldiers whose occupational situation has substantial, volatile low and high intensity stress? Hence, for a measure to be relevant to an assessment of a soldier's neurocognitive functioning, it must provide some indication of his cognitive performance within high and low threat settings.

Developments in the field of VR offer new opportunities to improve ecological validity. Virtual environments (VEs) allow for creation of simulated realistic environments in which individuals can be analysed and trained in systematic fashion. By designing VRs we can create environments that incorporate challenges based on functional behaviours bringing greater ecological validity to the assessment. Within such a VR, the experimental control required for rigorous scientific analysis and reproduction can still be maintained within simulated contexts that symbolize the complex challenges found in true-to-life situations.[9]

3.2 Subjects and Case Studies for the Dissertation Work

Daily routine of the soldiers is busy and arduous. Daily activities on week days i.e Monday to Saturday, begins as early as morning 4.30 am to late night 10.30 pm. Evenings of Wednesday and Saturday are generally earmarked for the maintenance of the unit area and living barracks. While, Sundays are used for various recreational activities, like movies, hobbies club, uniform maintenance, room inspections and so on. After a lot of deliberations the unit authorities agreed to spare the soldiers.

Time required for data recording of one subject has been worked out to be approximately 40 minutes; viz 5-10 min for recording physiological parameters and 30-35 min for psychological tests, depending on the performance speed of the subjects. Based on the time allotted by the unit and the time required for each recording, without compromising on the expected outcome of the dissertation work, a total of 50 recordings were finalised excluding any repetitions. The data recording was carried out as per the following case studies:-

(a) Case-I: This study was carried out to get acquainted with the hardware, software and other equipment that were to be used during the dissertation work. For this study, 5 healthy subjects form the IITR were selected. Various physiological signals of these subjects were recorded. The physiological parameters recorded under various conditions were studied to get familiarise with the procedures and finalise the best methodology for carrying out dissertation work. Studies were also conducted with the Vienna Test System software modules in the biomedical lab to finalise the test modules for our study.

(b) Case-II: A group of 20 healthy male subjects from the Army unit participated in this study (n=20, male=20). They were divided into two groups as follows:-

(i) Group I – 10 soldiers of age less than 26 years and having no combat experience.

(ii) Group II – 10 soldiers of more than 26 years of age and having prior combat experience.

The key objective of this study was to record the physiological and psychological data of these subjects prior to the exposure to the virtual battlefield.

(c) Case-III: Same two groups of 10 soldiers each participated in this study. They were immersed in the virtual reality environment developed for them. The key objective of this study was to record physiological and psychological data post the exposure and carry out comparative analysis between the two cases for any changes in cognitive enhancement of the subjects due to the VR intervention.

3.3 Conclusion

VR application that focuses on component cognitive processes, including attention processes, memory, spatial abilities and executive functions has been developed for this study. Within a VR environment, it is possible to systematically present cognitive tasks to soldiers that target military pertinent neuropsychological performance other than what are presently available using traditional methods.

A group of 20 subjects were selected and subjected to the virtual battlefield to study the cognitive changes in them, if any.

CHAPTER 4

STATE OF ART METHODS FOR ASSESSMENT OF COGNITIVE ENHANCEMENT

In chapter number 2 we studied various methods used as interventions for cognitive enhancement and in chapter 3 we finalised the intervention for our study. Once the enhancement is undertaken using the intervention, it is required to be assessed using various tools. In this chapter we would discuss various assessment methods. Cognitive assessment can be undertaken by measuring various physiological signals or testing psychological parameters. The state of art methods available and employed for the assessment of cognitive enhancement is shown in the figure below:-

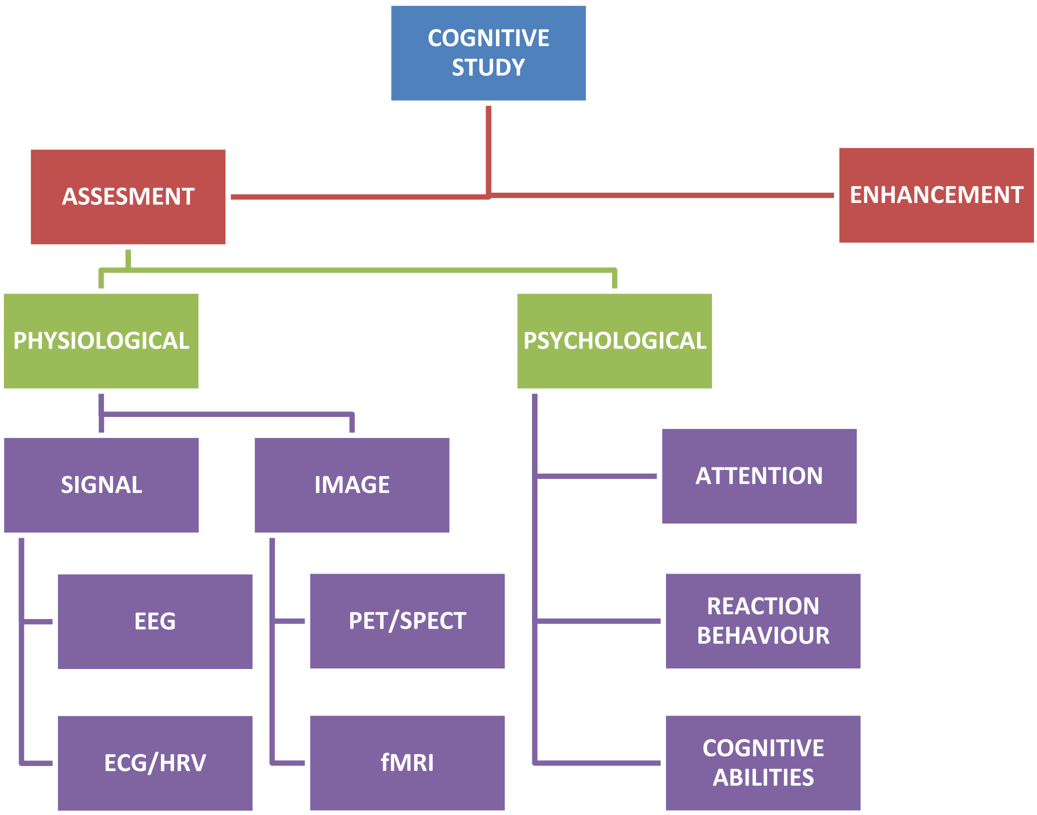


Fig 4.1: Cognitive Tree Showing all the Aspects of Cognitive Assessment

4.1 PHYSIOLOGICAL ASSESSMENT

4.1.1 Physiological Signals

Physiological signals are electrical/magnetic signals generated by some organic activity in the human beings. A change in physiological signal is the result of change in the mental state of an individual. Various modalities effectively used in the field of cognition to measure these mental states are:-

(a) Electroencephalography (EEG). EEG measures the electrical fields created by large number of neurons in the cerebral cortex by placing a series of electrodes on the scalp of the subject. Electrophysiological study of brain provides electrical projection of functional correlation between biomechanical system and cognitive physiology. EEG signals represent not only the brain function but also the status of the whole body [10].

(b) Heart Rate Variability (HRV). The physiological phenomenon in which the time duration between heart beats vary is called the Heart Rate Variability. The HRV can be best determined from the heart rate or RR interval of an electrocardiograph (ECG) signal. The heart rate or RR interval varies as a result from the various inputs received by the Sino-Atrial node. The main inputs include sympathetic and parasympathetic nervous systems (PSNS). Sympathetic activity is fight or stimulus response, related with the excitation, arousal and the parasympathetic is a counter stimuli or rest response. HRV in normal conditions are controlled by PSNS. Also, many mental states could be suitably reflected in the different frequency bands of HRV such as low and high frequency bands. [11]

(c) Blood pressure (BP). Blood Pressure or the arterial pressure is the pressure that is exerted on the walls of the blood vessels by the blood circulating in them, due to the pump action of the heart. BP varies between maximum (systolic) and a minimum (diastolic) pressure during each heartbeat. The cycles of systolic and diastolic BP is affected by different cognitive state of the brain and thus is a useful cognitive indicator. The decline in the cognitive function is indicated by elevated BP. Keeping the BP within desirable limits has a significant beneficial effect on the maintenance of cognitive abilities. Thus this modality can be used for tracking the cognitive state of individuals [12].

(d) Skin Conductance/Galvanic Skin Response (GSR). GSR is a method of measuring the electrical conductance of the skin which varies with its moisture level. This is of interest because the sweat glands are controlled by the sympathetic nervous system; so skin conductance is used as indication of physiological and psychological arousal. Therefore, if the sympathetic branch of ANS is highly aroused, then the sweat gland activity will also increase, which in turn increase skin conductance. The stimulus event can be fear, anxiety, anger, love etc which are related to sympathetic activity. In this way, GRS can be used as measure of cognitive response.

4.1.2 Functional Imaging

Functional imaging involves analysing activities of brain to comprehend the information processing in the brain. Various types of imaging techniques often used for studying the cognitive functions are:-

(a) Functional Magnetic Resonance Imaging (fMRI). "fMRI measures the relative amount of oxygen rich blood that flows into different parts of the brain ". When an area of brain is in use, it requires more oxygenated blood. Since the oxy-haemoglobin has diamagnetic properties and deoxy-haemoglobin has paramagnetic properties which generate different types of MR pattern, thereby clearly generating an image pattern of active part of the brain or oxygen starved part of the brain. Therefore, different parts of brain can be studied effectively for the subjects administered with certain tasks.

(b) Positron Emission Tomography (PET) and Single PET (SPET). "These methods use radioactive isotopes which are injected into the subject blood stream ". More blood is carried out to the active area of the brain and therefore the isotopes. Depending on the complexity of task given to the subjects, the different parts of the brain absorbs different amount of isotopes and therefore a 3D image of the brain can be obtained.

4.2 PSYCHOLOGICAL ASSESSMENT

The psychological tests could be done manually using paper pen evaluation or through computer based psychological assessment. Some of the commonly tested cognitive traits and the corresponding tests have been tabulated on the next page:-

Table 4.1: List of Cognitive Traits and Corresponding Tests

S No	Cognitive Traits	Corresponding Tests
1	Attention	Accuracy Vigilance
2	Cognitive Abilities	Anticipation of Movement Memory English Knowledge Logical Reasoning Numerical Abilities Spatial Abilities
3	Reaction Behaviour and Visual Functions	Reaction Time Visual Perception
4	Senso-motor Functions	Eye Hand Coordination Fine Motor Skills

4.3 Conclusion

The external stimuli in terms of interventions are reflected in the mental states and various physiological and psychological parameters of the individuals. The effects of these interventions on the cognitive functions can be measured through various physiological signals such as EEG, ECG, HRV, BP and skin conductance or using functional imaging techniques such as fMRI and SPECT/PET. These interventions also guide the psychological behaviour of the individuals and can be accessed through various psychological tests such as attention, concentration, senso-motor functions and memory.

CHAPTER 5

METHODOLOGIES FOR ANALYSIS OF COGNITIVE ENHANCEMENT

Among the various methodologies discussed in the previous chapter, few methodologies which have been used for the present thesis work have been discussed in detail in this chapter. These methodologies have been selected based on their availability, portability for on-field testing and suitability for the thesis work. For the present thesis work, I intend to use multi-pronged methodologies for the analysis of cognitive enhancement in order to have better assessment and assess convergence/divergence of various methods towards the cognitive enhancement of the subjects by the selected intervention. Methodologies that will be used for the present work are:-

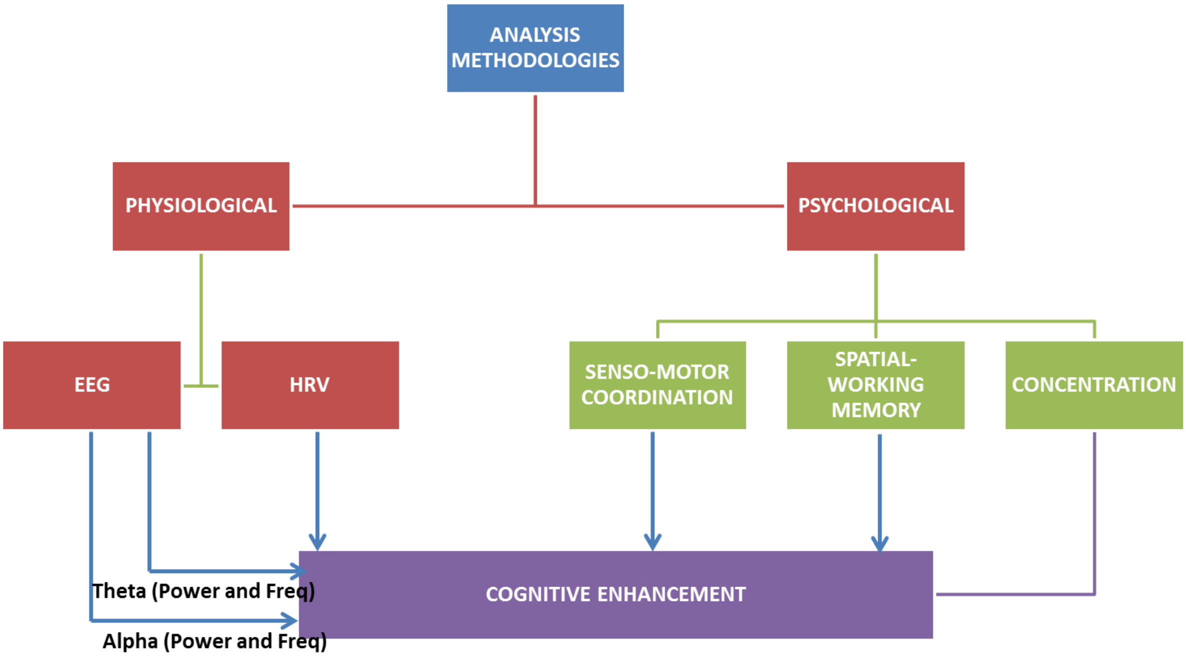


Fig. 5.1: Block diagram indicating the analysis methods used for the study

(a) Analysis of Physiological Signals: These would include Electroencephalogram (EEG) and Heart Rate Variability (HRV).

(b) Psychological Analysis: These would include sensory-motor /2 Hand Coordination, Attention and concentration (Cognitron-COG) and Spatial Working Memory (Forward Block Tapping Test).

5.1 Analysis of Physiological Signals

5.1.1 Electroencephalography (EEG)

EEG measures the electrical activity of large population of neurons in the brain by placing electrodes on the scalp. EEG measured from the human brain comprises of signals in various frequency bands. [14] Characteristics of each frequency bands have been tabulated below:-

Table 5.1: Characteristics of EEG frequency band

Freq Bands	Frequency Range	Dominant Region on Scalp	Mental State
Delta	.5 to 4Hz	Broad or diffuse; Generally frontally in adults, posteriorly in children.	Highest in amplitude and lowest in frequency (slowest wave). **Subjective feeling state:** deep dreamless sleep, non REM sleep, trance, unconscious. **Associated task and behaviours:** lethargic, not moving, not attentive.
Theta	4-7 Hz	Usually regional, may involve many lobes, can be lateralized or diffuse.	Slow Activity. Strong during meditation, prayer and spiritual activity. Abnormal in wake adults but normal during sleep and

			children. **Subjective feeling states:** fantasy, imagery, dreamlike, drowsy. **Associated tasks & behaviours:** Observed in anxiety and behavioural activation. Artistic, sensitive; may be distracted, unfocused. **Effects of Intervention:** if enhanced, can induce drifting, trance-like state. **If suppressed, can improve concentration, ability to focus attention.**
Alpha	8-12 Hz	Posterior regions of head, strong occipital; Best observed with closed-eyes & under physically relaxed condition without any mental inactivity. Peaks around 10 Hz.	Good alpha promotes mind resourcefulness, mental coordination, enhances source of resourcefulness and fatigue. **Subjective feeling states:** Relaxed, not agitated, calm and conscious. **Associated tasks & behaviours:** alert, but not very actively processing information. **Effects of Training:** can produce relaxation. **Lower alpha (8-10)**: Inner-awareness of self, mind/body integration and balance. **Upper alpha** (10-12): Healing, mind/body connection and cognitive functions.
Beta	12-3- Hz	Symmetrical distributed on both sides & most evident frontally.	High frequency and low amplitude waves. **Subjective feeling states:** Active, busy or uneasy thinking, active concentration.

			Associated tasks & behaviours: state of brain when eyes open, listening and thinking during decision making, problem solving and information processing.
Gama	30-100 Hz	Found in every part of the brain.	Certain cognitive or motor functions. Involves in consolidation of information during simultaneous processing of multiple information. Associated with good memory.

In the present thesis work we would be basically analysing the Alpha, Beta and Theta frequencies of the subjects as the power and frequencies in these bands are more closely related to the cognition. The data recorded by B-Alert X 10 EEG system was used for the analysis purpose.

5.1.2 Heart Rate Variability (HRV) Analysis

HRV is the phenomenon of variation in beat to beat interval. The most common methods used for detection of beats are blood pressure (BP) and electrocardiogram (ECG). HRV is said to be closely related to cognitive functions and emotional arousal as the heart rate may be increased by the sympathetic activity or decreased by the parasympathetic (vagal) activity. A decrease of heart rate indicates an increased HRV and vice versa. Balance between these two opposite branches of autonomous nervous system (ANS) is referred to as sympatho-vagal balance. Various researches indicate that anxiety, depression, panic disorders have negative impact on autonomic function, typically causing depletion of the parasympathetic tonus.[11]

HRV analysis can be done in either using time domain or frequency domain methods. In general the standards that are followed are:-

(a) Frequency-Domain Methods: Used for processing of short-term recordings generally of 5 minutes, made under physiologically stable conditions.

(b) Time-Domain Methods: Used for nominal 24-h recordings.

Since in the present case we would be recording the signal for 5 min, we would use the spectral analysis in the frequency domain for our thesis work. HRV spectrum is integrated into different frequency bands to evaluate the following parameters:-[20]

(a) High Frequency (HF) Power Spectrum (0.15-0.4 Hz). "This band reflects the parasympathetic (vagal) tone. The HF activity has been found to reduce under the condition of elevated stress, anxiety, emotional strain and time pressure; presumably related to focused attention and motor inhibition. In the individuals with post-traumatic stress disorder, HRV and its HF component is found to be reduced, while the low-frequency (LF) component is elevated"

(b) Low Frequency (LF) Power Spectrum (.04-0.15 Hz). "This band reflects both sympathetic and vagal tone. A decreased PSNS activity or increased SNS result in reduced HRV".

(c) Very Low Frequency Power Spectrum (0.0033-0.04 Hz). "The physiological meaning of this band is very vague. " Generally the VLF assessed from short-term recording i.e 5 min, is a dubious measure and should be avoided for the study purpose".

(d) Sympathetic-Vagal Balance (Ratio of LF/HF powers). The ratio is used to indicate the balance between sympathetic and vagal tone. A decrease in this score might indicate either increase in vagal or decrease in sympathetic tone".

5.2 Psychological Assessment

To evaluate psychological parameters, we have used computer based psychological assessment tool from M/s Schuhfried called Vienna Test System (VTS). The various test parameters used in the study are discussed below:-

5.2.1 Two Hand Coordination

The two hand coordination test using VTS is used for testing of speed and accuracy of visuomotor coordination i.e coordination of eye-hand and left and right hand. The test requires the subjects to move a dot along a predefined path using joystick with both hands on VTS test panel. The track consists of three sections that vary in difficulty viz circular arc, V-shape and inverted L, as shown in fig below:-

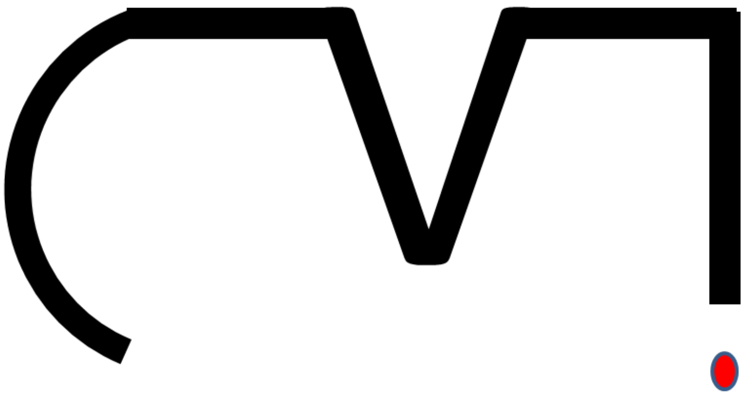


Fig. 5.2: Schematic representation of the track for Two Hand Coordination test

The following variables are scored:-

(a) **Total Mean Duration:** This is the average time taken to travel the track. This gives a measure of speed of movement.

(b) **Total Per cent Error Duration**: This is the ratio of total error duration to total duration. This gives a measure of quality of performance and hence accuracy.[21]

5.2.2 Cognitron (COG)

The cognitron test using VTS is used for assessment of attention and concentration through comparison of figures. The subject is required to compare an abstract figure with a model and press a green button on VTS test panel as soon as two similar figures appear on the screen within a time frame of 1.8 seconds. Once the answer is entered next item follows automatically. Total 200 different combinations are presented to the respondent. Individual is required to work as quickly and accurately as possible. The response time limit of 1.8 sec is expected to create time pressure.

The followings main variables are scored:

(a) **Total correct rejections:** Number of items to which a correct response was made. This gives a measure of accuracy.

