

Cognitive Enhancement of Sports Persons Using Multiple Object Tracking

A dissertation submitted in partial fulfilment of the requirements for the
award of degree of

**Master of Engineering
In
Electronic Instrumentation and Control**



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DECLARATION


I hereby certify that the work is being presented in this thesis work entitled "Cognitive Enhancement of Sports Persons Using Multiple Object Tracking" in partial fulfillment of award of degree of **Master of Engineering in Electronic Instrumentation & Control** submitted in Electrical & Instrumentation Engineering Department, Thapar University, Patiala is an authentic record of my own work carried under the supervision of **Dr. Ravinder Agarwal**, Professor, Department Of Electrical & Instrumentation Engineering, Thapar University, Patiala, Punjab.

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"Achievement is finding out what you would be doing, what you have to do. The higher the summit, higher will be the climb." It has been rightly said that we are build on the shoulders of others but the satisfaction that accompanies the successful completion of any task would be incomplete without the mention of the people who made it possible.

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ABSTRACT

The study inspected and investigated the electroencephalographic signals of a sports person during the Multiple Object Tracking (MOT) task and their responses to various tests of cognitive assessment battery (cogstate) and D2 test after being provided with appropriate enhancement training. Nineteen healthy sports persons contributed in this study, of which 12 were trained with proper intervention and seven were counted in the control group. Cognitive enhancement, i.e., advancement or betterment of mental abilities, is initiated with assessing cognitive abilities. In the present research work, intervention was delivered through MOT. The physiological signals (EEG) were acquired during MOT, cogstate assessments and D2 test as a part of pre-recording followed by intervention through MOT itself and there after post recording was carried out with same tests. MATLAB (EEGLAB TOOLBOX, WAVELET) and comparison of the various features was done for analysis. The accuracy was calculated using Support Vector Machine (SVM) and Linear Discriminant Analysis (LDA) classifiers. Results after comparing pre and post intervention physiological signals showed beta/theta ratio of power in FC5 and FC6 increases in case of selective attention and power of alpha band increases in channels F3, F4, O1 and O2. For selective attention, the accuracy using SVM found 66.67% and with LDA was 68.42%, whereas working memory was found 55.56% and 57.89% respectively. The pre-intervention and post-intervention results were also compared using t-test for the purpose of significance.

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1.1 General

Cognition is the process whereby beings procure knowledge from the surroundings. Cognition can be well-defined as the progressions an individual uses to establish information. This comprises of acquiring information (awareness), representing (thoughtful) selecting (devotion or attention) and retaining (memory) information and making information useful for reasoning. The field of cognitive neuroscience has become progressively imperative for inaugurating the scientific work and principles of brain function associated with the human performance.

Cognitive enhancement is defined as the intensification or strengthening of principal capabilities of the mind through upgrading or expansion of internal or external information processing systems. As cognitive neuroscience has advanced, the list of eventual internal, natural enhancements has gradually lengthened. External hardware and software support human beings to gain effective cognitive abilities that too in many respects.

Studies suggest that many games help in improving cognitive abilities of a human being. A lot of work has been carried out to enhance the cognitive abilities of sports persons. During an extremely competitive game a sports person it is mandatory to uphold the cognitive abilities. Field sports players need to track number of objects concurrently. The visual cognition ability of these players needs to be higher for a successful player. Sports person has to take swift decision to succeed. Moreover, sustained and focused attention is required to execute the game. There is a strong connection between the two terms: sports and cognition. The capability of a sports person to make quick decisions while in the field relates to a lot of cognitive abilities like strength, decision making, *etc.* Cognition is very

important in sports. The players must be able to make highly quick decisions. He/she must anticipate efficiently before taking actions.

Chapter 1 gives the introduction to the study. It sketches the need for the project undertaken. A brief insight into sports cognition is also provided.

Chapter 2 explains all the important concepts like cognitive assessment, interventions, cognitive enhancement, Electroencephalography (EEG).

Chapter 3 deals with the review of researches carried out previously.

Chapter 4 describes the materials and methods used in the study. Detailed schematic diagrams and descriptions of the various functional blocks in research discussed. The details of various signal processing methods used are discussed.

Chapter 5 comprises of the results obtained and their analysis. The various results obtained are illustrated and analysed.

1.2 Problem Definition

A lot work has been done in abroad in the area of sports cognition in addition to ADHD, brain diseases. The present research work has been focussed on healthy sports persons from engineering background for certain physiological parameters. It has been stated that for selective attention, beta/theta power ratio increases in channels FC5 and FC6, and for working memory, alpha power increases for channels F3, F4, O1 and O2. Hence, the present was to enhance cognitive abilities like selective attention and working memory of the players. To validate the results psychological tests of cogstate and d2 test were carried out.

BIBLIOGRAPHY OF ESSENTIAL CONCEPTS

2.1 Cognition

Cognition refers to the cerebral process of knowing aspects such as wakefulness, reasoning, perception and judgment, thinking [1]. In science, cognition is a group of mental processes that includes memory, attention, producing and sympathetic language, learning, decision making, problem solving and reasoning. Cognition studies are used in various disciplines such as linguistics, psychology, computer science and philosophy. However, in psychology and cognitive discipline, "cognition" usually refers to an information understanding view of an individual's psychological functions. It is also used in a division of social psychology called social cognition to explain attitudes, acknowledgment and group's dynamics. In cognitive psychology and cognitive engineering, cognition is typically supposed to be information processing in a participant's or operator's mind or brain [2].

"Cognition" is a word that dates back to the 15th century and meant „thinking and awareness“ [3]. Cognitive processes can be conscious or unconscious, natural or artificial. These processes are analysed from dissimilar perspectives within different contexts, remarkably in the fields of linguistics, neurology and anaesthesia, psychiatry, psychology, anthropology, philosophy and systemic. Within psychology or philosophy, the idea of cognition is closely related to abstract concepts such as brain, intelligence. It encompasses the mental processes (thoughts), mental functions and states of intelligent entities (humans, collaborative groups, highly autonomous machines, human organizations and artificial intelligences).

2.2 Cognitive Assessment

A cognitive assessment is an inspection conducted to determine someone's level of cognitive function. There is a numeral of reasons to perform such an exam and this test can

be administered by a neurologist, mental health professional or education professional. Numerous standardized assessments have been published [4] and people can also develop their personal, mixing and matching elements of various tests which can be used to compute cognitive function.

In the cognitive assessment, the subject will be asked to complete a series of tasks that require cognitive skills. Exams may be broken up into a number of different components to test things like understanding language, reasoning and so forth. Each section is scored independently and the results can be compared with those of other people who have taken the test to see where someone falls on a scale of cognitive performance. Earlier in the cognitive testing mainly involves the use of pencil and paper tasks to assess a wide range of abilities, including memory, attention, problem-solving, intellectual functioning and language skills. It is the procedure of determining a patient's cognitive strengths and weaknesses through qualitative (approach to tasks and observed performance) and quantitative (standardized and scaled measures) approaches. Test scores are observed on the basis of normative data and expected level of performance for a given individual based upon their educational/occupational level and premorbid estimates of their intellectual functioning.

There are assured predefined cognitive assessment batteries for performing cognitive assessment. The one used in this research is described below.

2.2.1 Cogstate Cognitive Assessment Battery

The brain can practice information at up to 120 meters/second, generates up to 23 watts and consists of about 100 billion neurons. It's an amazing instrument; our business is to keep it that way. But healthy cognitive function is not universal; it can be affected by drugs, disease or injury. As such, the need to assess, observe and improve cognitive function represents a growing market need.

Cogstate Ltd (ASX: CGS) is a multi-faceted cognitive assessment and training company, determined on the development and commercialization of rapid, computerized tests of

cognition (brain function). Driven by more than a decade of peer-reviewed scientific research, Cogstate has produced and commercialized computer assessment programs for monitoring, assessing and improving cognition. These tests are easy to use, universal and commercially viable. Detection of drug effects and of previous interventions on human cognitive processes requires careful development of theoretical and empirical experimental models, with attention to study design, execution and analysis [5].

Some of the tests of this battery are explained as follows:

2.2.1.1 Identification Task

- Administration Time (in healthy volunteers): 2 Minutes
- Cognitive Domain Usually Measured: Visual Attention / Vigilance
- **Task Description:** The pre-task on-screen instructions ask: “Is the card red?” The test supervisor will read full instructions to the subject from the test supervisor script. To begin the task, the test supervisor or subject must press the “Enter” key. A playing card is presented in the centre of the screen. The card will flip over so it is face up. As soon as it does this the subject must decide whether the card is red or not. If it is red he/she should press “Yes”, if it is not red he/she should press “No”. The subject will practice until they reach the required number of responses, or until the practice period expires. Then, on screen instructions for the real test are presented. The test supervisor or subject must press the “Enter” key to start the real test. The subject should be confident to work as quickly as they can and be as accurate as he/she can. For example, the subject should try not to press either the “Yes” or “No” key before a card flips over. If he/she makes a mistake they will hear an error sound.
- **Primary Outcome measures:**
- Unit of measurement: Log10 milliseconds
- Description and interpretation of scores: Speed of performance; mean of the log10 transformed reaction times for correct responses. (Lower score = better performance)