(b) **Mean Time Correct rejections**: Mean time taken to record correct or incorrect answers when under time pressure. This gives a measure of speed of performance.[22]

5.2.3 CORSI Block Tapping Test Forward

Block-Tapping tests are a good indicator of the development of cognitive functions. It measures the storage capacity of spatial short-term memory and learning in spatial working memory. On the computer screen the respondent sees a set of nine irregularly positioned blocks. A mouse cursor moves about the screen and selects the blocks in a particular sequence. The subject is required to remember and select three sets of 1 to 9 blocks in the same sequence as previously selected by the cursor.

The following main variable is scored:

Immediate Block Spans (German abbreviation-UBS): This corresponds to the longest sequence that was correctly reproduced in at least two of the three presented. This tests the storage capacity of working memory. [23]

5.3 Conclusion

EEG measured from the human brain comprises of signals in various frequency bands. Among the different frequency bands alpha and theta frequency bands are closely related to the individual's cognitive functions. EEG recording from B-Alert X 10 EEG system was used for analysis purposes.

HRV is also closely related with the cognitive processing and emotional arousal of the individuals. ECG is considered as superior method for measuring of HRV. Normally the frequency domain analysis method is used for short term recording of 5 minutes.

The effect of Virtual Environment on various psychological parameters related to the cognitive performance of the soldiers was analysed using computer based psychological assessment tool from M/s Schuhfried called Vienna Test System (VTS). The various test parameters used in the study were: two hand coordination test for testing of speed and accuracy of visuomotor coordination; cognitrone test assessment of attention and concentration through comparison of figures and Block-Tapping tests to measure the storage capacity of spatial short-term memory and learning in spatial working memory.

CHAPTER 6

METHODOLOGY FOR DATA RECORDING

The data will be collected for 20 subjects for the study of case-II and the case-III study as discussed in chapter number 3. All the subjects need to be free from any disease or disorder. Total data samples of 1800 minutes will be recorded from 20 subjects during the study period. A block diagram representation of collection of data samples over period of intervention is shown below:-

Physiological Data: - 400 min (EEG: 5 min x 40 = 200 min; ECG: 5 min x 40 =200)

Psychological Data: - 1400 min (2Hand+ Cog+ COSRSI: 35 min x 40= 1400 min)

Total Data Recorded: - 1800 minutes

Fig. 6.1: Block diagram representation of data recording schedule.

6.1 METHODOLOGIES FOR RECORDING OF PHYSIOLOGICAL SIGNALS

6.1.1 Data Acquisition Hardware and Software

The data acquisition of EEG and ECG signals was done using B-Alert X10 EEG Headset System. The B-Alert X 10 system includes:-

(a) B-Alert X10 Sensor Headset

(b) Sensor Strips

(c) Foam Sensors and12cc Syringe

(d) Conducting Gel

(e) ECG and Mastoid Leads

(f) Disposable Electrodes

(g) USB Host device and B-Alert Dongle

(h) B-Alert Software

Acquisition Length: European Heart Journal recommends a minimum of 5 minutes recording for frequency domain analysis of HRV signal. Acqk Software guide recommends minimum 30 seconds recording for EEG analysis. Based on the above facts and sample recordings we have chosen acquisition length of 5 minutes.

6.1.2 Electroencephalography (EEG) Recording:

The B-ALERT X10 acquires nine channels of mono-polar EEG recordings with a linked mastoid reference. The 10th channel is a programmable gain option that can be used for EOG or ECG. The B-ALERT X10 consists of: Head and Host Units for bi-directional transmission of digitized physiological signals, a Neoprene Strap, and a Sensor Strip with

EEG sensor sites in the frontal (Fz, F3 and F4), central (Cz, C3 and C4) and parietal-occipital (POz, P3, and P4) regions.

The Sensor Headset collects physiological signals from the sensors placed on the user sampling at 256 Hz. The headset performs analog-to-digital conversion, encoding, formatting and transmitting of all signals. The signals communicate using a 2.4 to 2.48 GHz radio transmitter. B-Alert Acquisition utilizes the bi-directional capabilities of the system to initiate scalp-electrode impedance monitoring, and monitors the battery capacity in the Head Unit. A custom USB Host Device (B-Alert Dongle) is used as the base unit affixed to the PC workstation.

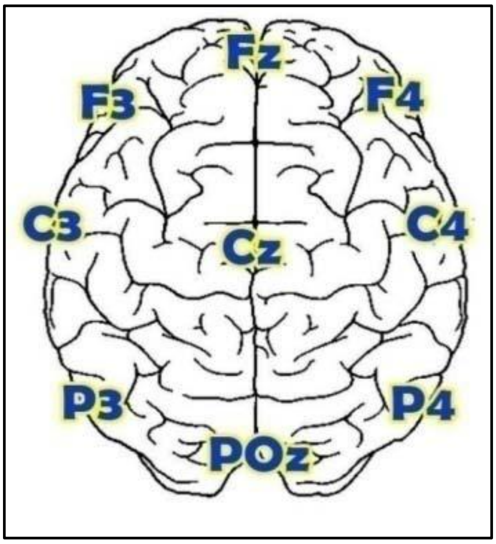


Fig. 6.2: B-Alert X10 Electrode Sites

6.1.3 ECG Recording for HRV Analysis:

The B-Alert ECG algorithms rely on peak to peak measurements to compute the beat to beat (and second to second) Heart Rate. The ECG signal is robust and the sensor placement is somewhat flexible. BIOPAC's recommended placement is to have the Left (blue) ECG Lead on the lower most rib and the Right (grey) lead on the right collarbone. Alternative ECG placements however can be used if the recommended configuration is not ideal for a given application. For alternative ECG placement, the appropriate leads must be placed across the heart (blue lead always on the Left side of participant and grey lead always on the right side). The adhesive electrodes should be placed on boney parts of the participant, where there is little potential for movement (from breathing or muscles) which can compromise signal integrity.

Fig. 6.3: Position disposable electrodes for ECG measurement

6.1.4 Steps for acquiring the EEG and HRV data are as follows:-

Step 1: Set the hardware

(a) Preparing Sensor Headset

(i) Ensure that the fuzzy side of the Neoprene is facing out and the strip connector triangle is pointing up.

(ii) Using a clean Neoprene Strap, feed the Strap ends through each side of the Sensor Headset strap holders and fasten the Velcro. Do this equally to both sides, but leave loose for easy application to subject later.

(iii) Verify that the Mastoid Leads are plugged into the system (b) Connect Ethernet cable to MP150 system and laptop.

(b) Preparing Strip

(i) Attach the foam pieces to the sensor sites. Ensure the foam is centred within the black circle to maximize the contact surface between the sensor site and the foam.

(ii) Using the provided syringes with curved tip applied, fill each foam piece with gel.

(iii) Make sure to completely fill foam piece. Each sensor will hold 0.4-0.6 cc of gel.

(iv) The foam should be saturated with gel and the centre hole should be filled to the top.

Step 2: Prepare subject and application

(a) Place the Sensor Headset onto the subject's head and tighten the Neoprene Strap to provide a snug fit.

(b) Verify that the Neoprene Strap is centred on the subject and that it is not resting on the ears.

(c) While holding the strip in front of the subject, with the foam pieces facing away from the face, attach the strip to the front of the Neoprene Strap by feeding triangular tip through the hole adjacent to site Fz.

(d) Carefully bring the strip over the top of the subject's head, verifying that the strip is centred and that the subject's inion is below the alignment hole. Ensure electrodes are properly clean.

(e) While holding the strip in place over the inion, take the two strip arms closest to the inion and attach them to the Neoprene Strap.

(f) Tighten the remaining strip arms in pairs, from the back of the head to the front, so that the strip sits flat against the subject's head, while maintaining the correct alignment on the scalp.

(g) Gently plug connector on the back of the Strip into the Sensor Headset. The connection between headset and strip is snug; be gentle when plugging/unplugging.

(h) Place the ECG electrodes as explained before. Insert the ECG lead plug into the two pin receiver on top of the sensor headset.

(i) Position the mastoid leads directly over the mastoid bone and insert the mastoid lead plug into the three pin receiver on the bottom of the sensor headset.

Step 3: Set the software.

(a) Open B Alert software

(b) Plug in the USB Host Device (B-Alert Dongle) to an available USB port on the computer running B-Alert Software.

(c) Verify the Sensor Headset is synced to the B-Alert Dongle by switching on the sensor headset and viewing the indicator lights on the front of the sensor headset. The headset has established connection when the green indicator light turns solid after 5-seconds. If the red indicator light stays on while the green indicator light is blinking, the headset is not properly connecting.

(d) Click '**Find Port'** to connect the software to the wireless sensor headset

Step 4: **Begin data collection.**

(a) Ask the subjects to fully relax and close their eyes. Once they are comfortable, press '**Test Impedance'** to check whether all the electrode impedances are within the specified limit (below 40 kΩ).

(b) Once all electrode impedances are within limits press '**Acquire B Alert Baselines**'. The acquisition of baseline data is used to create the individualized EEG profiles required for the B-Alert cognitive state metrics. The "Baseline" AMP obtains 5 minutes each of a 3-choice psychomotor vigilance task (3CVT), eyes open (EO), and eyes closed (EC). Typically baseline data only needs to be obtained one time for each individual, if performed on a healthy, rested subject.

(c) Once the baselines have been created press '**Acquisition**' to start the data acquisition. Stop data collection after 5 mins.

6.3 METHODOLOGIES FOR RECORDING OF PSYCHOLOGICAL DATA

6.2.1 Vienna Test System (VTS)

To evaluate psychological parameters, we have used computer based psychological assessment tool from M/s Schuhfried called Vienna Test System (VTS). The VTS provides a reliable means of measuring personality traits and ability of an individual. The computer based technology guarantees maximum objectivity, precision, efficiency and security against miscalculation as compared to the traditional pen-paper methods. The psychological assessment is carried out using Vienna Test System (VTS). The system includes: [16]

Base Administrative Software: "This provide interface for administering the test, scoring the results and managing clients data. Other functions include security aspects managing test batteries etc".

A Wide Range of Tests: "The system includes both computerised version of conventional pen-paper tests as well as a wide range of auditory, multimedia and adoptive tests".

Input Devices: "These include a response panel and joysticks, for measuring reaction time, reactive stress tolerance and sensorimotor coordination".

6.2.2 Steps to conduct Psychological Test

Step 1: Form Test battery of the desired tests:-

Setup>Test Batteries>Rename>2Hand/S2>COG/S4>CORSI/S1>Save

Step 2: Form Subject Database:-

Person>New>Enter personal details of the subjects.

Step 3: Start test using battery:-

Person>Check Subject>Test>Test Battery>Start Testing

Step 4: Export results in SPSS form for further analysis.

6.3 Conclusion

EEG and ECG data recording were carried out for 5 minutes duration using B-Alert EEG system. B-Alert is a Bluetooth wireless system and sensor headset integrated with AcqKnowledge software to record up to 9 channels of mono-polar EEG and one optional channel of ECG data. B-Alert Cognitive States Analysis software can be additionally used to create a "Baseline" file of a subject's EEG profile by administering some simple onscreen tests and storing this session data as a permanent reference for future EEG recordings. The B-Alert Brain State Gauges can be used to display a real-time view of B-Alert headset data as it is being acquired. The EEG data itself is recorded in AcqKnowledge via the wireless B-Alert hardware. Psychological data were recorded using the computer based psychological analysis hardware and software from Vienna Tests System.

CHAPTER 7

DEVELOPMENT OF VIRTUAL REALITY ENVIRONMENT

7.1 Introduction

The invention of virtual reality in computer systems dates back to the early 1950s. In 1963, Ivan Sutherland a researcher at Massachusetts Institute of Technology (MIT) prototyped Sketchpad program which pioneered the use of graphical user interface in the world of computing. With Sketchpad, he could use a light pen to draw vector lines on a computer screen. Two years later, he designed and developed the Head Mounted Display (HMD) and an immersive 3D virtual environment. His work paved way for opportunities in Human Computer Interaction (HCI) research work. HCI describes the point at which computer science and human behavioural sciences intersect.

Virtual reality describes an immersive 3-D virtual environment system which allows a user to manipulate and navigate through it while the user is experiencing interaction with the virtual environment rather than the computer. In other words, the virtual reality system application senses a user's inputs, and manipulates the virtual scene which is generated from numerical data, in real-time according to the user's input. This makes the user feel immersed in the system, and therefore the mind can relate with non-existing things as if they do exist.

Improvements and advances in virtual reality technologies have provided means of allowing interactive virtual environments (VE) to be implemented on personal computers for interactive software applications. It can be implemented in various fields e.g. military combat trainings, surgery and medical diagnosis, games industry etc. The three main functional components of virtual reality are shown in the figure:-

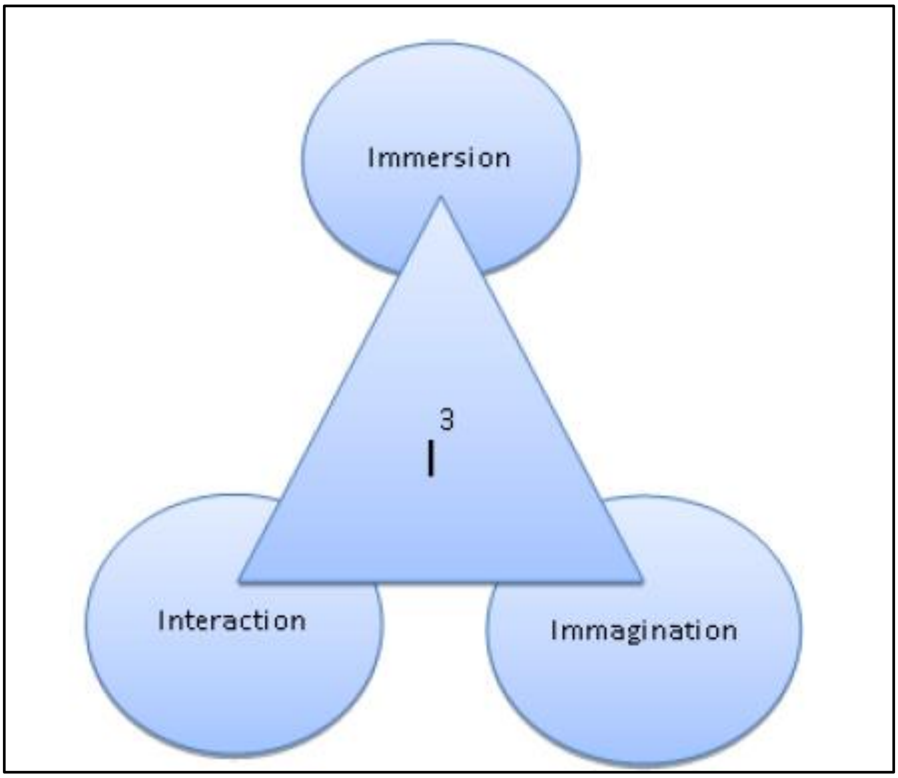


Figure 7.1. Components of Virtual Reality

7.1.1 Immersion

Immersion describes a state of been engrossed into a virtual system thereby causing the consciousness of the real word to diminish as the user responds to stimuli presented by this virtual system. Immersive virtual reality systems makes use of its basic controls from human responses i.e. for a user to view an object sideways, the user has to physically turn the face sideways. The rendering and animating of images in real-time provides a sense of immersion and increases the user’s presence. These effects create depth perception and make it possible to have effects which are present in real world. Further development work on this can help in training purposes.

7.1.2 Interaction

Interaction is defined as the ability of a user to physically initiate actions that lead to movements in a virtual world. It also describes the level of responses virtual objects give in reactions to actions initiated by the user. Everything associated with input reads from the user which is applied to constructing display changes in the virtual environment.

7.1.3 Imagination

Imagination describes the mind's capacity to perceive a world or environment that does not exist i.e. creating and placing non-existing objects. It gives meaning and understandable knowledge about virtual reality experiences.

7.2 Virtual Environment Systems

These systems use interactive three dimensional virtual images, generated from geometrical data that give users the experience of immersion as they navigate through it. It is mainly characterized by stimuli or sensory modalities which cause direct interaction with the objects in the virtual system. This enables a user to integrate physical surroundings with the elements in the virtual system in real-time. It is very important for a VE system to feel realistic and immersive as much as possible. At the development level in VE systems, all the entities are modelled to point to realism. The navigation software interprets gestures from the input device and applies it into processing movements. This is made possible by mapping particular gestures into known familiar motions e.g. the forward key on the QWERTY keyboard can be mapped to an object's direction in the z-axis. Collisions can also detected by making the VE system search constantly for objects which might be occupying the same location in 3D-space, and therefore uses the physics engine to calculate the reactions that could occur from these collisions.

Virtual environment data types can be categorized according to the details of the virtual entity it represents in the virtual environment. Figure 3.1 shows an example of a virtual environment developed from three different categories of data types in the virtual environment, namely; graphical, functional and measurement data type.

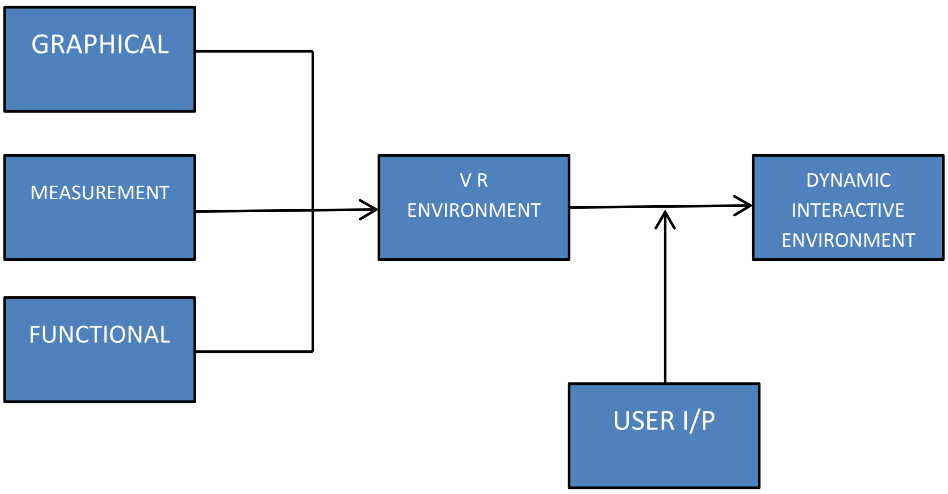


Fig 7.2: The data types to create an immersive virtual environment

The graphical data consist of the geometric information of the objects which are presented as physical objects in the virtual environment by two or three-dimensional spatial objects similar to the real objects they represent. Their geometric data structures consist of polygons, b-splines, sub-divisional surfaces etc., and they are rendered along with other different materials to determine interactivity with light. This contributes to the main idea and creation of illusion in the virtual world. Measurement data on other hand are signal information from the sensors. Functional data are entities created through analysis of all graphical and measurement data.

7.3 Creation of Virtual Reality Environment

To develop a virtual reality environment in Unity 3d, we first need to make ourselves familiar with Maya, 3ds Max or Blender. These are the modelling softwares needed to develop the objects required in the virtual environment. I have used 3ds Max to develop the objects in virtual battlefield.

7.4 Creation of Models for Virtual Environment Using 3ds Max

Autodesk 3ds Max, formerly 3D Studio Max, is a 3D graphics program for making 3D models along with their animations. It has modelling capabilities, flexible plugin architecture and can be used on the Microsoft Windows platform. It is used for movie effects and movie pre-visualization.

Autodesk 3ds Max is primarily, although not completely, based on polygon modelling. Polygon modelling is used more extensively in game design than in other animation application as it offers a highly specific control over individual polygons that make up the model. This feature of polygon modelling also allow for greater optimization of the model.

Usually, the design process begins at the selection of a primitive model bundled with 3ds, which is then further refined as per need. The current versions have a simplified mesh editing interface and using the ‘edit poly’ modifier which moves the tools available in the primitive model, higher in the modifier stack, allowing them to be used on top of other modifications.

In the 3ds Max software various unique primitive shapes such as teapots, cones, pyramids and cubes are available which can be used as a base for model development.

Although polygons are the method of choice for model building, surfaces are easier to define using other methods. 3ds Max’s subdivision surface support allows for smoothened surfaces and with the use of tools like Soft Selection, which allows manipulation of vertex clouds into the desired shape without distortions from unwanted shapes and displaying smooth surfaces. The sculpting brush feature allows smooth surfaces to be drawn by hand, if polygons give a distorted image, although functionality is limited.

7.4.1 Designing Workflow

You start with a new unnamed scene when you open 3ds Max. You can also start a new scene at any time by choosing New or Reset from the Application menu.

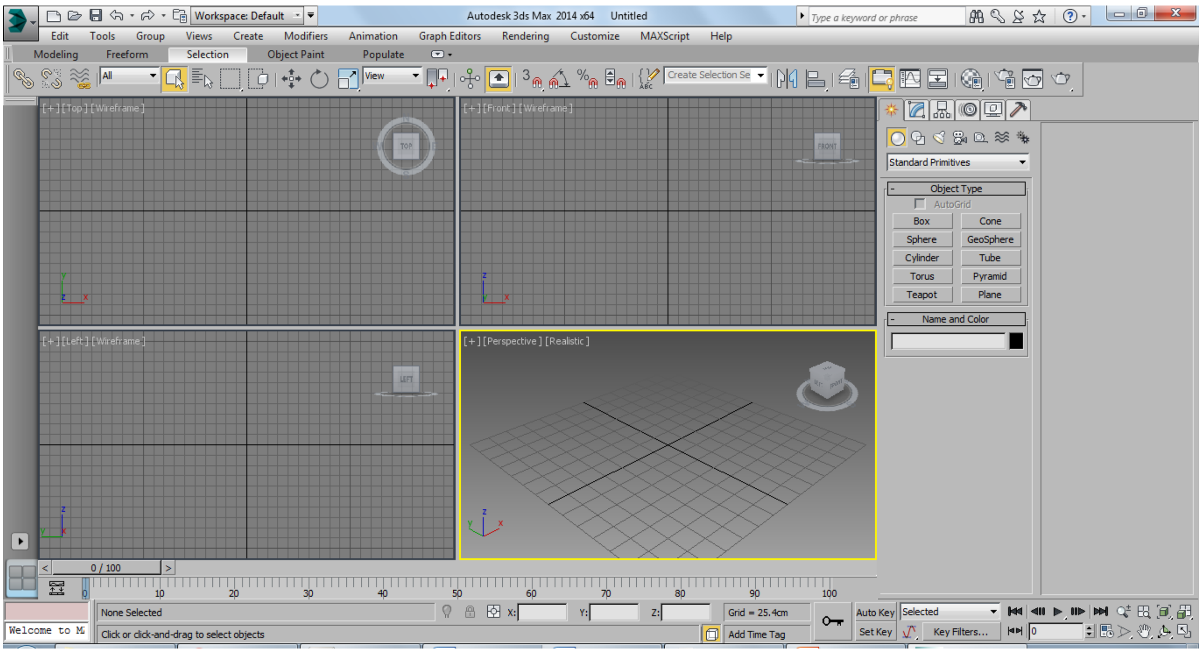


Fig 7.3: New Unnamed Scene in 3ds Max

Everything in 3ds Max is located in a three-dimensional world that you view through one or more viewports. You have a variety of options for visualizing this enormous stage-like space, from the tiniest details to the full extent of your scene.

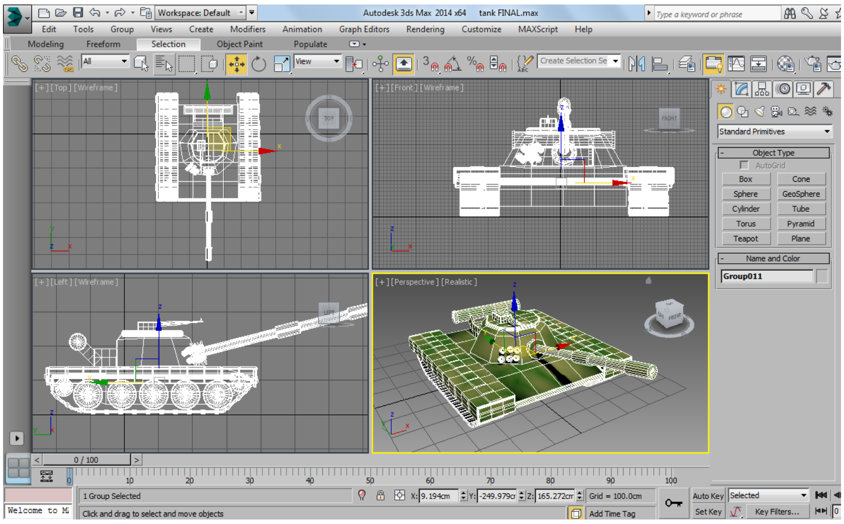


Fig 7.4: Viewports in 3ds Max (Top, Front, Left & Perspective)

7.4.2 3ds Max Interface Overview

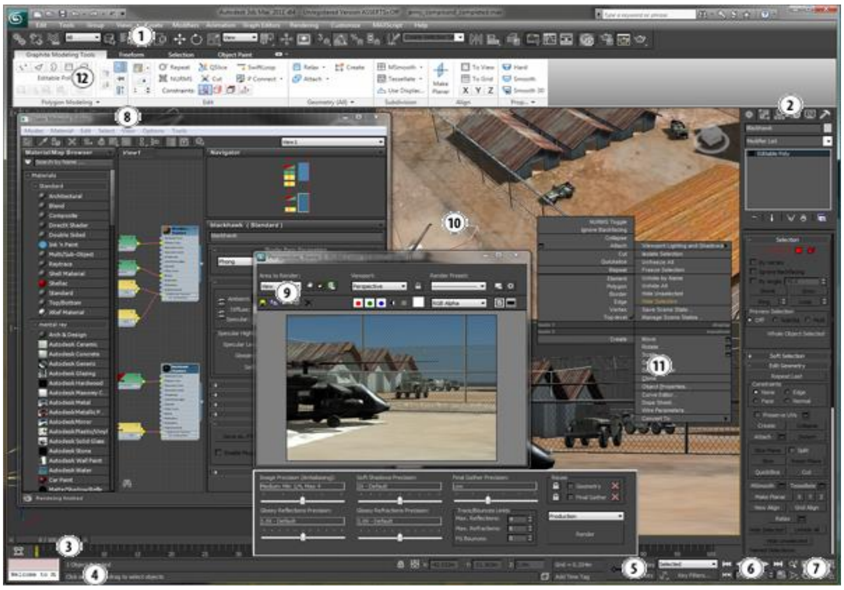


Fig 7.5: 3ds Max Interface Overview

(a) 1**: Main Toolbar:** The main toolbar provides quick access to tools and dialogs for many of the most common tasks in 3ds Max.

(b) **2: Command Panel:** The command panel comprises six user-interface panels that give you access to most of the modelling features of 3ds Max, as well as some animation features, display choices, and miscellaneous utilities. To switch between the different panels, click their respective tab at the top of the command panel.

(c) **3: Time Slider:** The time slider lets you navigate along the timeline and jump to any animation frame in your scene. You can quickly set position and rotation or scale keys by right-clicking the time slider and choosing the desired key from the Create Key dialog.

(d) **4: Status Bar Controls:** The 3ds Max window contains an area at the bottom for prompt and status information about your scene and the active command. To its right, is the coordinate display area, in which you can manually enter transform values. To its left, is the MAXScript listener window, where you input single-line scripts.

(e) **5: Animation & Time Controls:** Between the status bar and the viewport navigation controls are the animation controls, along with the time controls for animation playback within viewports. Use these controls to affect your animation over time.

(f) **6: Animation Playback Controls:** Use these buttons to see your scene in motion through time.

(g) **7: Viewport Navigation Controls:** Use these buttons to navigate your scene within the viewports.

(h) **8: Slate Material Editor:** The Slate Material Editor, which you open with the M key, provides functions to create and edit materials and maps. Materials are assigned to objects and create greater realism in a scene by using different maps.

(i) 9: Rendered Frame Window: The rendered frame window displays a rendering of your scene. Press F9 to trigger the rendering process. Using Rendered Frame Window controls, you can change render presets, lock the rendering to a single viewport, render regions of the viewport for faster feedback, and change mental ray settings such as final gather and reflections without having to access other portions of the program.

(j) 10: Viewport: When you start 3ds Max, the main screen contains four viewports showing the scene from different angles. You can set a viewport to show a simple wireframe or shaded view of the scene, and you can also employ advanced but easy-to-use Review features such as shadows (hard-edged or soft-edged), exposure control, and ambient occlusion to display highly realistic, near-rendered results in real time.

(k) 11: Quad Menu: When you click the right mouse button anywhere in an active viewport, except on the viewport label, a quad menu is displayed. The options available in the quad menu depend on the selection.

(l) 12: Graphite Modelling Tools: Graphite Modelling Tools combines a wealth of new polygon-modelling features, including freeform sculpting and powerful loop-modelling tools, with the tried and true toolset in a dynamic, configurable new "ribbon" interface.

7.4.3 Creating a New Object

(a) Put the cursor at a point in any viewport where you want to place the object, and hold the mouse button down (do not release the button).

(b) Drag the mouse to define the first parameter of the object; for example, the circular base of a cylinder.

(c) Release the mouse button. The first parameter is set with this release. In some cases, such as Sphere, Teapot, and Plane, this completes the object. You can skip the remaining steps.

(d) Move up or down without touching the mouse button. This sets the next parameter; for example, the height of a cylinder. If you want to cancel: Until you complete the next step, you can cancel the creation process with a right-click.

(e) Click when the second parameter has the value you want, and so on. The number of times you press or release the mouse button depends on how many spatial dimensions are required to define the object. (For some kinds of objects, such as Line and Bones, the number is open-ended.)

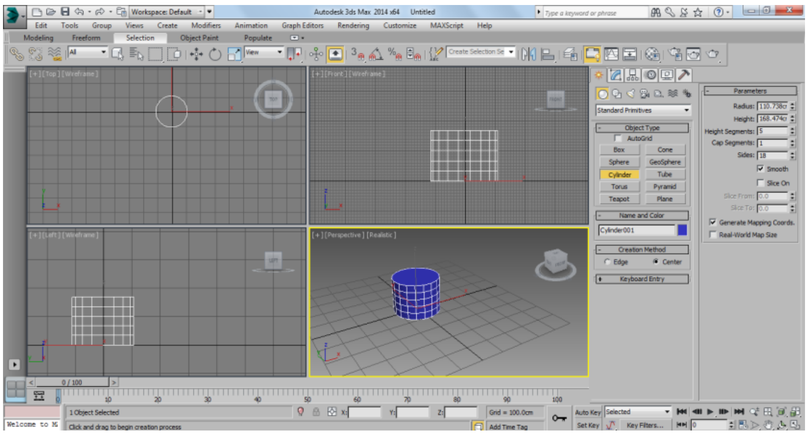


Fig 7.7: Creating a Cylinder in 3ds Max

7.4.4 Modifying the New Object

(a) After adding objects to your scene from the Create panel, you often move to the Modify panel to change an object's original creation parameters and to apply modifiers. Modifiers are the basic tools for reshaping and adjusting primitive geometry.

(b) Once you've applied modifiers to an object, you can use the Modifier Stack to find a particular modifier, change its parameters, edit its sequence in the modifier stack, copy its settings to another object, or delete it entirely.

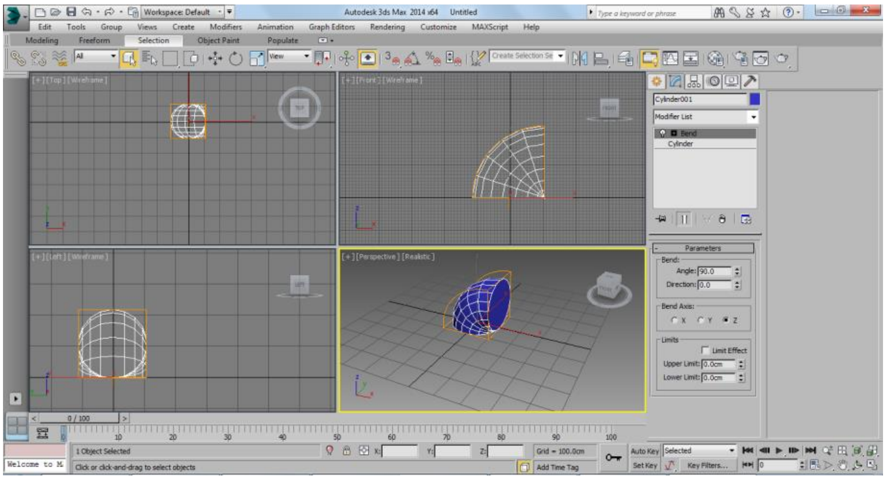


Fig 7.7: Modified Cylinder in 3ds Max

7.4.5 Using Materials

Using the methods given above and after some experience complex designs can be made. A Battle Tank to be used in the virtual battlefield has been made by me. However, without using the materials it looks plain as shown on the next page:-

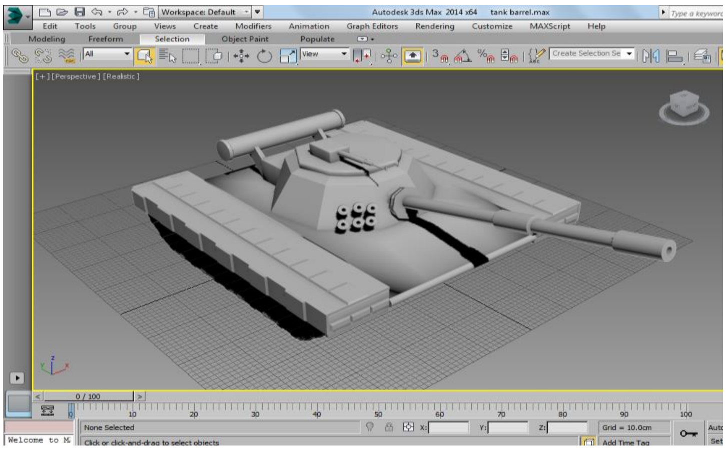


Fig 7.8: Battle Tank Modelled Using 3ds Max

(a) You set basic material properties to control such surface characteristics as default color, shininess, and level of opacity. You can create realistic, single-color materials using just the basic properties.

(b) You extend the realism of materials by applying maps to control surface properties such as texture, bumpiness, opacity, and reflection. Most of the basic properties can be enhanced with a map. Any image file, such as one you might create in a paint program, can be used as a map, or you can choose procedural maps that create patterns based on parameters you set. 3ds Max also includes a ray-trace material and map for creating accurate reflections and refraction.

(c) You can view the effect of materials on objects in a shaded viewport, but the display is just an approximation of the final effect. Render your scene to view materials accurately.

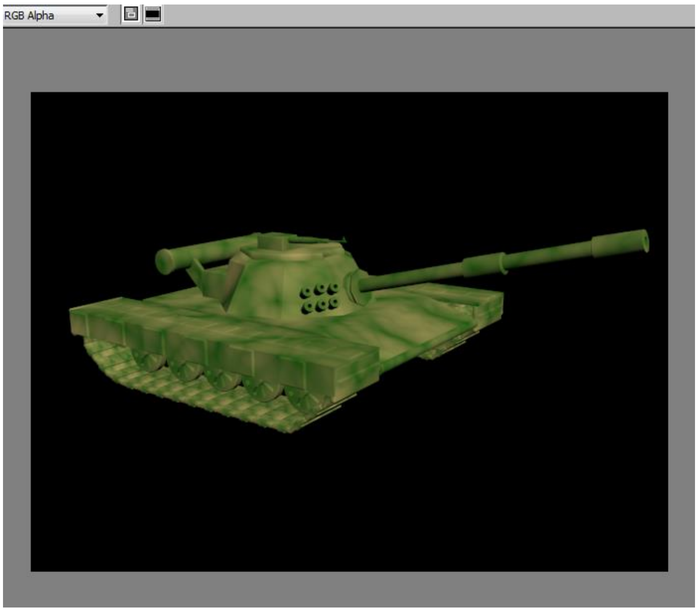


Fig 7.9: Rendered Battle Tank Modelled Using 3ds Max

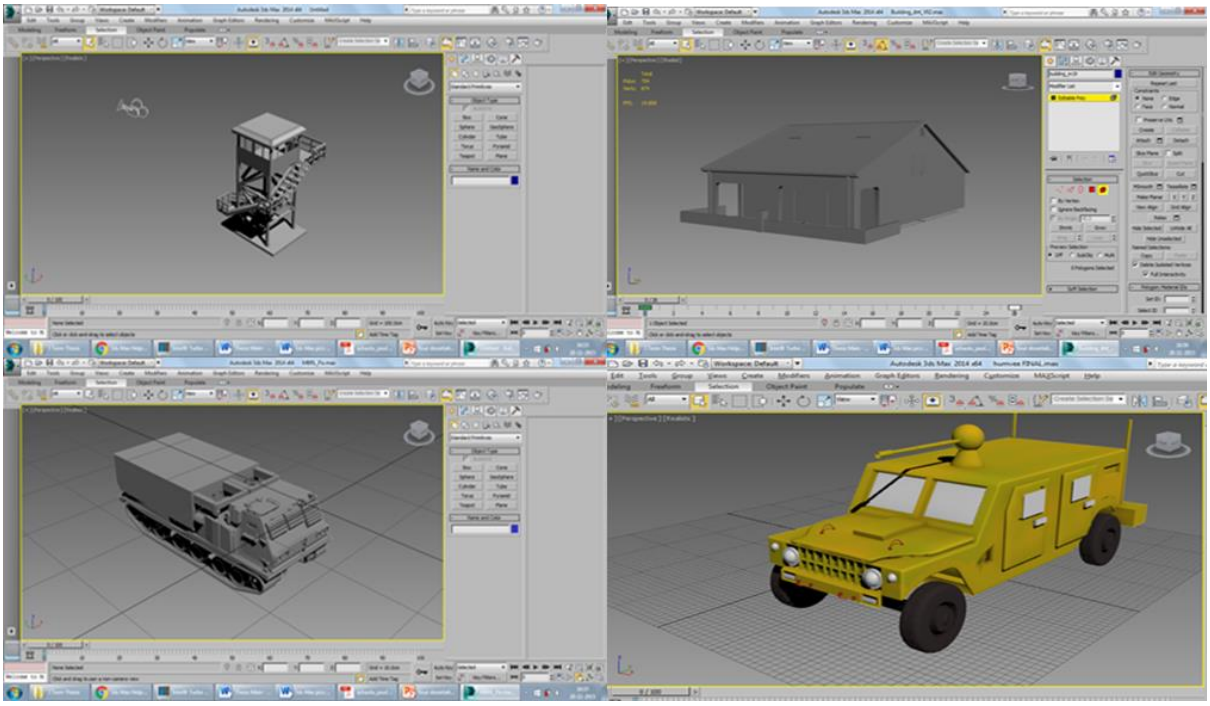


Fig 7.10: Other Objects Modelled Using 3ds Max for the Purpose of the Study

7.5 Creation of Virtual Reality Environment Using Unity 3d Game Engine

This section discusses the development of the virtual battlefield using Unity 3D, a game engine. The virtual environment with the terrain and various objects was developed in the Unity3D engine development tool. Unity 3D is cross-platform game engine software. It supports three scripting languages which are open-source Mono framework; C#, JavaScript and Boo (a dialect of Python). Unity 3D also supports varieties of assets including animations, textures, sounds and allows imports of 3D models created in Maya, 3ds Max, Blender etc. A custom rendering engine is combined with physics engine to render real-time graphics and perform collision detection and response to the virtual environment. The physics engine properties give mass, drag, collision detection etc. to objects.

7.5.1 Unity3D interface and controls

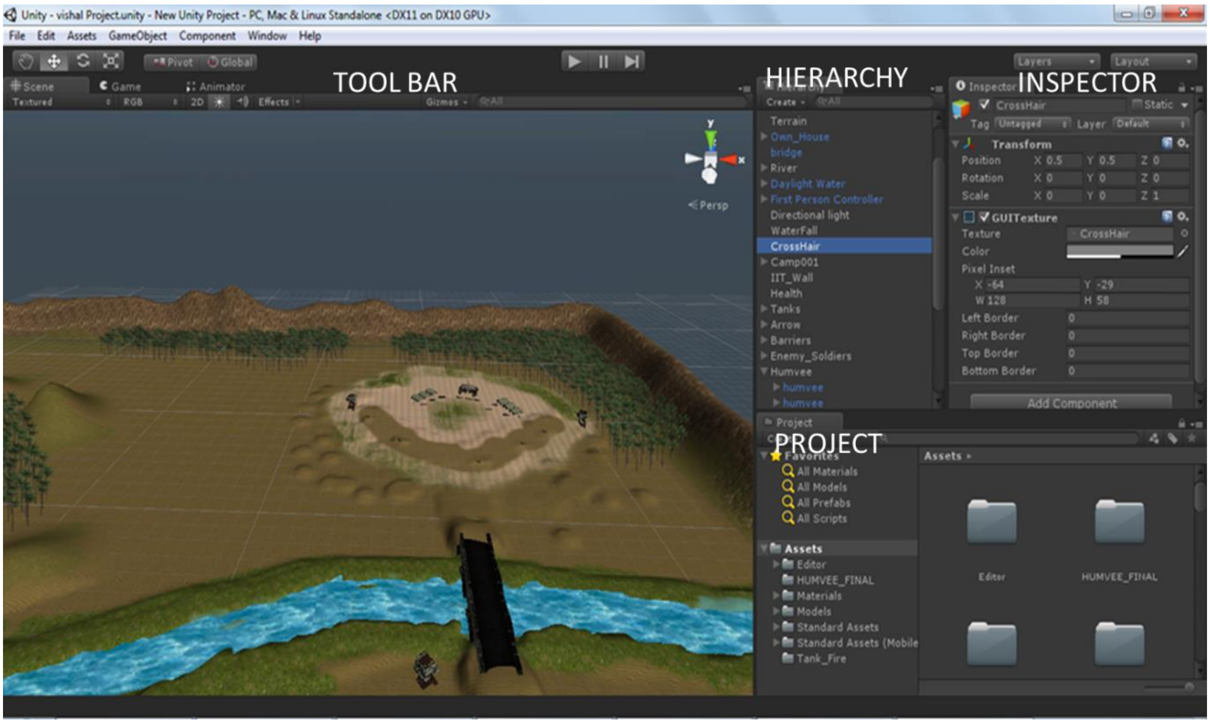


Fig 7.11: Unity3D Editor

The interface is made up of five tabbed windows; Hierarchy, Inspector, Game, Scene and the Project as seen in Figure 7.11.

The hierarchy lists all the game objects in the current scene, usually in a tree form that shows the relationships existing between the game objects. Figure 7.12 shows the First Person Controller parenting the camera game object and the camera object inherits properties of the First Person Controller i.e. speed, rigid body etc. Parenting in Unity describes a concept of objects when dragged into a desired parent object; the dragged object becomes a child object and inherits the movement and rotation of its parent.