2.2.1.2 Groton Maze Chase Task

- Administration Time (in healthy volunteers): 0.5 Minutes
- Cognitive Domain Usually Measured: Visual Motor Function
- **Task Description:** The aim of this task is to introduce the subject to the rules of the Groton Maze tasks. The pre-task on-screen instructions condition: “Chase the Target”. The test supervisor will read the full task commands to the subject. To start the task, the test supervisor or subject must press the “Enter” key. The subject will first complete a practice test. The subject is shown a 10 x 10 grid of tiles on a computer touch monitor. The subject is asked to tap the blue tile in the top left corner of the lattice with the stylus pen. As the target moves, the subject „chases“ it by tapping on the tiles one at a time. The subject cannot move diagonally and cannot skip a tile. If the subject makes a mistake, they must go back to the last correct tile. The subject should be confident to move as quickly and accurately as possible. Once the test supervisor judges that the subject understands the rules, the subject is instructed to click on the “Finish” button in the upper left corner of the screen. The subject is then asked to do again the same task for a timed period of 30 seconds. The same rules apply as in the practice. The subject chases the target until the task stops.
- **Primary Outcome measures:**
- Unit of measurement: Moves per second
- Description and interpretation of scores: The total number of correct moves made per second. (Higher score = better performance)

2.2.1.3 Groton Maze Learning Task

- Administration Time (in healthy volunteers): 5 Minutes
- Cognitive Domain Usually Measured: Spatial Problem Solving/Executive Function
- **Task Description:** The subject is shown a 10 x 10 grid of tiles on a computer touch monitor. A 28-step pathway is hidden among these 100 possible locations.

The start is indicated by the blue tile at the top left and the finish location is the tile with the red circles at the bottom right of the grid. The subject is instructed to move one step from the start location and then to continue, one tile at a time, toward the end (bottom right). The subject moves by touching a tile next to their current location with the stylus. After each move is made, the computer indicates whether this is correct by revealing a green checkmark (i.e. this is the next step in the pathway), or incorrect by revealing a red cross (i.e. this is not the next step in the pathway, or the subject has broken a law, see below). If a choice is incorrect (i.e. a red cross is revealed), the subject must touch the last correct position (i.e. the last green checkmark revealed) and then make a different tile choice to move ahead toward the end.

While moving through the hidden maze, the subject is necessary to adhere to two rules. Firstly, the subject cannot move diagonally or touch the same tile twice in series. Secondly, the subject cannot move backwards along the pathway (e.g. move back to a position that displayed a green tick, but from which they have since moved on from). If the subject chooses a tile that is not part of the hidden pathway, but the tile choice is within the rules, this is recorded as a different type of error (ex. not a rule break). This could be due to chance (the first time through the maze) or due to misremembering the path on subsequent attempts. The subject learns the 28-step pathway through the maze on the basis of this trial and error feedback. Once finished, they are returned to the start location and repeat the task, usually 4 more times, trying to remember the pathway they have just completed. There are 20 well-matched alternate forms for this task, and these are selected in pseudo-random order to ensure that no subject will complete the same hidden path on any two different testing sessions throughout a study.

- **Primary Outcome measures:**
- Unit of measurement: Errors
- Description and interpretation of scores: Total number of errors made in attempting to learn the same hidden pathway on five consecutive trials at a single session. (Lower score = better performance).

2.2.1.4 International Shopping List Task

- Administration Time (in healthy volunteers): 5 Minutes
- Cognitive Domain Usually Measured: Verbal Learning & Memory
- **Task Description:** The expression “Shopping List Learning” is displayed on monitor. The pre-task on-screen commands tell the test supervisor to start this task with the screen facing the supervisor so that the subject cannot see the screen.

Trial 1

The subject is told by the test controller: “In this task, I am going to read you a shopping list. I would like you to remember as many items from this list as probable. Are you ready to start?” To begin, the test supervisor presses the “ENTER” key. The test supervisor reads the list of words as they appear on the computer monitor at a rate of one word every two seconds. When the test supervisor has read all the words they ask: “Tell me as many of the items on the shopping list as you can remember?”

As the subject recalls each word, the test controller clicks the appropriate button on the screen with the stylus or mouse. If the subject says a word that was not on the list, the test controller will click “Other Word”. If the subject repeats a word, the test supervisor will click the corresponding button as many times as the word is said. If a key is clicked by mistake, the test supervisor can select “Undo Last” and then continue recording. **Trial 2 (and subsequent trials)**

When the subject cannot recall any more items then the test supervisor instructs, “I am going to read you that same shopping list. Try and keep in mind as many items as you can. Are you ready to start? the whole word list is read again, in the same order as it was read previously. To begin, the test supervisor presses the “ENTER” key and reads the list of words as they show on the computer display at a rate of one word every two seconds. When the test supervisor has read all words they ask: “Now what were the objects on the shopping list?”

Again, the test supervisor notes the items recalled by the subject by clicking/touching the corresponding key on screen with the stylus or mouse. In the standard version of this test, 3 learning trials are presented following this format. The difficulty level of this task can be adjusted by presenting less or more words. The list of words can be anywhere from 2 to 16.

- **Primary Outcome measures:**
- Unit of measurement: Number of correct responses
- Description and interpretation of scores: Total number of right responses made in remembering the list on three successive trials at a single session. (Higher score = better performance).

2.2.1.5 Two Back Task

- Administration Time (in healthy volunteers): 2 Minutes
- Cognitive Domain Usually Measured: Attention / Working Memory
- **Task Description:** The pre-task on-screen commands ask “IS THE CARD THE SAME AS THAT SHOWN TWO CARDS AGO?” The test supervisor will read the task instructions from the writing. To start the task, the test supervisor or subject must push the “Enter” key. A playing card is presented face up in the centre of the screen. The subject must decide as each card is presented whether it is identical to the one just before. Therefore the first two answers are always “No”. If the face up card is the same to the one presented two cards before, the subject should push the “Yes” key, if it is not the subject should push the “No” key. The card in the centre will go to the back of the set revealing the next card. As soon as it does the subject must decide whether or not it is the same as the card they saw two cards previously. The subject will practice until he/she reaches the required number of responses, or until the practice period expires. Then, on screen instructions for the real test are presented. The test supervisor or subject must press the “Enter” key to begin the real test. The subject should be encouraged to work as quickly as he/she can and be as precise as possible. For example, the subject should try not to push either “Yes”

or “No” key before a card turns over. If the subject makes a mistake he/she will hear an error noise.

- **Primary Outcome measures:**
- Unit of measurement: Arcsine proportion correct
- Description and interpretation of scores: Accuracy of performance; arcsine transformation of the square origin of the proportion of correct responses.

(Higher score = better performance) [6].

2.2.2 D2 Test

As a part of cognitive assessment D2 test has been used in this research. The d2 Test of Attention is a neuropsychological measure of selective and sustained attention and visual scanning speed [7]. It is a paper and pencil test that asks participants to cross out any letter "d" with two marks around above it or below it in any order. The neighbouring distracters are usually similar to the target motivation, for example a "p" with two marks or a "d" with one or three marks. The original account of the test was created by **Brickenkamp (1981)** in Germany as a cancellation task. The standard edition of the d2 Test is a one-page paper-and pencil cancellation test, consisting of 14 rows (trials), each with 47 interspersed “p” and “d” characters. The characters have one to four dashes that are configured independently or in pairs above and or below each letter. The target symbol is a “d” with two dashes (hence “d2”), in spite of whether the dashes appear both above the “d”, both below the “d”, or one above and one below the “d”. Thus, a “p” with one or two dashes and a “d” with more or less than two dashes are distracters. The participant’s task was to cancel out as many target symbols as possible, moving from left to right, with a time limit of 20s/trial. No pauses are allowed between trials [8].

2.3 Interventions

A diseased brain’s activity is corrected by use of medicines. On the other hand, activity of a healthy brain can be enhanced using some non-invasive or invasive interventions. Interventions are the procedures used for cognitive enhancement. Interventions are of many types such as meditation, colour, odour, music, virtual reality, etc.

2.3.1 Meditation

Meditation is usually defined as a state that is practised when the mind dissolves and is free of all thoughts. In the very old period, Meditation is a pure spiritual aspect which is helpful to achieve an enlightened personality. In the present scenario, meditation was proved to have more concern with health, consciousness, intellect and self-realization. Meditation is helpful in reducing anxiety, stress and depression, improving psychological health, memory and intelligence, self-concept, problem solving effectiveness, academic performance *etc.* [9].

2.3.2 Colour

By using colours cognitive levels can be enhanced by considering the example of a class of students. If a teacher uses chalks of different colours on the board, the students can be expected to become more attentive. Hence, this increases the cognitive abilities [10].

2.3.3 Odour

Odour can be used for cognitive enhancement. Smell is often our first response to stimuli. Different odours are given to subjects, some having good fragrance and some having bad. Good fragrances are like fragrance of flowers, fruits etc. Bad fragrances are like fragrance of garbage etc. After some time cognitive level is checked whether it is improved or not [11].

2.3.4 Music

Music can also be used in cognitive enhancement. Music is of different types like classical, folk, etc. People listening to music for sufficient amount of time can be expected to have better cognitive levels [12].

2.3.5 Neuro-feedback

Biofeedback is a self-intervention. EEG biofeedback is use an intervention for cognitive enhancement. EEG biofeedback is known as Neuro-feedback. Biofeedback is a treatment

technique in which people are trained to improve their health by using signals from their own body. Specialists in many different fields use biofeedback to help their patients cope with pain. Biofeedback machines are used to detect a person's internal bodily functions, this information may be valuable for both patients and therapists use to gauge and direct the progress of treatment [13].