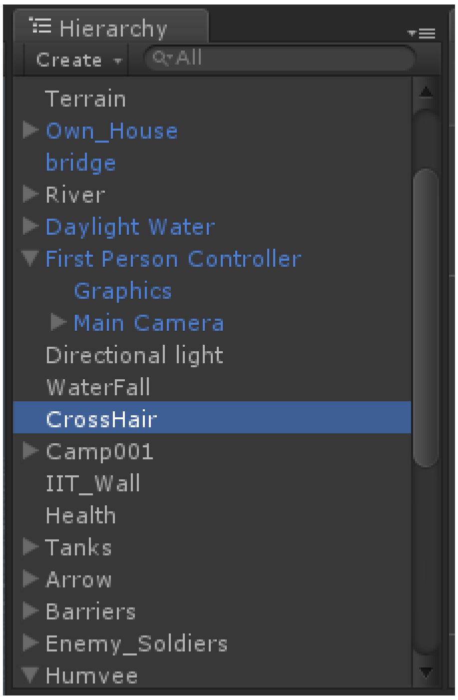
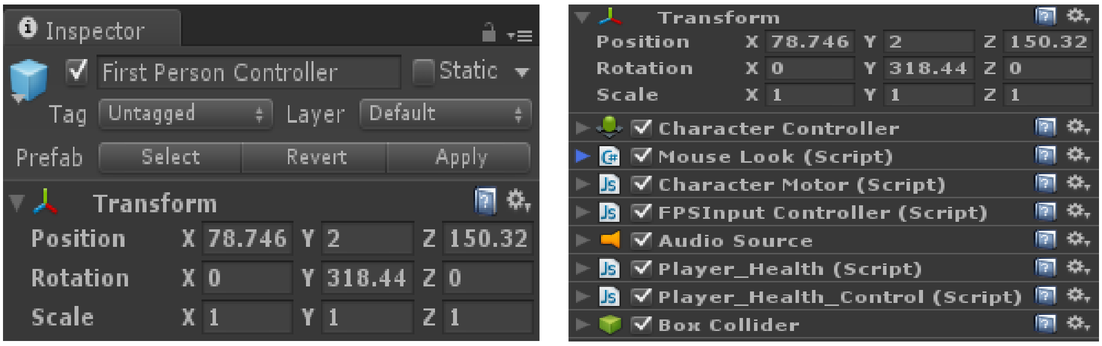


Fig 7.12: Hierarchy tab arranging objects according to the relationships

The inspector shows a detail list of all components and values of the selected game objects in the scene. It also shows the scripts attached to the objects. Figure 3.13 shows the inspector window of the First Person Controller, listing the transformation and rotation values. The First Person Controller has five scripts attached to it. The Mouse Look script is a JavaScript which handles the direction in which the user looks in the VR environment. The Character Motor and FPS Input Controller scripts written make sure user moves as per the inputs from the computer. The Player Health and Player Health Control scripts are for controlling and displaying the health of the user after being hit by some bullets.



(a) (b)

Fig 7.13: Inspector Tab

(a) Shows the transformation of the selected First Person Controller game object, in the world axes

(b) Shows the attached scripts

The project window shows all the files in the project's asset folder, including the imported models, textures and materials. The battlefield vehicles and various other items in the scene were modelled in 3ds Max and exported into Unity's project files. From there, they can be used in the scene. The Scene window presents a view in which game objects are positioned and manipulated. It functions as the interactive sandbox.

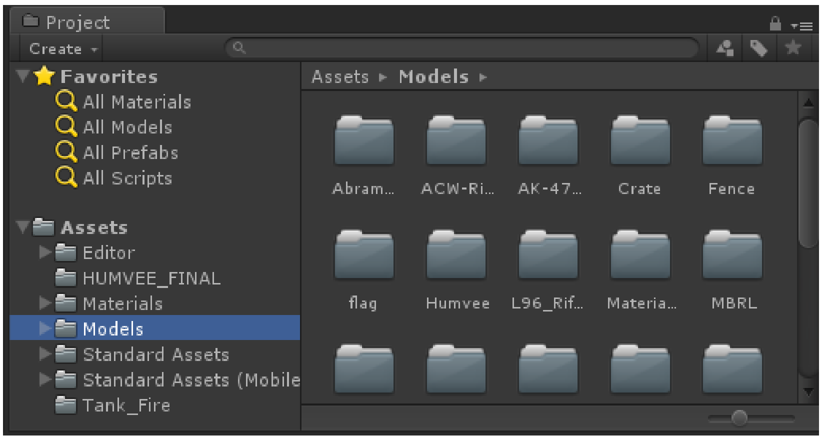


Fig 7.14: Project Files in the Models Folder

7.5.2 The Unity3D Terrain Engine

The Unity terrain engine consists of an editor and tools located in the editor which were used to create realistic terrains with three dimensional desert environment objects. Although, it is also possible to import terrains from an external program into Unity3D, but there are limitations of tree painting and lighting.

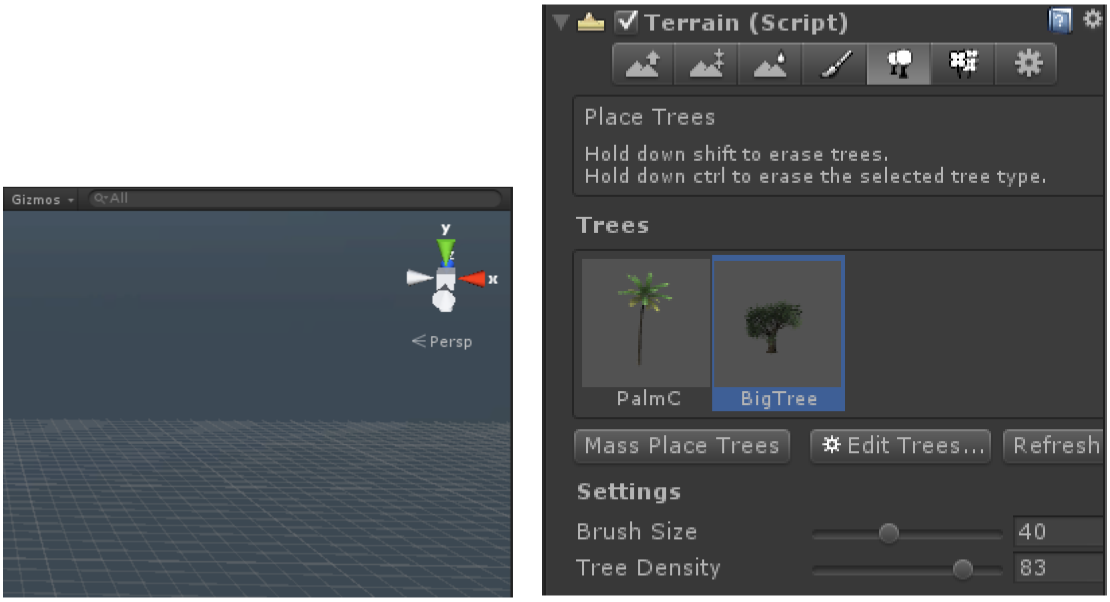


Fig 7.15: (a) Terrain without textures (b) 2-D terrain textures

The terrain for this thesis work was created in the terrain engine by constructing a regular mesh with the resolution height map set to fit in a desert scenario. The height map describes the grey scale map in which the pixel values specify the height of the vertex in the terrain. Two dimensional textures as seen in figure were applied to the terrain mesh to make it visually realistic. Blended textures were applied to the natural objects in the terrain to obtain the desired landscape of hills and low-lands. Trees created with the Unity tree creator were also massively placed in the terrain, and rendered in-game (refer to figure). Unity3D engine renders trees near the camera in full three dimensions, and far ones as two dimensional billboards. By so doing, many trees can be rendered without any significant performance hit.

Fig 7.16: Terrain with Trees

The terrain for the virtual battlefield has been chosen to be the desert. The terrain has been made which consists of mountains on the sides, sand dunes, a water fall, a stream, a pond and coconut trees as shown in the figure on the next page.

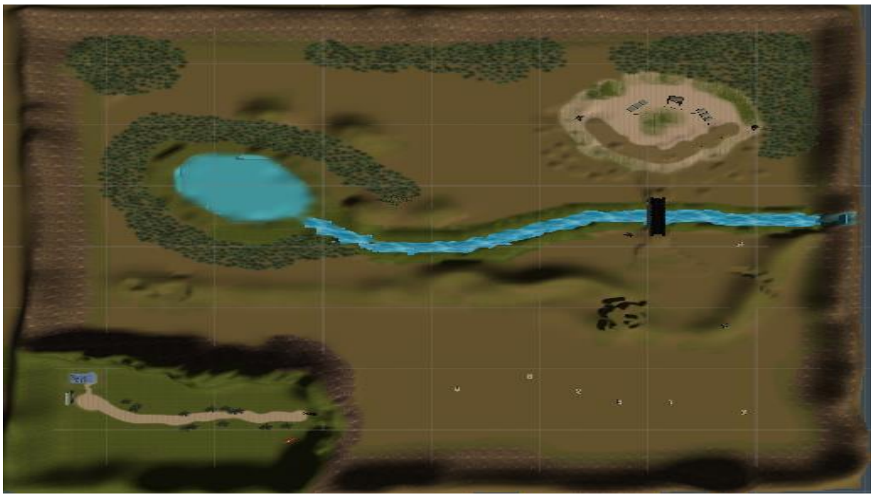


Fig 7.17: Top view of the Terrain

7.5.3 Placement of Objects in the Terrain

Various objects to be used in the virtual battlefield have been made in the 3ds Max and imported in the Unity 3d. The objects include Tanks, Soldiers, Multi Barrel Rocket Launcher (MBRL), Watch Towers, Machine gun Posts, Bridge, Humvee, Tents etc. In the objects mentioned above Tanks, Soldiers and various other objects fire at the user once the user gets close to them. The JavaScript for it is as follows:-

```
function Shoot(seconds)
{
    {
    if(seconds!=savedTime)
    {
    var bullit = Instantiate(bullitPrefab,
                        transform.Find("spawnPoint").transform.position,
                        Quaternion.identity);
        bullitPrefab.gameObject.tag = "enemyProjectile";
        bullit.rigidbody.AddForce(transform.forward * 8000);
          //audio.Stop ();
        audio.PlayOneShot (Firesound);
        savedTime= seconds;
    }
```

Fig 7.18: JavaScript for Shooting

7.5.4 Pictures of Virtual Battlefield

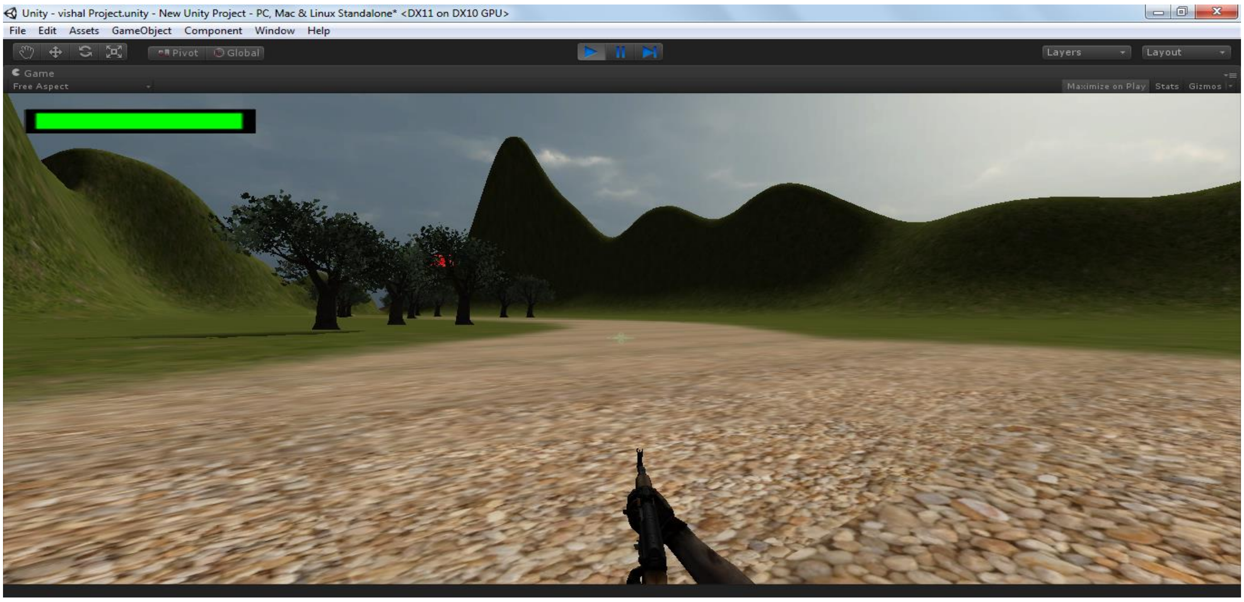


Fig 7.19: Opening Scene

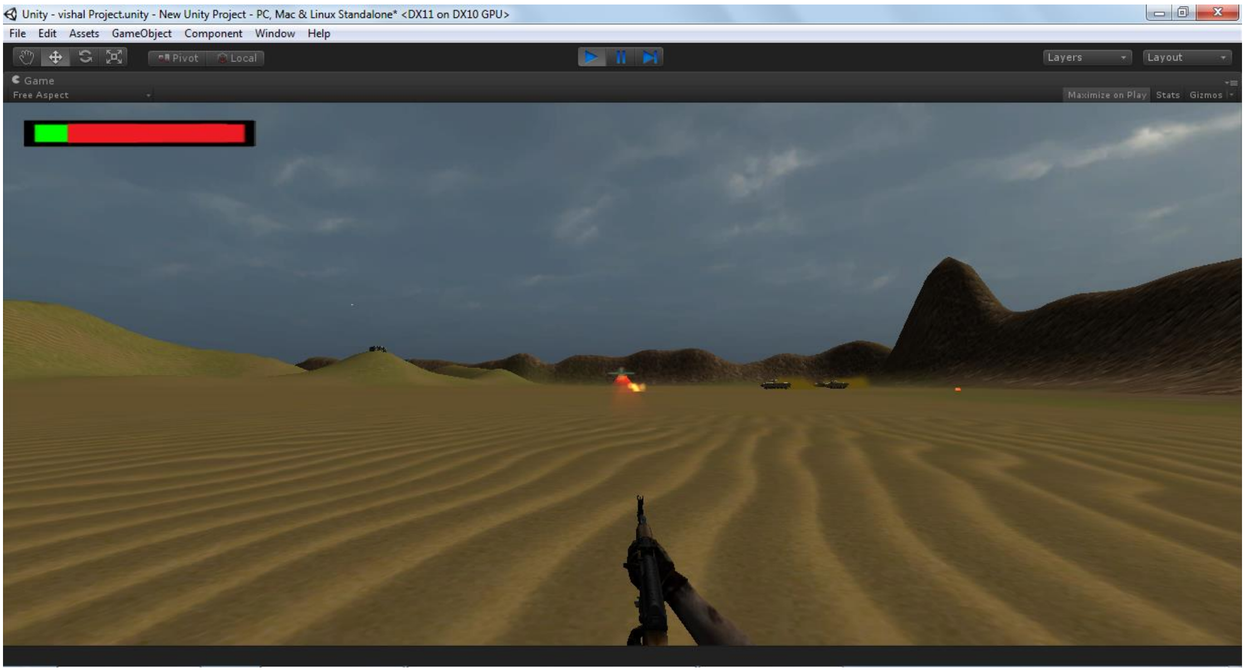


Fig 7.20: Tank Battle

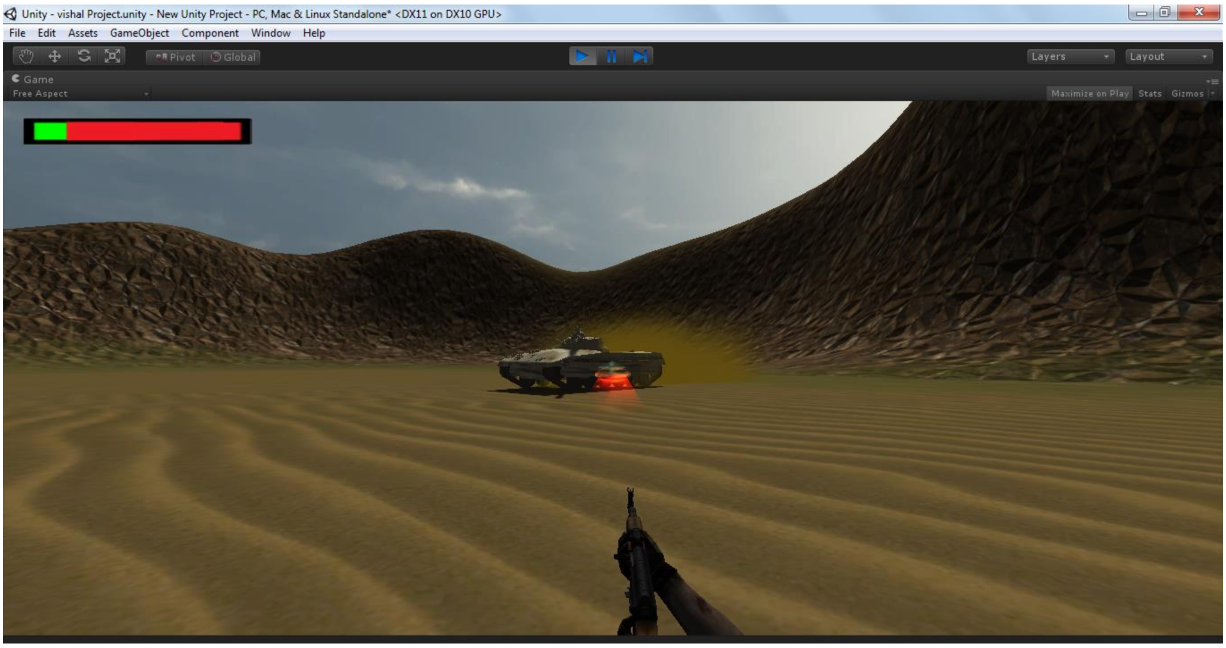


Fig 7.21: Tank Battle

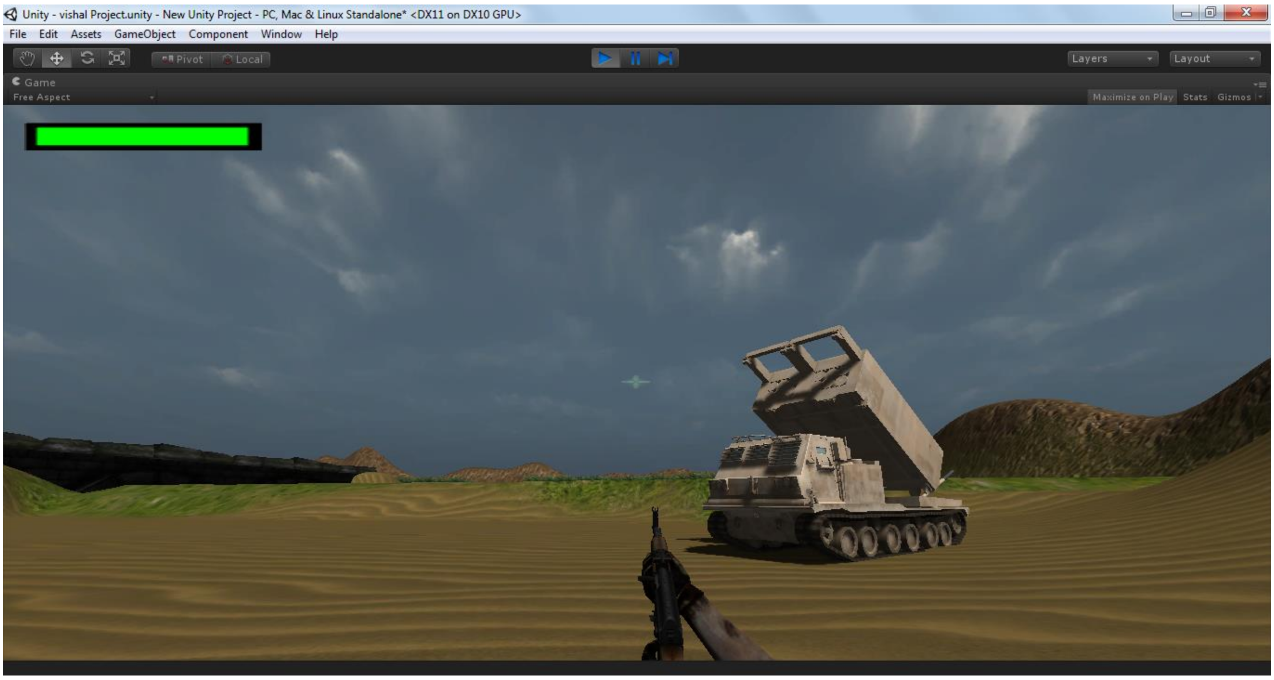


Fig 7.22: View of a Multi Barrel Rocket Launcher

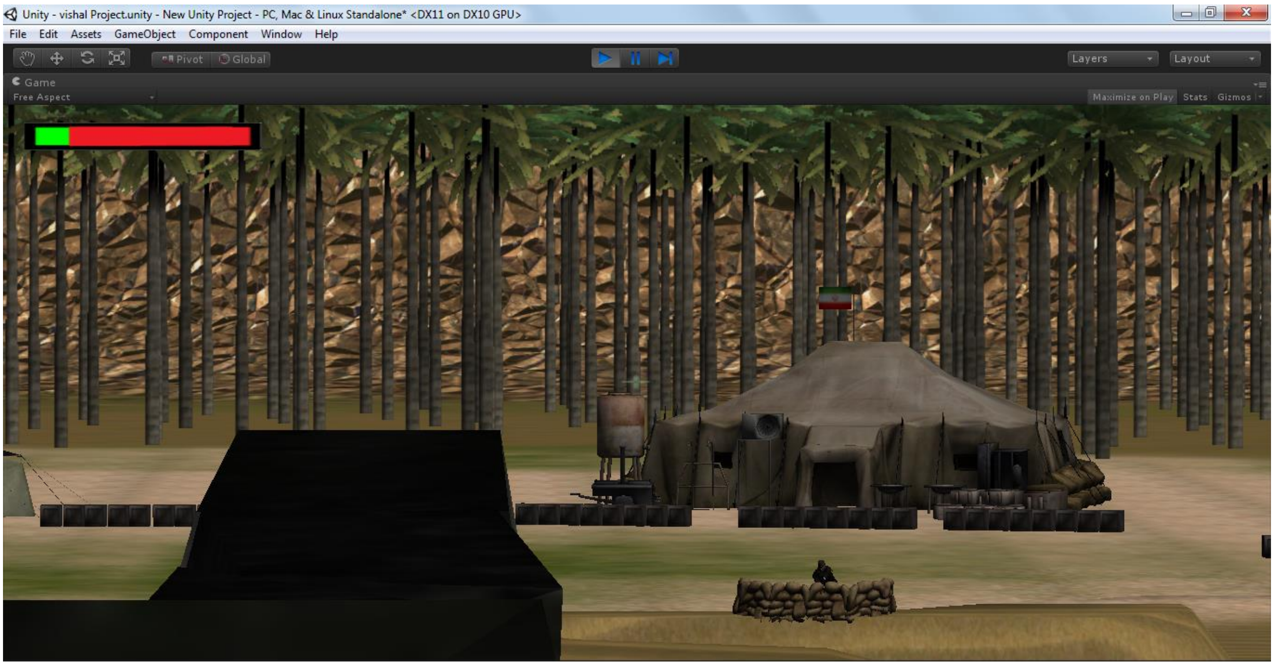


Fig 7.23: View of an Enemy Camp

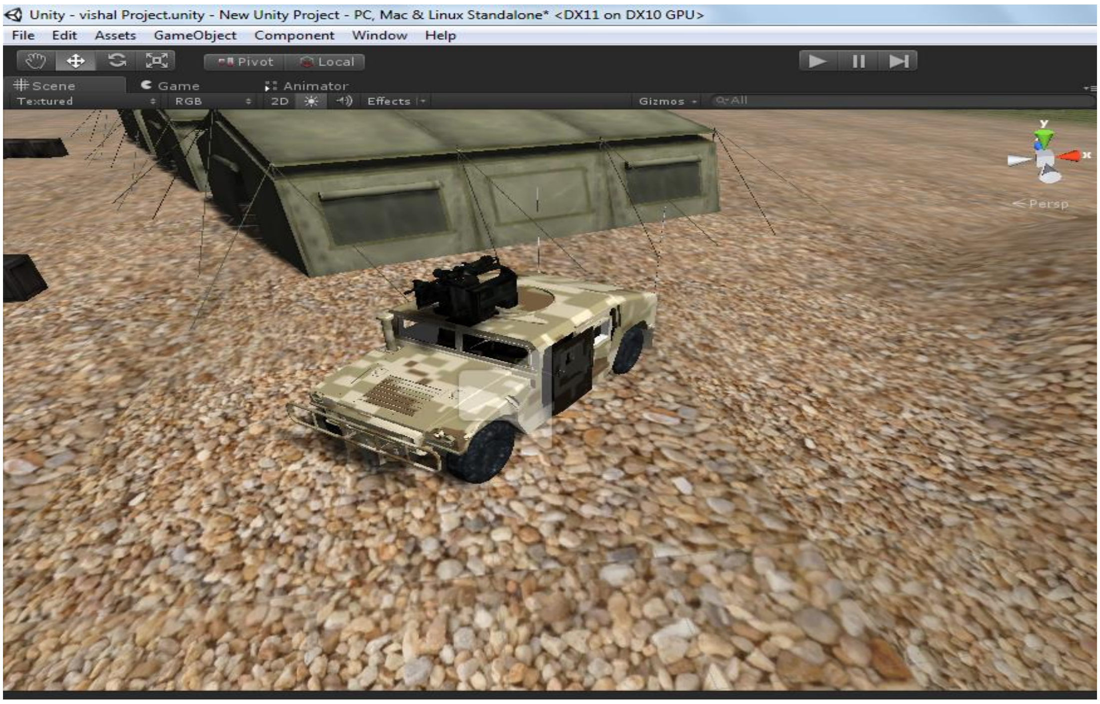


Fig 7.23: View of an Enemy Camp

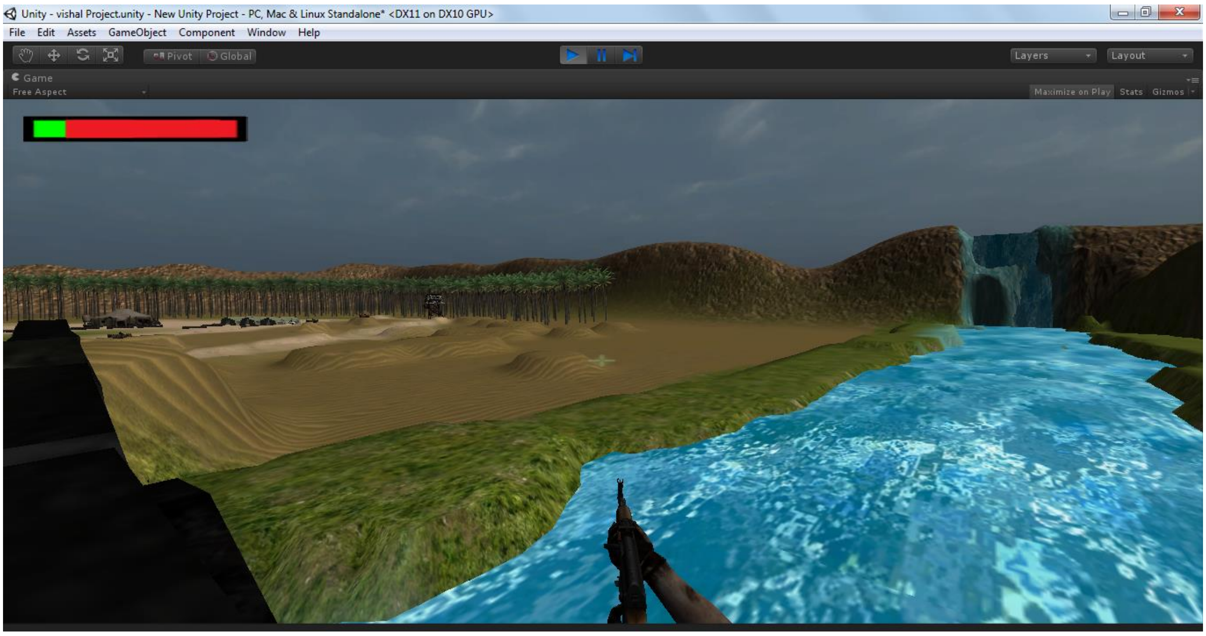


Fig 7.24: View of General Terrain

7.5.5 Conclusion

Development of a VR environment requires knowledge of minimum two softwares i.e. 3ds Max, the modelling software and Unity 3d, the game engine. Using both of these the virtual battlefield for this study has been developed.

Autodesk 3ds Max is useful software for learning and practicing animation and developing the skills required for 3D modelling and animation purposes. Along with having a very user friendly interface, it also can be used for managing professional projects in animation. One of the best features is added plug-in functionality which increases its features by a wide margin.

Unity 3d is a very powerful and relatively complex platform for creating virtual environments. It allows easy import of objects developed in 3ds Max, Maya or Blender. The layout of the user interface is very logical and easy to understand. The varieties of features that are available enable a user to go into the details of his world and develop in the virtual world. The programming language used also offers a choice between C#, JavaScript or Boo.

Using the 3ds Max and Unity 3d, very detailed and exciting VR can be created. Although they are aggressively being used by the game developers around the world, the VR enthusiasts are also making use of these.

CHAPTER 8

RESULTS AND ANALYSIS

8.1 Cognitive Performance Analysis

The aim of the study was to find out if Virtual Reality in form of a battlefield can have positive effects on the cognition of soldiers. To understand it more elaborately we divided the soldiers into two groups of 10 each. Group I had young soldiers (under 26 years of age, average age 24.6 years) who have not served in any counter insurgency or border areas i.e. they have no exposure to active fighting. Group II had mature soldiers (over 26 years of age, average age 35.5 years) who had at least one tenure in the counter insurgency or border areas and had actively been involved in any operation. It was desired to see if VR affected the two groups in different ways. The results and their analysis are discussed in succeeding paragraphs.

8.2 EEG Analysis

Both the groups were taken from the same unit following one routine so that all the participants had almost the same amount of activities throughout the duration of the study. Before being subjected to VE, initial readings of the subjects were taken using the B-Alert X 10 EEG system. Post the initial readings all the subjects were given VR exposure for 15-20 mins daily for the duration of 45 days. After 45 days another set of readings were taken. The trend shown by both groups is as under:-