2.3.6 Multiple Object Tracking (MOT)

Multiple Object Tracking, or MOT, is an experimental technique used to study how our visual system tracks multiple moving objects. It was developed in 1988 in order to test a theoretical proposed mechanism called a Visual Index or FINST (for FINgers of INSTantiation). The theory postulates a small number (around 4) indexes or pointers that pick out and stay attached to individual objects in the visual field independent of their changing properties, and thus allows them to be tracked.

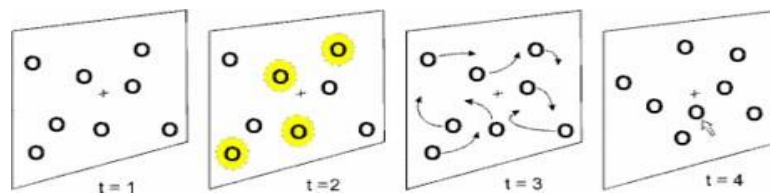


Figure 2.1: Sequence of events in a typical MOT experiment

The basic trial is shown in the Figure 1. First a display of eight identical objects is shown (t=1). Then a subset of 4 “targets” are briefly flashed to make them distinctive (t=2). Following this the objects stop flashing so “target” set becomes indistinguishable from the other objects. All objects then move in a random fashion for about 10 seconds (t=3). Then the motion stops (t=4) and observer’s task is to indicate all the tracked objects by clicking on each one using a computer mouse [14]. In a typical MOT experiment the subject indicates all the selected “targets” at the end of each trial. In some studies they might, instead, judge whether a particular object, flashed at the end of the trial, was a target.

The MOT task was first introduced by Pylyshyn and colleagues. The researchers carried out three experiments and the subjects attempted to track multiple items as they moved

independently and unpredictably about a display. Subjects in their first experiment viewed a display initially consisting of a field of identical white crosses. A certain subset of the crosses was then flashed several times to indicate their status as targets. All of the crosses then began moving independently and unpredictably about the screen. This motion continued for an interval ranging from 7 to 15 s. At fixed times, a small square was flashed on the display, and subjects pressed keys to indicate whether the square had been flashed at the location of a target, a non-target, or neither [15].

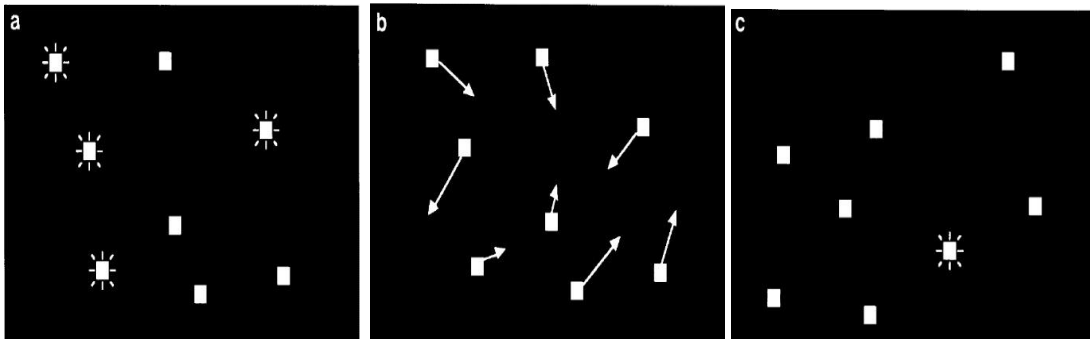
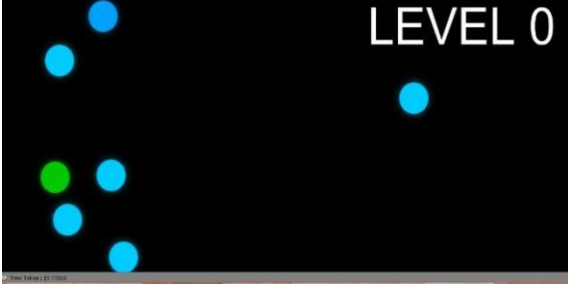
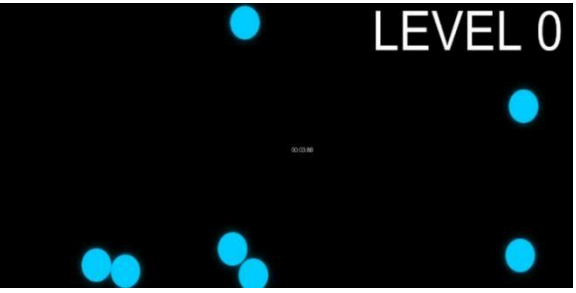


Figure 2.2: A schematic depiction of the multiple-object tracking task

In the present research work MOT created by UNITY software was used. The subject was shown number of balls which were of same colour except one. The aim was to detect the ball which was of different colour. The differently coloured ball was shown only for few seconds and then it got the same colour as of others. The balls then started moving randomly and the subjects were asked to keep an eye on that ball. After a while the movements of balls were stopped and the subjects were asked to click on the ball which was initially distinguished from others. For correct detection the subject was showedhis reaction time and moved to next level otherwise asked to repeat the level. The subject is presented with a number of balls which are of same colour except one as shown in Figure 2.3.