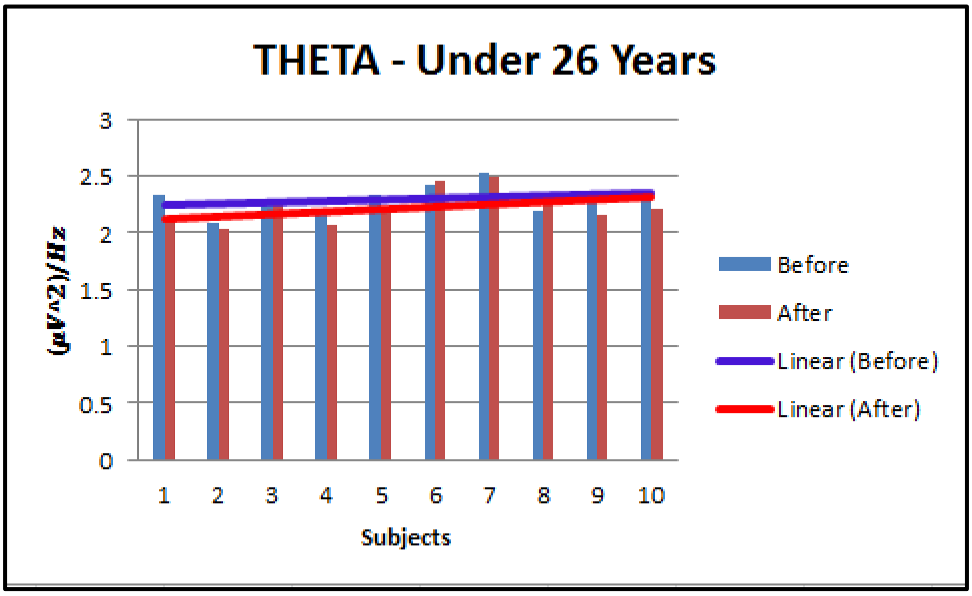


Fig 8.1: Theta Frequency Trend for Group I

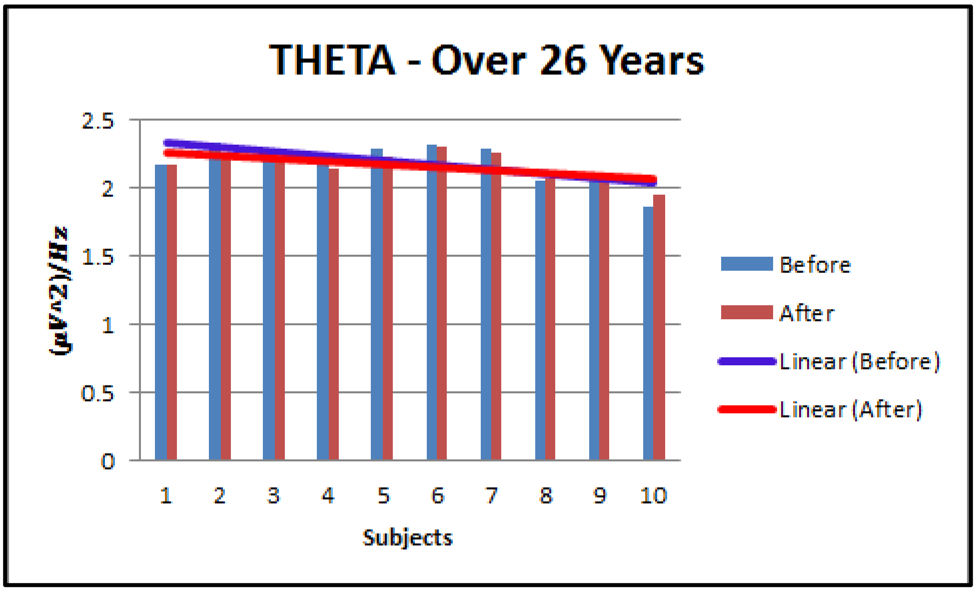


Fig 8.2: Theta Frequency Trend for Group II

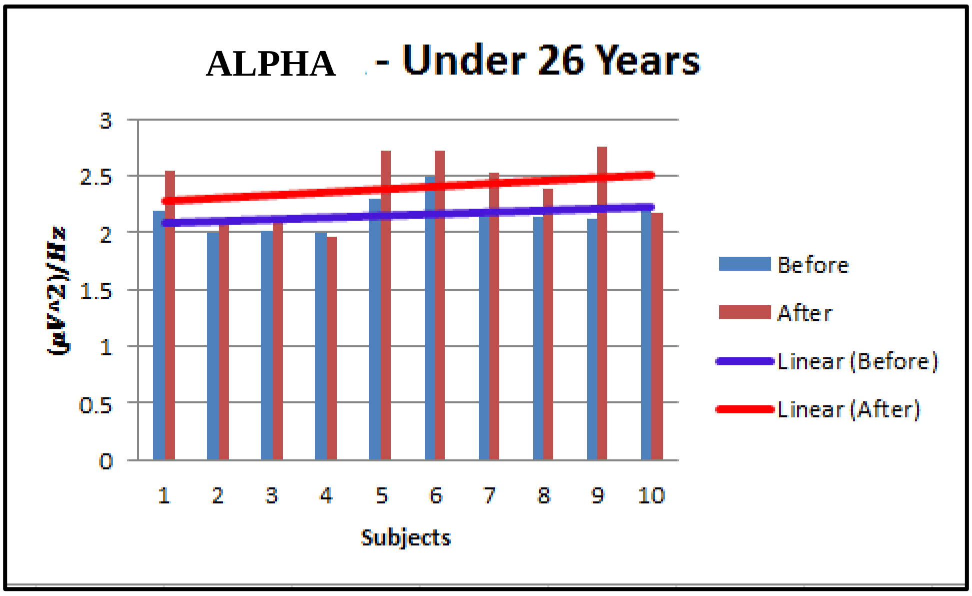


Fig 8.3: Alpha Frequency Trend for Group I

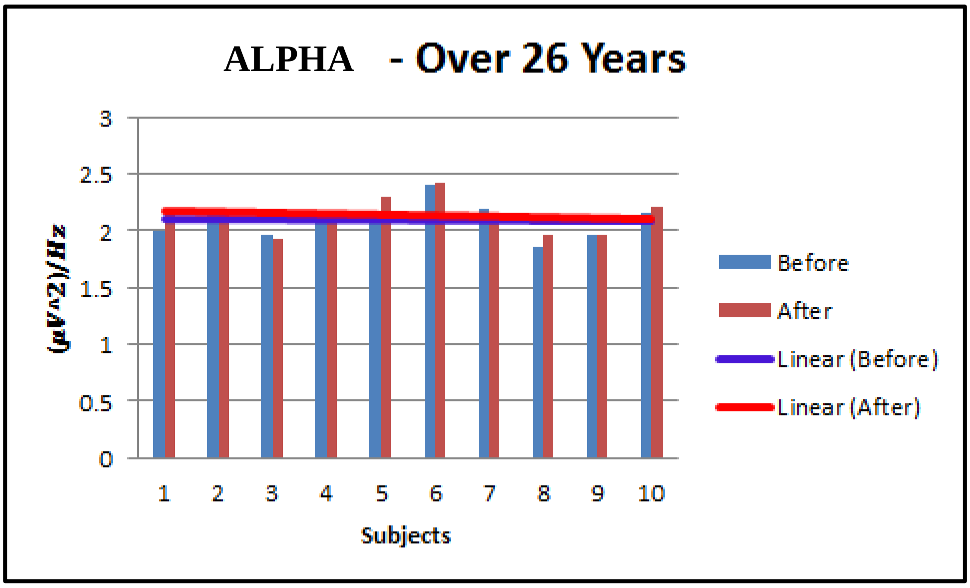


Fig 8.4: Alpha Frequency Trend for Group II

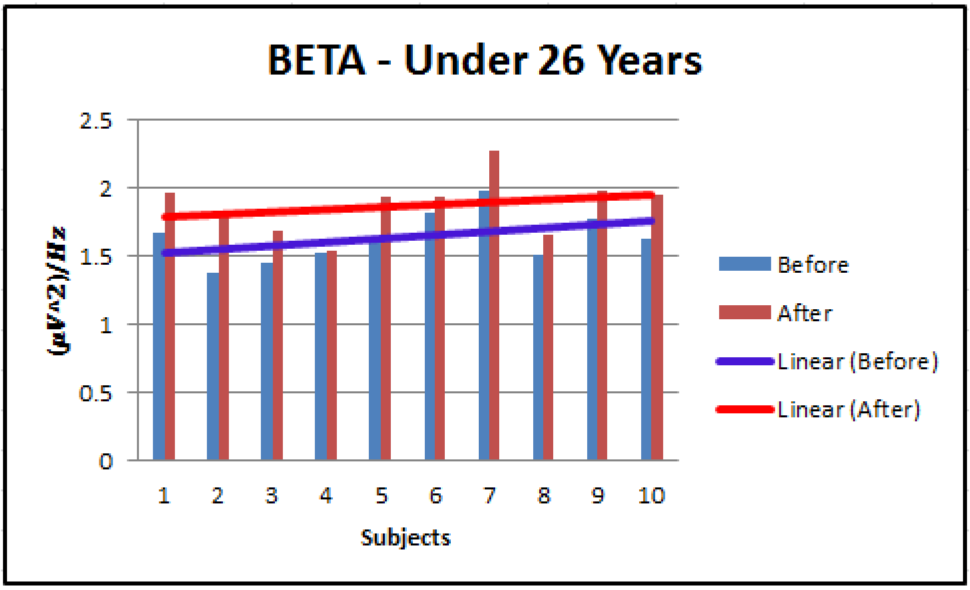


Fig 8.5: Beta Frequency Trend for Group I

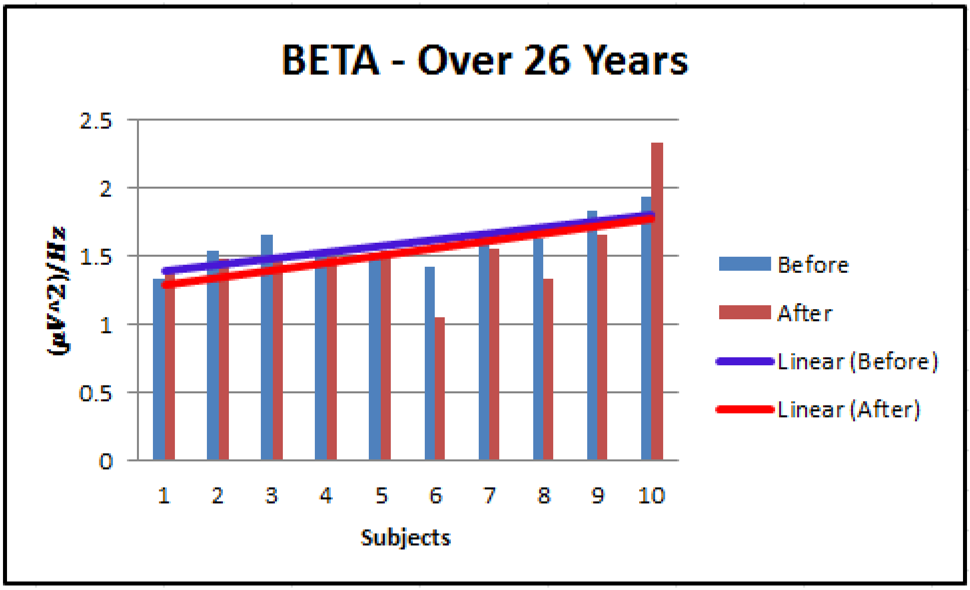


Fig 8.6: Beta Frequency Trend for Group II

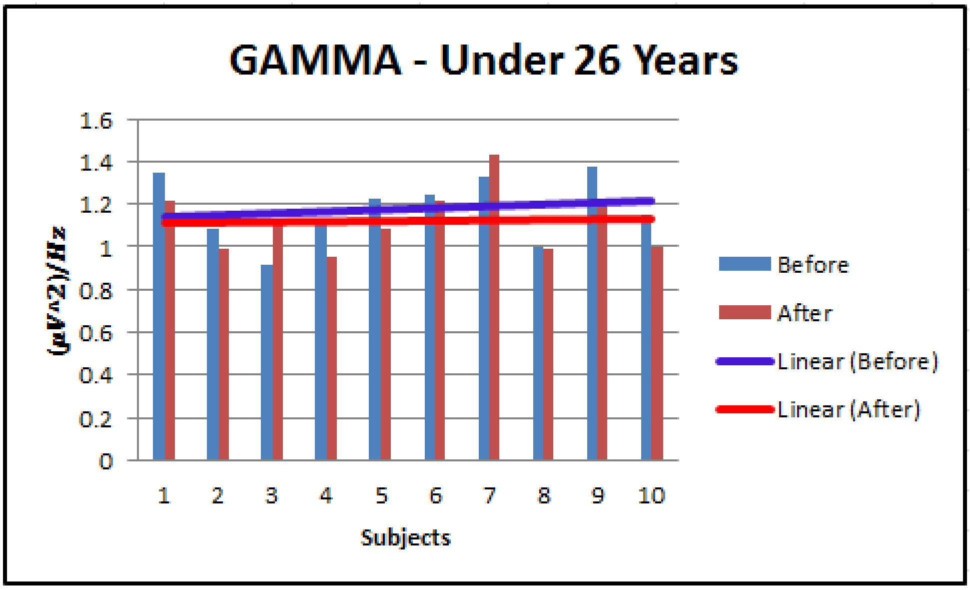


Fig 8.7: Gamma Frequency Trend for Group I

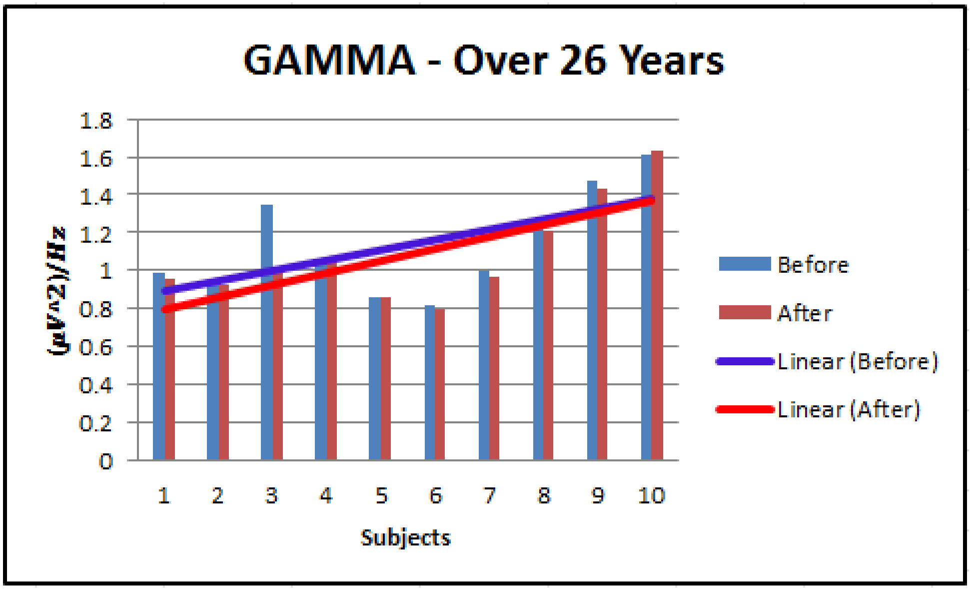


Fig 8.8: Gamma Frequency Trend for Group II

Table 8.1: Average values of EEG powers ($\mu V^2/Hz$) for two groups

Frequency Range	**Group I**			**Group II**		
	Before	**After**	**% Change**	**Before**	**After**	**% Change**
Theta	2.2969025	2.2219673	**-3.26**	2.1796182	2.1580072	**-0.99**
Alpha	2.1639341	2.3997484	**11**	2.0911797	2.1342275	**2.06**
Beta	1.6313648	1.8673856	**14.47**	1.5947931	1.5253538	**-4.35**
Gamma	1.1770706	1.1232358	**-4.57**	1.1345636	1.08378703	**-4.47**

(a) Both the groups have shown signs of improved cognition. However, Group I has shown a substantial increase in the alpha and beta frequency bands whereas Group II has shown a marginal increase in the alpha but a decrease in the beta band. For better cognitive performance lower frequency bands like theta must show a sign of decrease. Group I has exhibited more decrease in the theta band as compared to the Group II. Gamma values are almost similar for both the groups.

(b) Though Group II has shown decrease in theta and increase in alpha frequency band indicating enhanced cognition but it has also shown decrease in beta. This may be due to the fact that this group comprised of veteran soldiers who have seen combat action in their service and hence were not overwhelmed by the virtual battlefield. It can be inferred that their cognitive enhancement is a result of exposure to virtual reality environment and the virtual battlefield played less significant role in it.

(c) On the other hand, Group I has shown a decrease in theta band and a noteworthy increase in alpha as well as beta bands. This clearly indicates an enhancement in the cognitive functions of the young soldiers of this group.

8.3 Band Ratios

Group I has shown improvement in band powers of Alpha and beta and a decrease in delta and gamma. The beta power enhancement indicates an increase in cognitive functions like mental alertness but a decrease in delta and increase in alpha indicate the "well-being" or performance enhancement index of any human being. The specific band ratios have been studied in past and their effect on specific parameters has also been discussed.

Various band ratios have effect on specific physical or psychological parameter and the same is being discussed in detail as per the results obtained from the study. A table depicting relation between various band ratio parameters and the related activity is below:-

Table 8.2: Various band ratios and their values before and after intervention

Parameters	Activity	Group I		Group II	
		Before	After	Before	After
θ/α	**Heart Rate**	1.063522594	0.935563384	1.045513955	1.014695852
α/θ	**Performance Index**	0.942494563	1.08103025	0.962167698	0.990223665
β/α	**Arousal Index**	0.753714596	0.782611444	0.767621396	0.719226011
β/θ	**Neural Activity**	0.708521512	0.84119878	0.739043378	0.713913477
β/(α+θ)	**Cognitive Index**	0.36498797	0.404288092	0.37588748	0.357773379
θ/β	**CNS Arousal**	1.416331961	1.199514608	1.388040972	1.474644552
(θ+α)/β	**Vigilance Index**	2.751301409	2.488508854	2.716475261	2.930670224

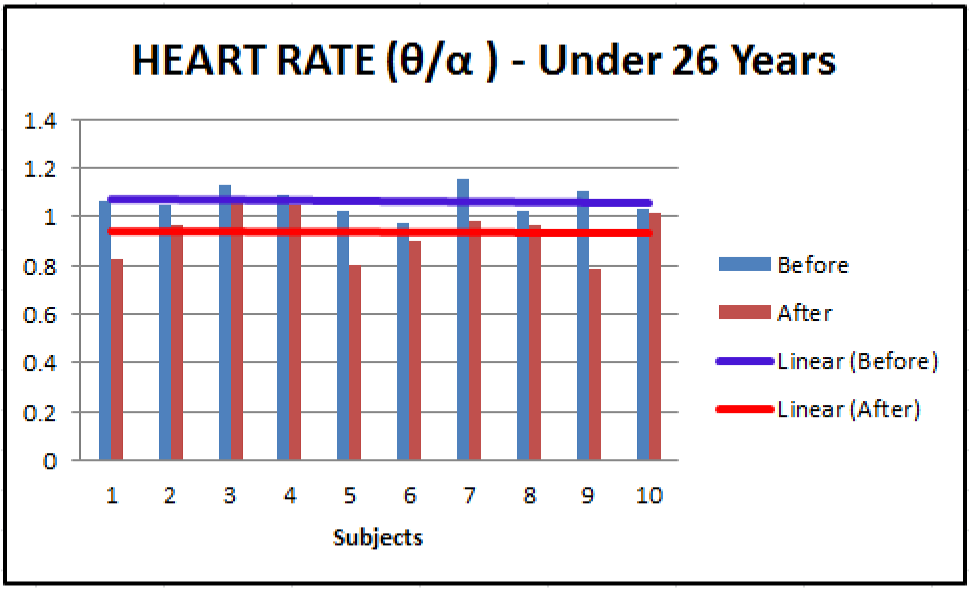


Fig 8.9: Heart Rate for Group I

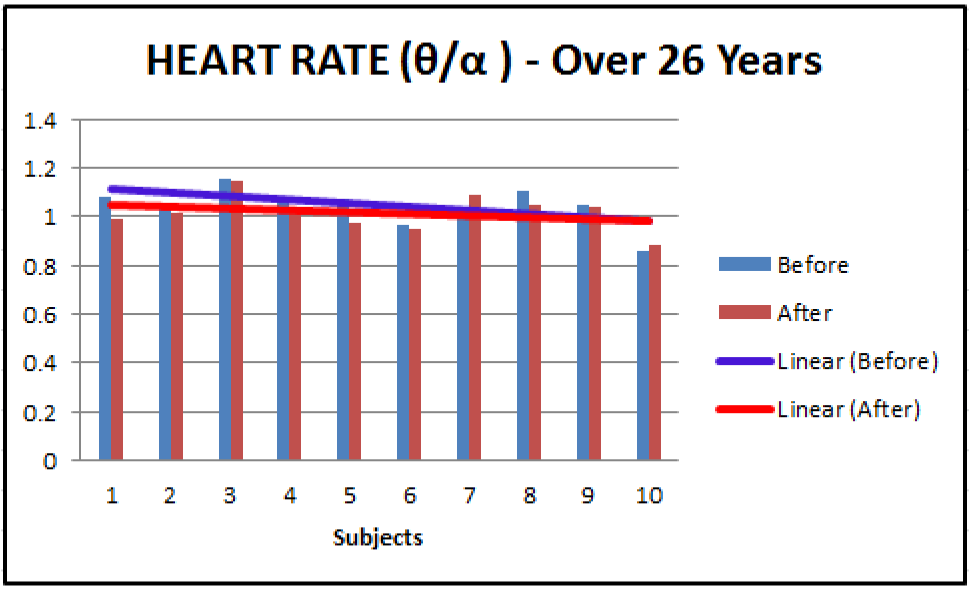


Fig 8.10: Heart Rate for Group II

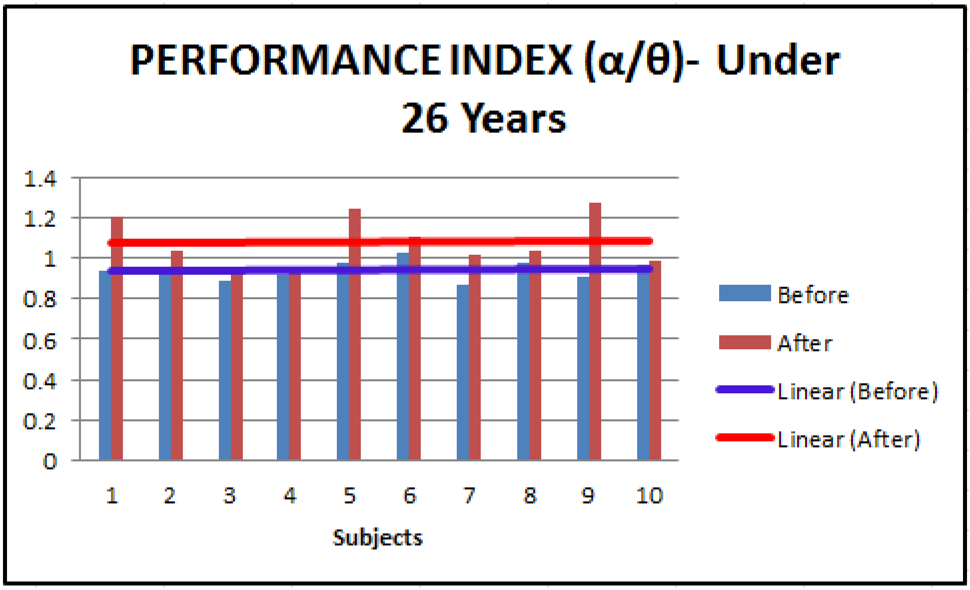


Fig 8.11: Performance Index for Group I

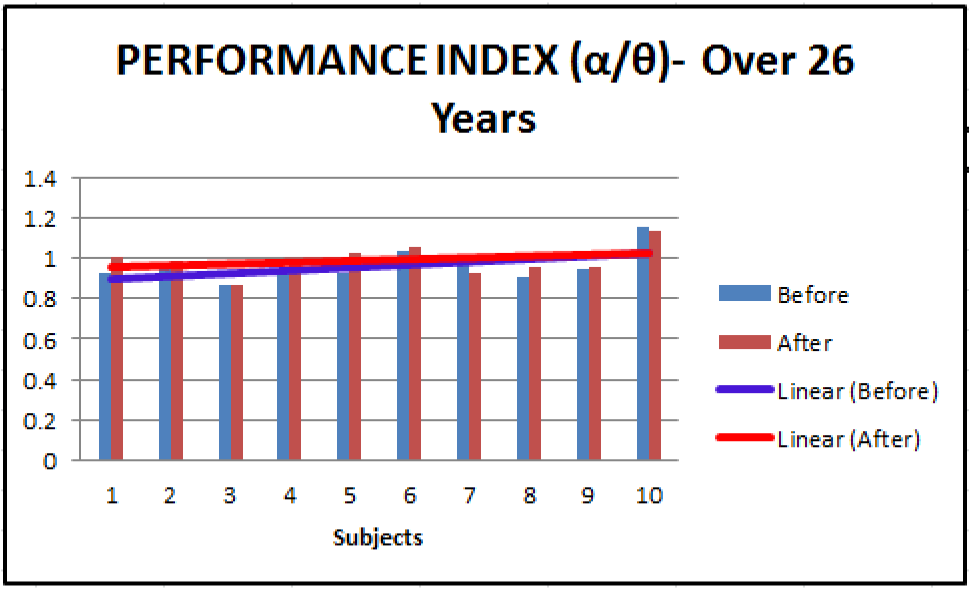


Fig 8.12: Performance Index for Group II

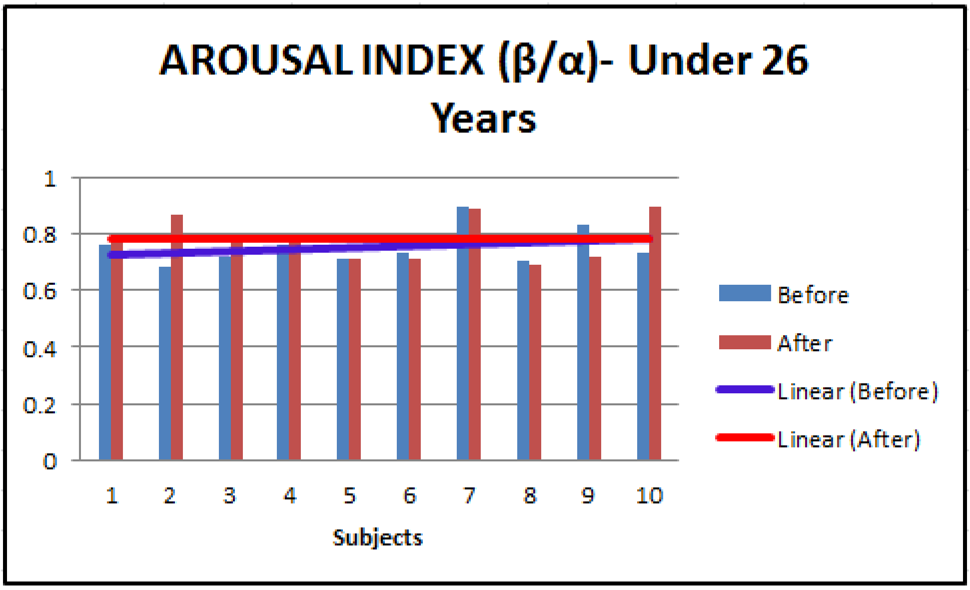


Fig 8.13: Arousal Index for Group I

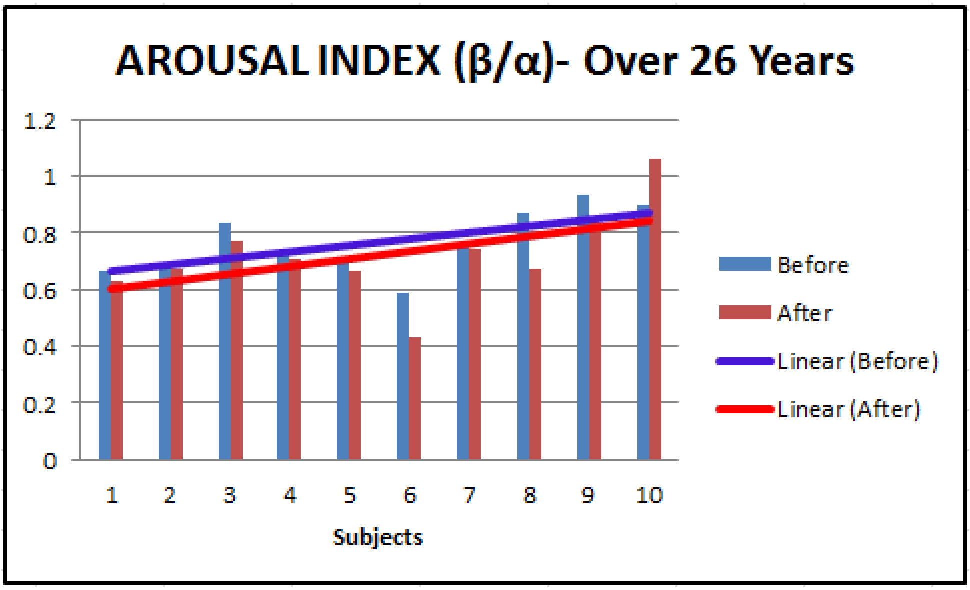


Fig 8.14: Arousal Index for Group II

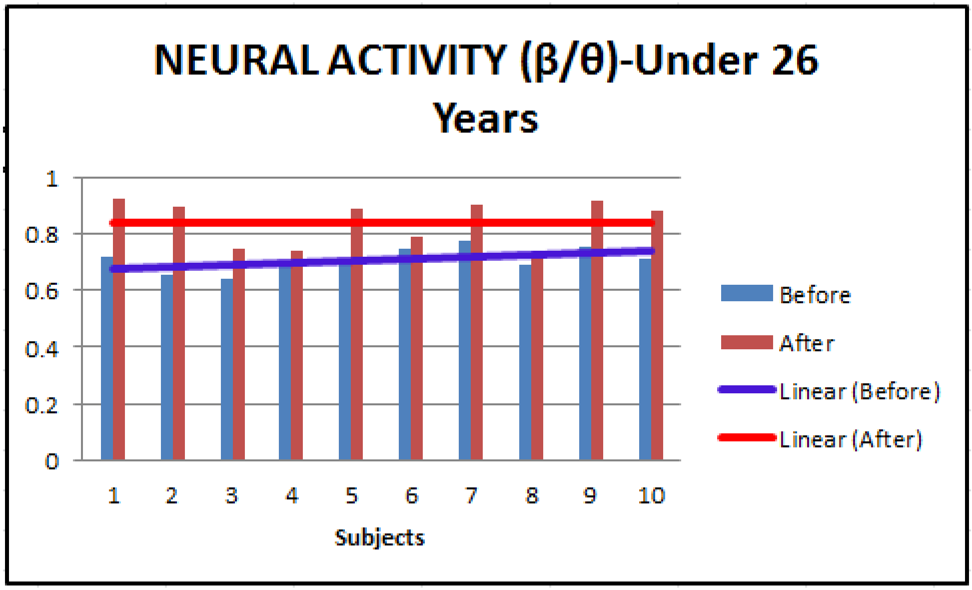


Fig 8.15: Neural Activity for Group I

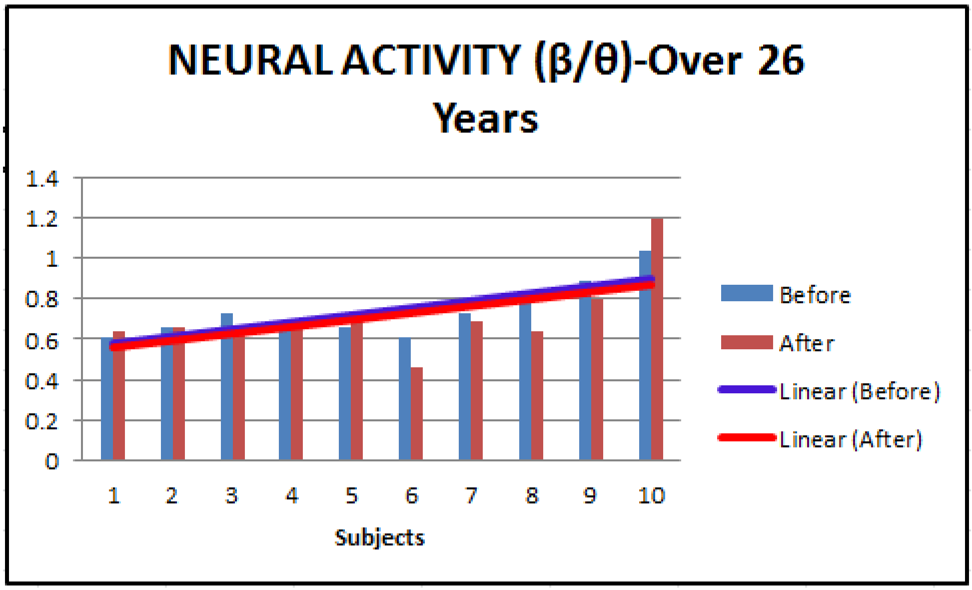


Fig 8.16: Neural Activity for Group II

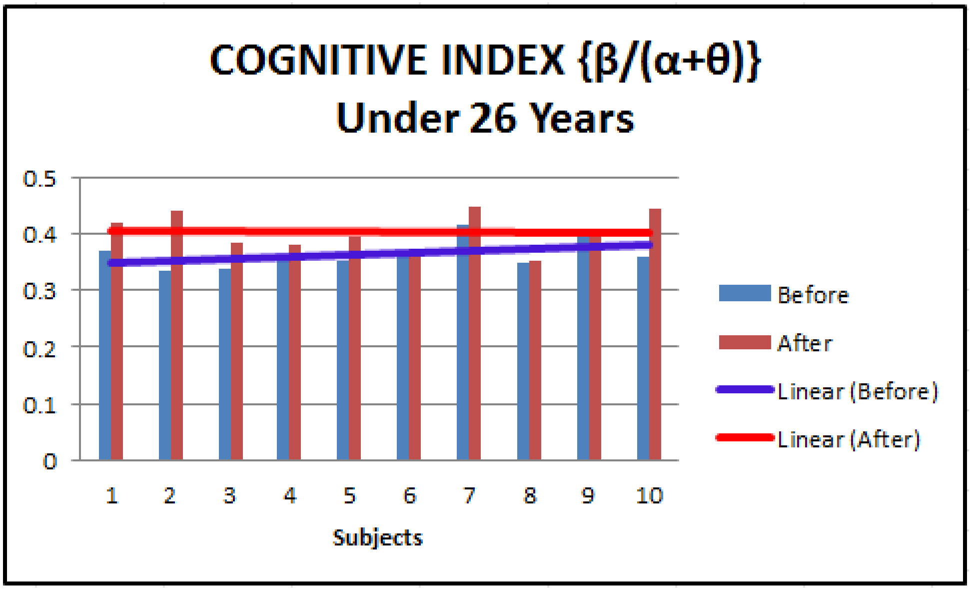


Fig 8.17: Cognitive Index for Group I

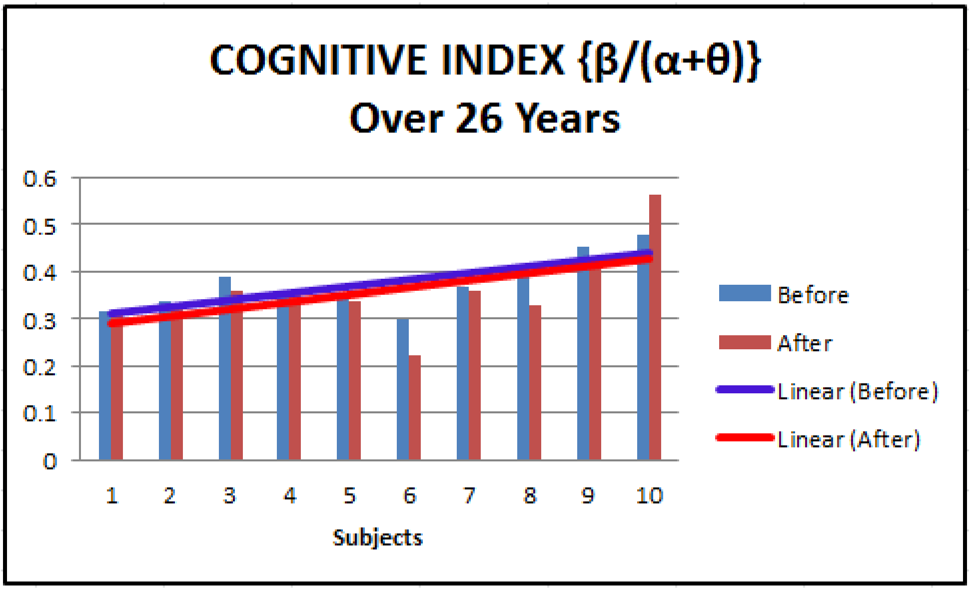


Fig 8.18: Cognitive Index for Group II

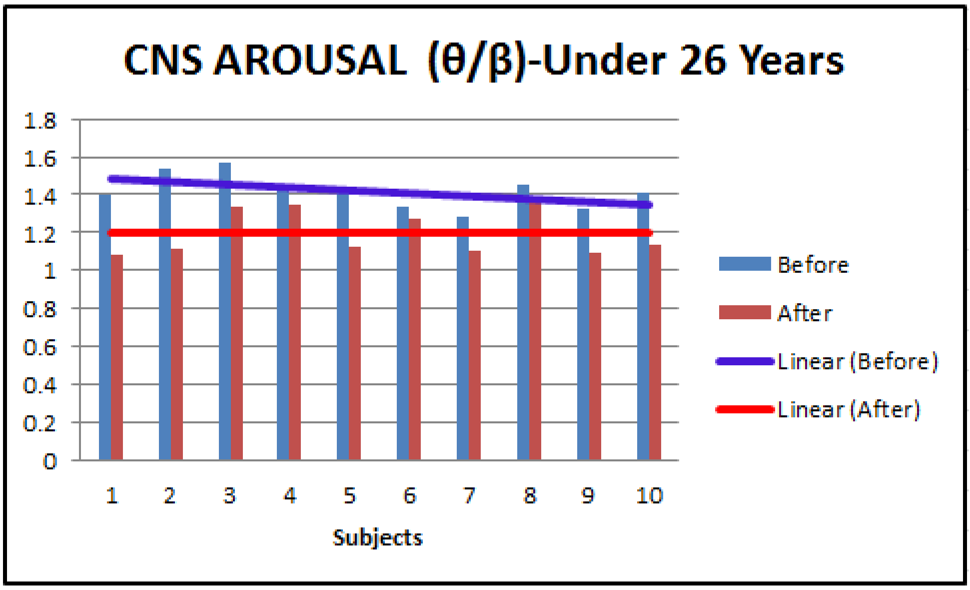


Fig 8.19: CNS Arousal for Group I

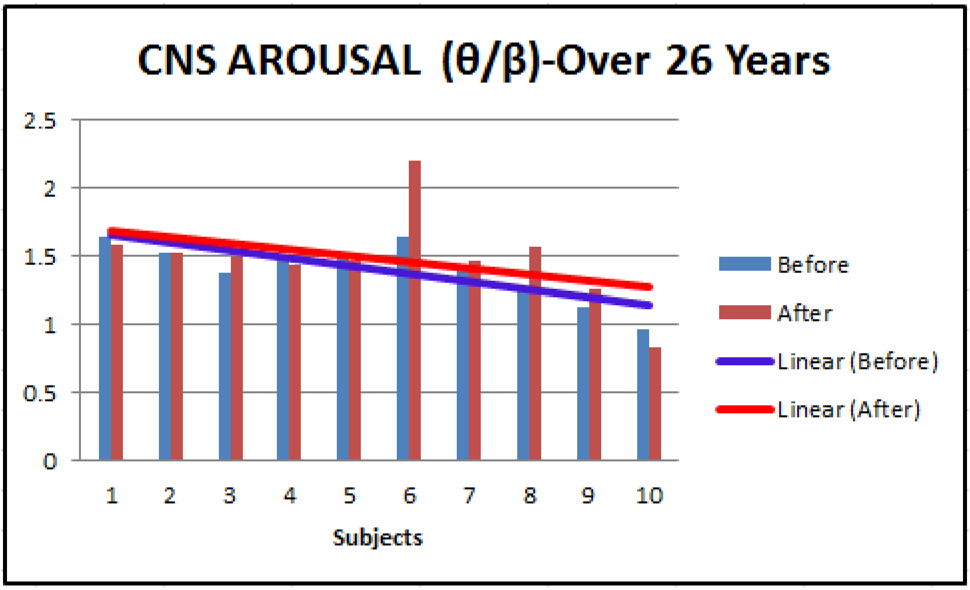


Fig 8.20: CNS Arousal for Group II

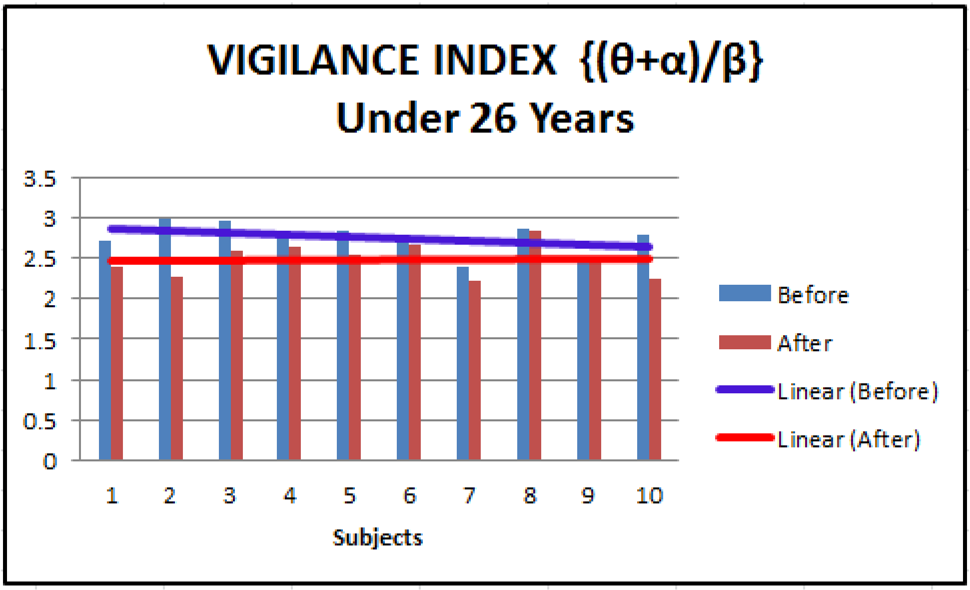


Fig 8.21: Vigilance Index for Group I

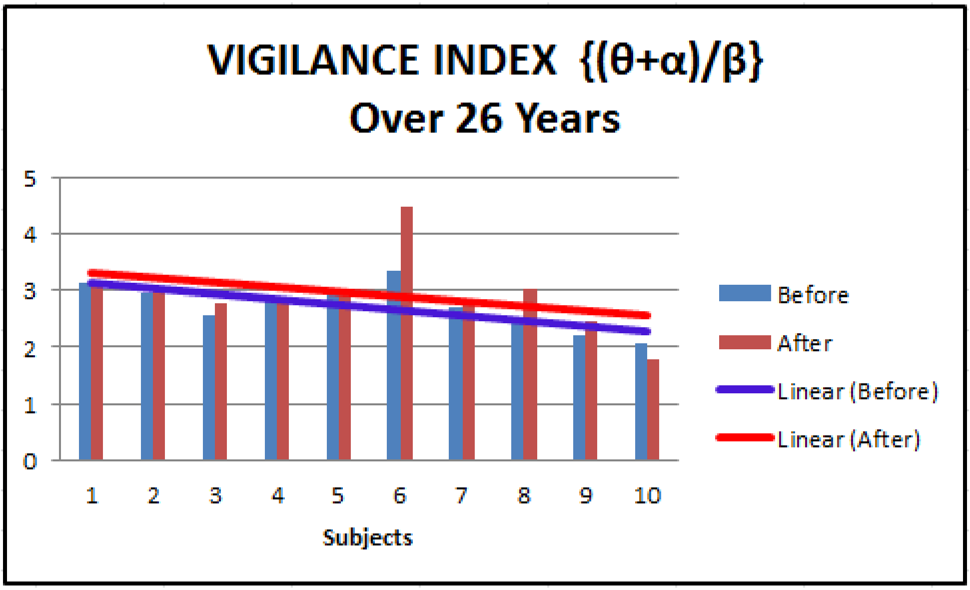


Fig 8.22: Vigilance Index for Group II

(a) The ratio θ/α is associated with heart rate (HR). This ratio decreased in both the groups. This decrease can either be due to the increase of alpha band power or the decrease of theta band power. Since alpha power increased more in Group I this ratio decreased by **12%** for this group, thereby signifying enhancement of certain cognitive functions (memory, attention) and improvement in the HRV. These in turn displays indirect improvement in certain cognitive functions such as reaction time.

(b) The ratio α/θ indicates performance enhancement index or "well-being". The ratio should be as higher as possible. The increase in ratio indicates better overall performance. An increase in alpha always indicates better cognitive functions (memory and attention) and increase in perception, well-being and improved HRV and the similar effects are seen with a reduced theta level. The alpha-theta neuro-feedback training is based on above observation for enhancement of cognitive functions. The α/θ ratio has increased more in case of Group I than in Group II. Group I has shown an increase of **14.7%** as compared to **3%** in case of Group II. Thus the overall well-being of a young soldier is improved more when VR exposure of a battlefield is given to him.

(c) The ratio β/α indicates the arousal index of human being. This ratio indicates arousal on the base on inter beat interval activity (IBI). Group I has indicated an increase of **3.83%** whereas Group II has indicated a decline of **-6.3%.** Group I has improved the Beta band power and alpha band power. The increase of ratio indicates better cognitive functions like alertness for Group I.

(d) The ratio β/θ indicates the neural activity of the brain. The increase in neural activity of brain is indicated by increase in value of beta and decrease in value of theta band power. Therefore the ratio β/θ will give out better representation of cognitive skills of human brain. The results in Fig 8.15 & 8.16 have shown an increase of

18.73% of neural activity in case of Group I and a decrease of **-3.4%** in case of Group II. The result shows that there is a definite increase in the brain activity of soldiers in Group I after the virtual battlefield exposure.

(e) The ratio $\beta/(\alpha+\theta)$ indicates Cognitive performance and Attention Resource index. As discussed above the increase on power of higher frequency bands like Beta and Alpha and decrease in frequency bands like Theta indicate overall attention or cognitive performance. Results have shown that cognition has improved in the case of Group I but not in case of Group II as shown in Fig 8.17 & 8.18.

(f) The ratio θ/β indicates CNS (Central Nervous System) arousal and an increase in the ratio indicates under arousal. A reduction in value indicates a shift in values of alpha and theta towards beta frequency band. The beta frequency band is responsible for alertness, concentration and memory thus a reduction in the value θ/β indicates a better CNS arousal. The ratio was found to be reduced by **15.31%** in Group I as compared to an increase of **6%** in Group II as in Fig 8.19 & 8.20.

(g) The ratio $(\theta+\alpha)/\beta$ indicates the vigilance index of human being. The reduction in value indicates improvement in the vigilance index. The results have shown that the vigilance index has improved in Group I but not in Group II.

8.4 HRV Analysis

The HRV of each of the 20 soldiers was measured by using B-Alert X-10 system. The result is shown in Table 8.3 and discussed subsequently. The HRV is an indication of body ANS (Automatic Nervous System) and it has a direct relation with neural activity also. The ANS is composed of two kinds of activity: Sympathetic and Para-Sympathetic (Vagal). The HRV spectrum can be divided into various frequency spectrums which give us clear analysis of both sympathetic and Para-sympathetic tone and gives out overall well-being and functioning of the human heart. The Sympathetic-Vagal balance is important for cognitive functions of brain. The lower value of Sympathetic – Vagal balance is desirable for better cognitive functions and better overall health. The regular exercise is shown to have enhanced effect on the vagal tone and it leads to lower values of resting heart rate [25].

The results of the present study are discussed below:-

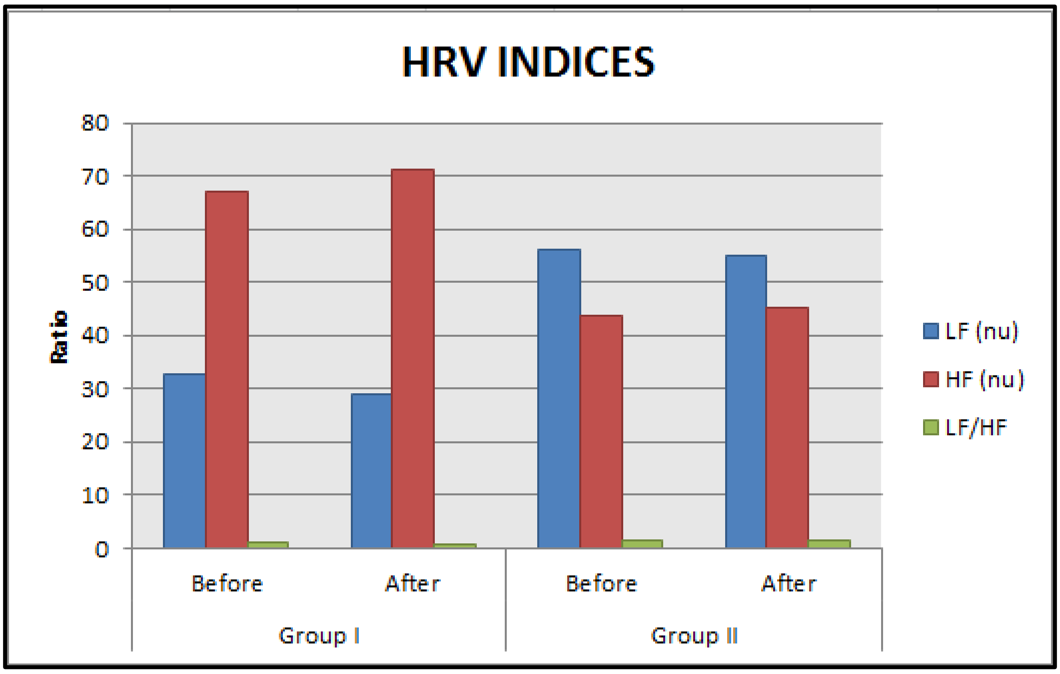


Fig 8.23: HRV Indices

Table 8.3: Various HRV Indices before and after intervention

Parameter	Group I		Group II	
	Before	After	Before	After
LF (nu)	32.87345461	28.78458046	56.2444672	54.82452029
HF (nu)	67.12654539	71.21541954	43.7555328	45.17547971
LF/HF	0.96	0.69	1.61	1.51

(a) The Low Frequency and High Frequency bands of HRV have been stated in normalized units (nu). The usage of these bands in nu enunciates the degree of control used and the relative balance of two types of the autonomic nervous system. Furthermore LF (nu) is believed to signify the sympathetic modulation more than the absolute units.

(b) For Group I, there is a significant reduction of **12.4%** in LF power and HF power has increased by **6.1%** whereas Group II has shown a reduction of **2.5%** in LF power while the HF power has increased by **3.3%**. The LF power indicates both sympathetic and parasympathetic modulation whereas HF power reflects parasympathetic activity. Hence, the decrease in sympathetic activity and an increase of parasympathetic activity results in slowing down in the cardiac activity. The ratio LF/HF has reduced by a considerable **28%** for Group I and by **6.2%** for Group II. This ratio is an indicator of autonomic ANS balance between sympathetic and parasympathetic nervous system.

(c) The above discussed points indicate that cognitive abilities have shown an improvement in both the groups but Group I comprising of young soldiers with no experience of military fighting have shown better improvement in consonance with the various band ratios and the EEG frequency bands.