	
<p>Figure 2.3: Level 0 with one distinguished ball</p>	<p>Figure 2.4: Level 0 begins and subject is asked to detect the distinguished ball</p>

The aim was to detect the ball, which was of different colour. The differently coloured ball was shown only for few seconds and then it gets the same colour as of others. The balls then started moving randomly and the subject had to keep an eye on that ball. After a while the movements of balls were stopped and the subject had to click on the ball which was initially distinguished from others.

2.4 Cognitive Enhancement

Cognitive enhancement (CE) is a technology aimed to optimizing specific class of information-processing functions, cognitive functions and physical realization of human brain. In modern day CE is special because of its function “level of granularity”. Level of granularity present us with a technology that very directly influences the core realizes of certain cognitive functions, on the molecular level of brain chemistry itself. Enhancement is usually used to characterize interventions designed to improve human functioning beyond what is necessary to sustain or restore good health .Enhancement modify physical or mental characteristics in individuals. Many neuropsychiatric illnesses occur on a spectrum that includes normal levels of functioning. This raises the question: if medications can improve cognition in people with cognitive impairment, for normal healthy people. This questions points to cognitive enhancement. Cognitive enhancement may be defined as the amplification or extension of core capacities of the mind through improvement or augmentation of internal or external information processing systems [16].

2.5 Electroencephalogram (EEG)

Electroencephalography (EEG) is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain. In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a short period of time, usually 20–40 minutes, as recorded from multiple electrodes placed on the scalp. Diagnostic applications generally focus on the spectral content of EEG, that is, the type of neural oscillations that can be observed in EEG signals. In neurology, the main diagnostic application of EEG is in the case of epilepsy, as epileptic activity can create clear abnormalities on a standard EEG study. A secondary clinical use of EEG is in the diagnosis of coma, encephalopathies, and brain death. A third clinical use of EEG is for studies of sleep and sleep disorders where recordings are typically done for one full night, sometimes more. EEG used to be a firstline method for the diagnosis of tumours, stroke and other focal brain disorders,[3] but this use has decreased with the advent of anatomical imaging techniques with high (<1 mm) spatial resolution such as MRI and CT. Despite limited spatial resolution, EEG continues to be a valuable tool for research and diagnosis, especially when millisecond temporal resolution (not possible with CT or MRI) is required.

Derivatives of the EEG technique include evoked potentials (EP), which involves averaging the EEG activity time-locked to the presentation of a stimulus of some sort (visual, somatosensory, or auditory). Event-related potentials (ERPs) refer to averaged EEG responses that are time-locked to more complex processing of stimuli; this technique is used in cognitive science, cognitive psychology, and psychophysiological research.

2.5.1 Basic Principles of EEG

The electrical activity of neurons in the brain produces currents that reach the surface of the scalp. EEG provides a non-invasive method of recording the voltage differences of these scalp potentials. These potentials are created by both cerebral sources and unwanted non-cerebral artifacts which tend to be exaggerated during movement. The EEG signal is

transmitted from the scalp electrodes to a differential amplifier in order to amplify the microscopic potentials severely attenuated by their passage through the skull. This signal is continuously sampled at a high rate (typically 256 Hz but often more) to provide a high temporal resolution. An analogue band-pass filter is used to filter the raw EEG signal and typically possesses a lower cut-off of 0.5 Hz and a higher cut-off of 50 Hz. The 50 Hz filter helps eliminate electrical noise originating from 50 - 60 Hz mains power. These filters also affect the processing of nearby frequencies so care must be taken to ensure the cut-off frequencies do not lie too close to the frequencies under investigation. The default cut-offs pose no problems in the sports sciences as the low to mid-range frequencies (e.g. 4–20 Hz) are normally those of interest.

After amplification and filtering, the EEG signal is (in modern digital systems) relayed to a computer where it can be processed as continuous data and, if desired, its spectral parameters compared with some criterion measure. This is the approach adopted by EEG-biofeedback training in sports and other performance domains which rewards desirable changes in specific frequency bands. An alternative approach is the study of event-related potentials (ERPs). These usually consist of data epochs of short duration reflecting the cortical response to an external stimulus. In order to offset data noise, many ERPs (often hundreds) are averaged to provide a favourable signal-to-noise ratio.

The typically wave like appearance of the EEG signal reflects the rhythmic activity of underlying synaptic processes. This rhythmicity is thought to reflect the synchronized activity of large neuronal assemblies possibly driven by thalamic pace-maker cells; although the simplicity of this interpretation has been questioned. Anatomically distinct cortical areas produce a variety of different rhythms which are observed as a composite EEG signal. Fourier spectral analysis is typically used to decompose this signal into its constituent frequency bands and to compute the amplitude of each band.