8.5 Psychological Tests Results and Discussion

8.5.1 Two hand Coordination

The two hand coordination test using VTS is used for testing of speed and accuracy of visuomotor coordination i.e coordination of eye-hand and left and right hand. As discussed before two parameters are checked in this test i.e. overall percentage error duration and overall mean duration. The results for both the groups have been summarised below:-

Table 8.4: Average values of scores of 2 Hand test for two groups

Parameter	**Group I**		**Group II**	
	Before	**After**	**Before**	**After**
Overall % Error Duration	50.7	74.1	54.2	66.7
Overall Mean Duration	30.41	25.96	39.7	35.94

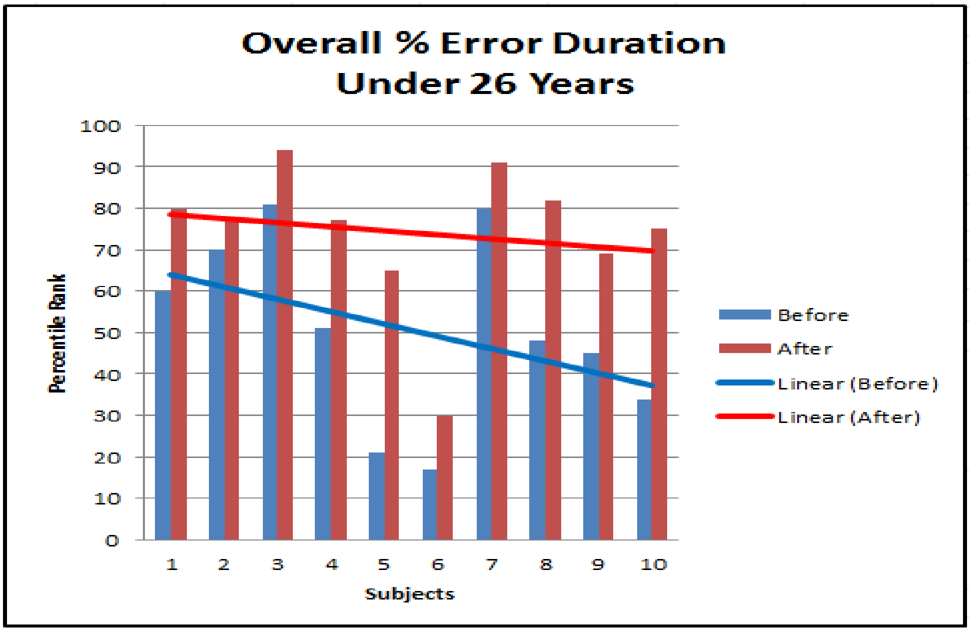


Fig 8.24: Overall Percentage Error Duration for Group I

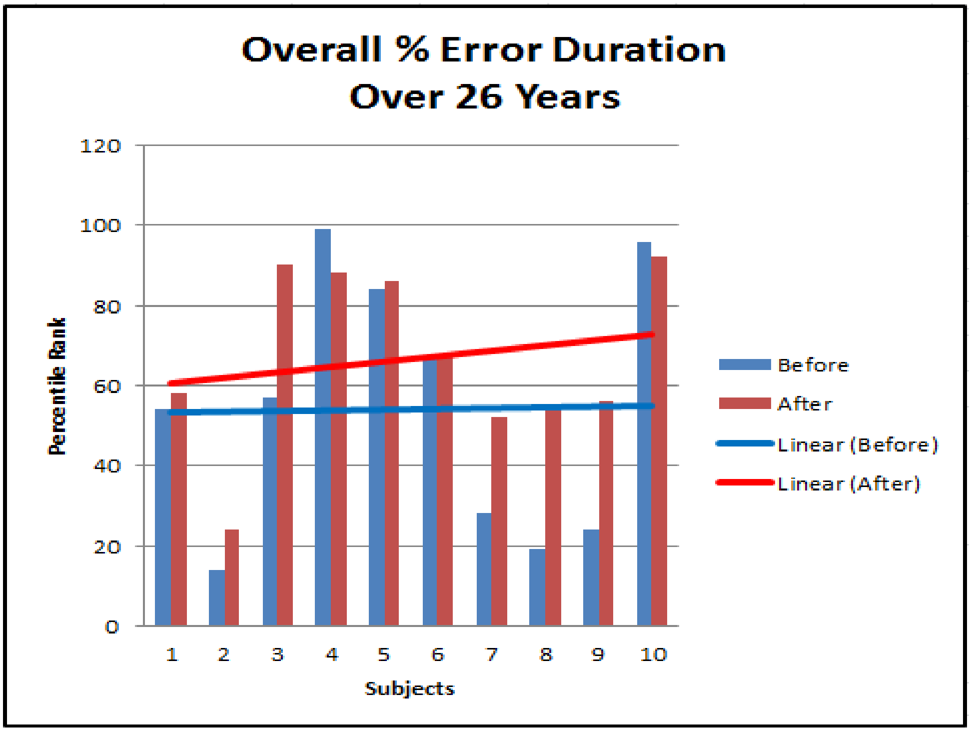


Fig 8.25: Overall Percentage Error Duration for Group II

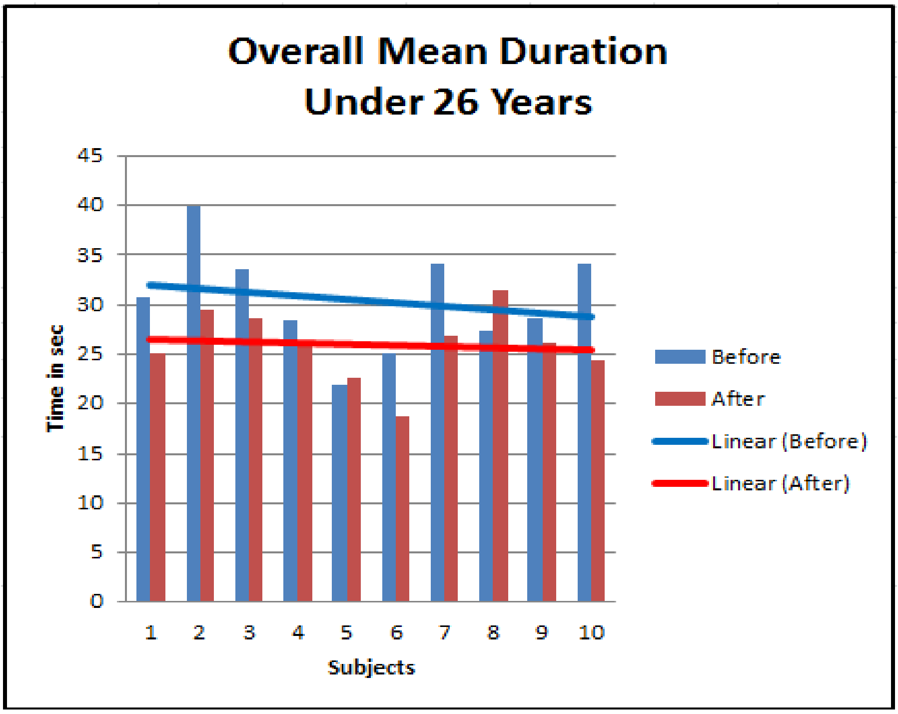


Fig 8.26: Overall Mean Duration for Group I

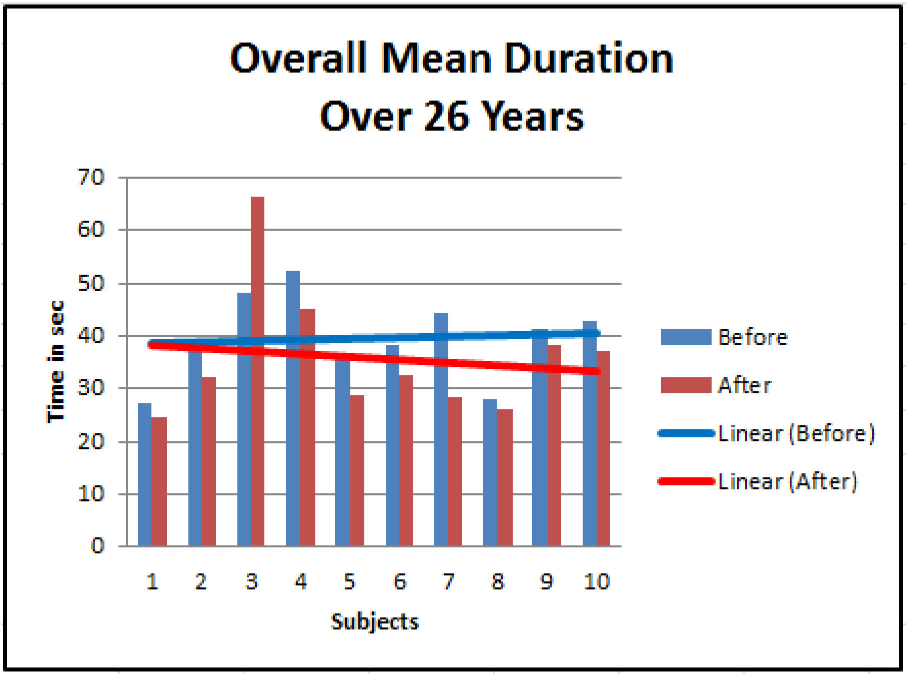


Fig 8.27: Overall Mean Duration for Group II

(a) It is evident from the data presented before that although both the groups have shown an improvement in the two parameters but Group I has shown a significant increase of **46%** as compared to **23%** for Group II in the overall percentage error duration. This means that Group I has enhanced its precision of fine motor movements and accuracy of information processing significantly.

(b) Group I has also reduced the mean time to cover the track by **14.6%** as compared to the **9.67%** for Group II. This is a measure of speed of movement thus of the subjects performance.

8.5.2 Cognitrone Test

The cognitrone test using VTS is used for assessment of attention and concentration through comparison of figures. The two parameters that are used in this test are mean time correct rejections and correct rejections. The results of both the groups are given below in tabular form:-

Table 8.5: Average values of scores of Cognitrone test for two groups

Parameter	**Group I**		**Group II**	
	Before	**After**	**Before**	**After**
Mean Time Correct Rejections	2.38	2.03	2.63	2.26
Correct Rejections	110.8	114.6	110.8	113.4

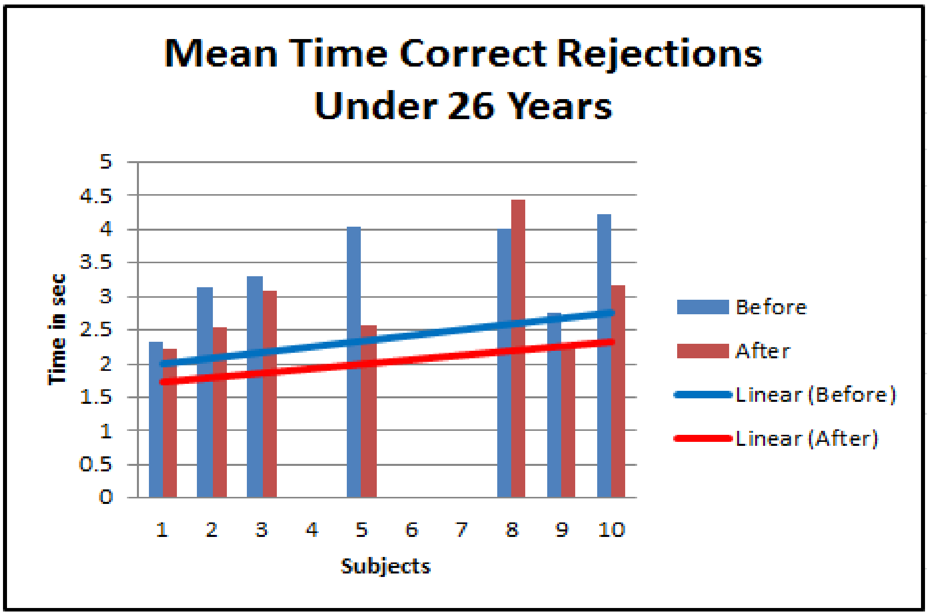


Fig 8.28: Mean Time Correct Rejections for Group I

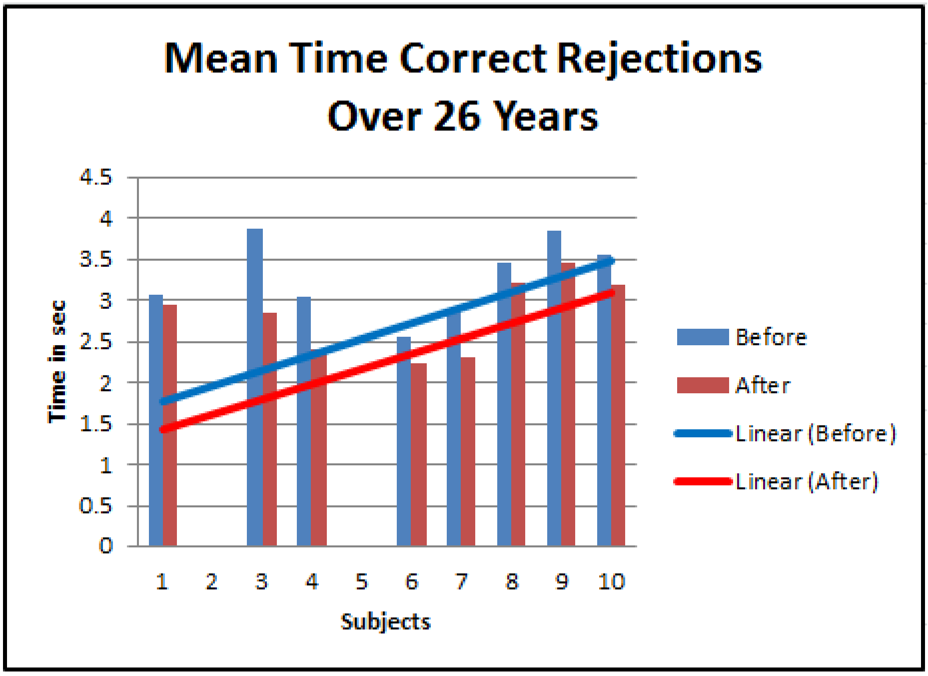


Fig 8.29: Mean Time Correct Rejections for Group II

The data given above for the cognitrone test illustrates that almost both the groups have achieved same amount of improvement in their concentration abilities. Hence no concrete inference can be drawn from the test.

8.5.3 CORSI Test

CORSI test measures the storage capacity of spatial short-term memory and learning in spatial working memory. The parameter tested is immediate block span which corresponds to longest sequence length that was reproduced correctly at least twice. The results of the test are tabulated below:-

Table 8.6: Average values of scores of CORSI test for two groups

Parameter	**Group I**		**Group II**	
	Before	**After**	**Before**	**After**
Correct Block Span (Percentile Rank)	25.6	76.4	33.9	71.5

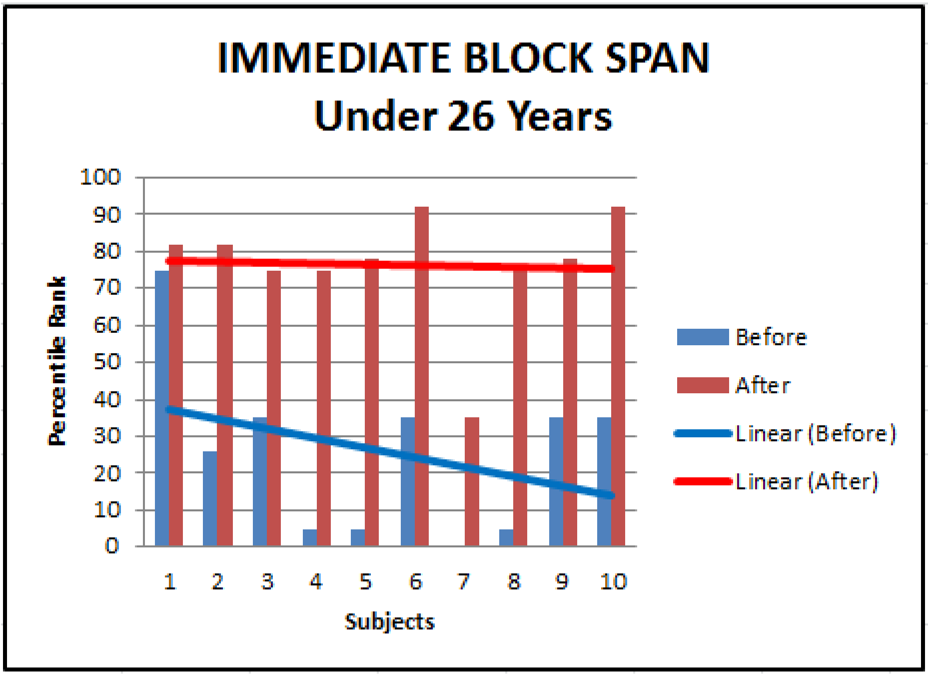


Fig 8.30: CORSI Test for Group I

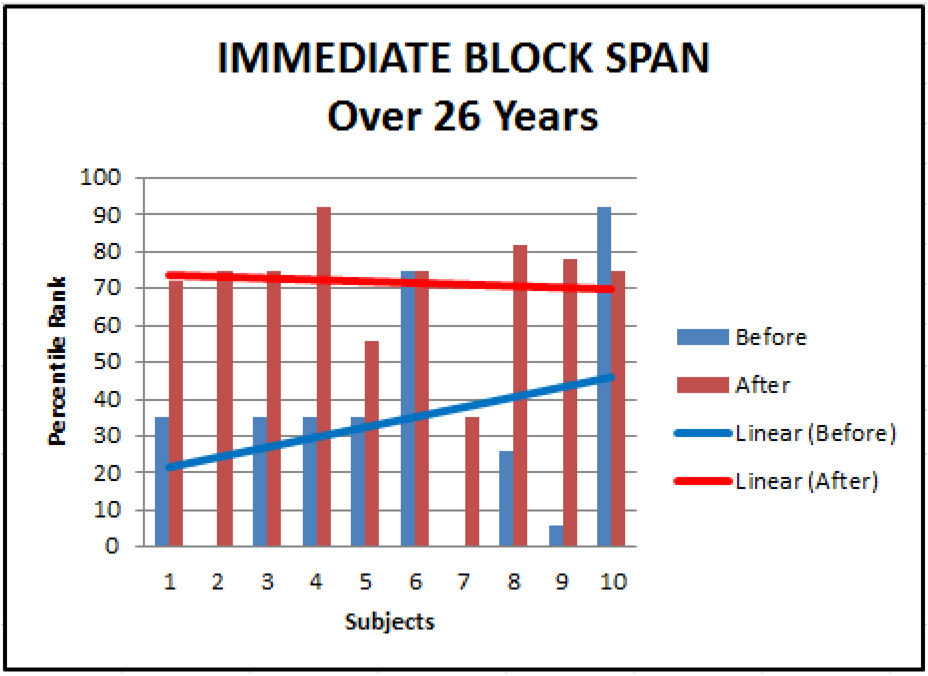


Fig 8.31: CORSI Test for Group II

The trends of block span show a substantial increase of **198%** in immediate block span test for Group I subjects as compared to **110%** for Group II subjects. This indicates that although both the groups have shown improvements in their spatial memory, Group I subjects were correctly able to remember and reproduce much better the blocks shown to them on the screen and therefore had a better short term visual memory.

8.6 Conclusion

Virtual Reality can help the user in reducing stress and at the same time can assist in improving the person's cognition, and therefore is being widely used as a means of cognitive enhancement. To study the effect of Virtual Battlefield on the combatants a group of soldiers were selected for exposure to VR along with their usual daily routine. A multipronged analysis was carried out using physiological and psychological tests.

The comparative analysis of cognitive enhancement of the soldiers using various physiological parameters like EEG and HRV and psychological parameters like hand coordination, attention, concentration and working memory showed a significantly higher cognitive enhancement of the soldiers with no combat experience and of age 26 years & below as compared to the other group of veteran soldiers. Following conclusion can be drawn from comparative test results:-

(a) Increase in EEG power in range of the higher frequency band but decrease in power in theta frequency band indicate good cognitive enhancement for soldiers of Group I. Since Group II soldiers showed increase in alpha but decrease in beta frequency band, definite conclusions cannot be made about their cognitive enhancement.

(b) A study of the band ratios of both the groups illustrates that although heart rate has reduced by 3% in Group II but due to 6% decrease in the power of beta frequency band various other band ratios like Neural Activity Index, Vigilance Index, CNS

Arousal, Cognitive Index etc do not indicate that there is an improvement in the cognitive abilities of this group.

(c) All the band ratios with respect to Group I confirm that this group has exhibited an increase in their cognitive functions.

(d) HRV analysis indicates that with an increase of 12.4% in LF band power and increase of 6.1% in HF band, Group I comprising of young soldiers with no experience of military fighting has shown better improvement in cognitive functions in consonance with the various band ratios and the EEG frequency bands.

(d) The results of psychological tests using Vienna Test System also supported the above results in terms of Group I. However as per these tests Group II has also exhibited marginal improvements in concentration, memory and hand eye coordination.

(e) Hence, this study proves that young soldiers with no prior combat experience when exposed to VR involving a battlefield show definite improvements in their cognitive functions. This would help them to cope up with real life combat situations in a better manner.

(f) The same cannot be deduced without doubt for the group containing veteran soldiers.

CHAPTER 9

CONCLUSION

Cognitive enhancement has been a topic of keen research all over the whole world and lot many interventions both conventional and non-conventional are being studied in detail. A lot of methods like yoga, video games etc have been proved to be effective in cognitive enhancement. Human being has various physiological factors like HRV, BP, EEG, ECG, EOG etc that not only depict the physical parameters but have a close relation with various psychological factors like stress, anxiety, vigilance, task load etc. The close relation between these physiological and psychological factors has been researched previously.

It is established fact that, the external stimuli in terms of interventions are reflected in the mental states and various physiological parameters of the individuals. The effects of these interventions on the cognitive functions therefore, were measured through various physiological signals such as electroencephalogram and electrocardiograph using B Alert X-10 system. It is also known that, these interventions guide the psychological behaviour of the individuals and therefore, various psychological tests such as attention, concentration, senso-motor functions and memory were also used for the evaluation using computer based psychological assessment system referred as Vienna Test System.

I have used that research to study the effect of Virtual Reality on cognitive enhancement of soldiers. The evolution of band ratios have given a more clear insight of various psychological factors like cognition, anxiety, vigilance, executive load index and other physiological factors like performance index, heart rate, LF:HF ratio etc. These factors not only tell overall well-being of a subject but also clearly indicate the cognitive enhancement in the individual. I have carried out the project on soldiers posted in the Roorkee cantonment. They were given VR exposure in form of a virtual battlefield.

The soldiers were divided into two groups as follows:-

(i) **Group I** – 10 soldiers of age less than 26 years and having no combat experience.

(ii) **Group II –** 10 soldiers of more than 26 years of age and having prior combat experience.

The soldiers were chosen from the same unit so that all of them follow the same unit routine for the duration of the test. Their physiological and psychological parameters were recorded initially. Thereafter they were given VR exposure for duration of 45 days. After this their parameters were recorded again.

The results have been very intriguing and it was found that overall cognition has improved significantly in Group I while for Group II results do not confirm an improvement in the cognition.

Group I showed increase in alpha & beta frequency bands while a decrease in theta band. Band ratios also confirm their cognitive enhancement by showing an increase in Performance Enhancement Index, Cognitive Performance Index, Neural Activity Index, Vigilance Index etc. The CNS arousal was found to be reduced by 15%. For Group II, due to 6% decrease in the power of beta frequency band various other band ratios like Neural Activity Index, Vigilance Index, CNS Arousal, Cognitive Index etc do not indicate that there is an improvement in the cognitive abilities of this group.

The results of Heart rate variability (HRV) have also indicated similar trends. The results have shown that there is a significant decrease in LF band and increase in HF band power in case of Group I. The results conclude that the Sympathetic-vagal balance has improved more in case of Group I as compared to Group II. This is an indicator of improved HRV and thus improved cognitive behaviour for Group I. The results were also compared with the band ratios α/θ and $\beta/(\alpha+\theta)$ which indicates overall performance index and cognitive performance respectively. The results of EEG analysis were found to be in sync with the ECG results for Group I. Psychological analysis also confirmed the above results by showing better results for Group I.

The study result can also be used to carry-out analysis of cognitive enhancement of soldiers using various operations of war and a VE can also be developed for counter insurgency operations. It is being suggested that Armed Forces can include Virtual Reality in their training curriculum in various training academies and centres.

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