2.5.2 Frequency Bands of EEG

The EEG is characteristically described in terms of rhythmic activity and transients. The rhythmic activity is separated into bands by frequency. These frequency bands are an issue of nomenclature (i.e., any rhythmic activity between 6–12 Hz can be described as "alpha"), but these designations arose because rhythmic activity within a certain frequency range was noted to have a certain distribution over the scalp or a certain biological significance. Frequency bands are usually extracted using spectral methods (for instance Welch) as implemented for instance in freely available EEG software such as EEGLAB or the neurophysiologic biomarker toolbox.

Most of the cerebral signal observed in the scalp EEG falls in the range of 1–20 Hz. EEG signals are composed of different oscillations. These rhythms have distinct properties in terms of spatial and spectral localization. There are 6 classical brain rhythms:

- Delta (0.5-4 Hz) □ Theta (4-8 Hz)
- Alpha (8-12 Hz)
- Beta (12-30 Hz)
- Gamma (>30 Hz)

Delta rhythm: Delta is the frequency range up to 4 Hz. It tends to be the maximum in amplitude and the slowest waves. It is seen normally in adults in slow wave sleep. It is also seen normally in babies. It may occur focally with subcortical lesions and in general allotment with diffuse lesions, metabolic encephalopathy hydrocephalus or deep midline lesions. It is usually most prominent frontally in adults and subsequent in children.

Theta rhythm: Theta is the frequency range from 4 Hz to 7 Hz. Theta is seen normally in young children. It may be seen in sleepiness or arousal in older children and adults; it can also be seen in meditation. Excess theta for age represents abnormal movement. It can be seen as a focal interruption in focal subcortical lesions; it can be seen in generalized allocation in diffuse disorder or metabolic encephalopathy or deep midline disorders or some instances of hydrocephalus. On the contrary this range has been linked with reports of meditative, relaxed and creative states.

Alpha rhythm: Alpha is the frequency range from 8 Hz to 12 Hz. Hans Berger named the first rhythmic EEG activity he saw as the "alpha wave". This was the "posterior basic rhythm" (also called the "posterior dominant rhythm" or the "posterior alpha rhythm"), seen in the posterior regions of the brain on both sides, higher in amplitude on the dominant side. It emerges with closing of the eyes and with relaxation, and mental exertion or attenuates with eye opening. The posterior basic rhythm is actually slower than 8 Hz in young children (therefore technically in the theta range).

Beta rhythm: Beta is the frequency range from 12 Hz to about 30 Hz. It is seen usually on both sides in symmetrical distribution and is most obvious frontally. Beta activity is closely linked to motor behaviour and is generally attenuated during active movements. Low amplitude beta with multiple and varying frequencies is often associated with active, busy or anxious thinking and active concentration. Rhythmic beta with a dominant set of frequencies is associated with a variety of pathologies and drug effects, especially benzodiazepines. It may be absent or reduced in areas of cortical damage. It is the dominant rhythm in patients who are attentive or anxious or who have their eyes open

Gamma rhythm: This rhythm concerns mostly frequencies above 30 Hz. This rhythm is sometimes defined as having a maximal frequency around 80 Hz or 100 Hz. It is associated to various cognitive and motor functions. It displays during cross-modal sensory processing (perception that combines two different senses, such as sound and sight). It is also shown during short-term memory matching of recognized objects, sounds or tactile sensations. A decrease in gamma-band activity may be linked with cognitive decline, especially when related to the theta band; however, this has not been proven for use as a clinical diagnostic measurement.

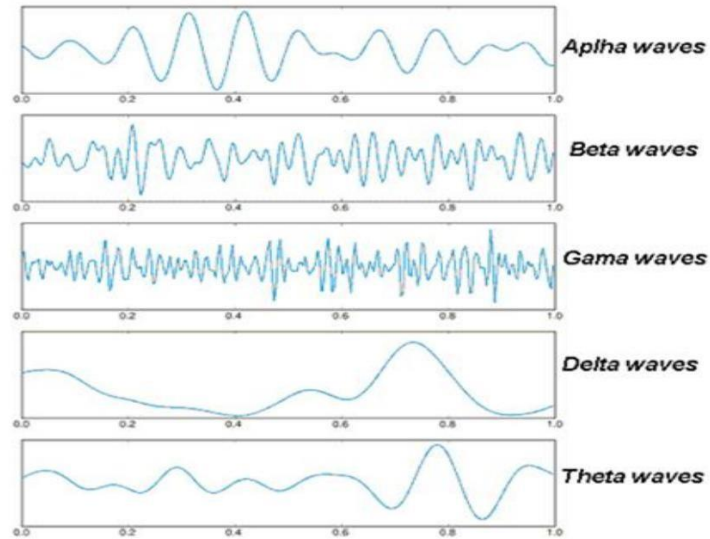


Figure 2.5: EEG rhythms

2.5.3 Recording Methods

EEG measurement consist the attachment of electrodes to standardized positions on the scalp. These electrodes are usually made of highly conductive silver or silver chloride (Ag/AgCl) although other metals such as tin, gold and platinum are also used. Nonmetallic material such as carbon fibre can also be employed to allow compatibility with other neuro imaging devices such as MRI. Electrodes are attached to the skin using conductive adhesive with impedances usually kept below 5 k. Prior to attaching the electrodes the skin is usually prepared with an abrasive paste such as Nu-Prep to reduce skin impedance. The number of active electrodes can range from one, which is sufficient for neurofeedback training, to multiple electrodes necessary for source localization with the number of electrodes typically varying from 20 to 128. Electrode placement is standardized to aid interpretability from one laboratory to another.

International 10/20 System:

Electrodes are generally placed according to a standard system called the 10-20 international system. This system has been originally considered for 19 electrodes;

however, extended versions have been developed to deal with a larger number of electrodes.

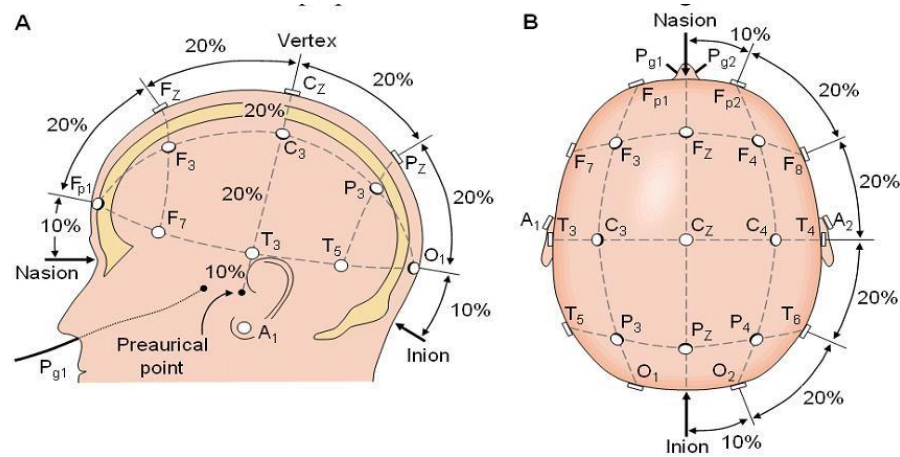


Figure 2.6: International 10-20 Placement

The 10-20 system or International 10-20 system is an internationally renowned technique to designate and apply the location of scalp electrodes in the EEG experiment. This method was established to confirm standardized reproducibility so that a subject's readings could be linked over time and subjects could be compared to each other. This system is based on the association between the site of an electrode and the underlying area of cerebral cortex. The "10" and "20" refer to the fact that the actual distances between adjacent electrodes are either 10% or 20% of the total front-back or right-left distance of the skull.

Each location has a letter to identify the lobe and a number to recognize the hemisphere location. The letters F, T, C, P and O stand for frontal, temporal, central, parietal, and occipital lobes, respectively. Note that there exists no central lobe; the "C" letter is only used for identification purposes only. A "z" (zero) refers to an electrode placed on the midline. Even numbers (2, 4, 6 and 8) refer to electrode positions on the right hemisphere, whereas odd numbers (1, 3, 5, and 7) refer to those on the left hemisphere.

Source of EEG activity

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

Scalp EEG activity shows oscillations at a variety of frequencies. Several of these oscillations have characteristic frequency ranges, spatial distributions and are associated with different states of brain functioning (e.g., waking and the various sleep stages). These oscillations represent synchronized activity over a network of neurons. The neuronal networks underlying some of these oscillations are understood (e.g., the thalamocortical resonance underlying sleep spindles), while many others are not (e.g., the system that generates the posterior basic rhythm). Research that measures both EEG and neuron spiking finds the relationship between the two is complex, with a combination of EEG power in the gamma band and phase in the delta band relating most strongly to neuron spike activity.

2.5.5 Artifacts

2.5.5.1 Biological Artifacts: Electrical signals detected along the scalp by an EEG, but that originate from non-cerebral origin are called artifacts. EEG data is almost always contaminated by such artifacts. The amplitude of artifacts can be quite large relative to the size of amplitude of the cortical signals of interest. This is one of the reasons why it takes considerable experience to correctly interpret EEGs clinically. Some of the most common types of biological artifacts include:

- Eye-induced artifacts (includes eye blinks, eye movements and extra-ocular muscle activity)
- ECG (cardiac) artifacts
- EMG (muscle activation)-induced artifacts

The most prominent eye-induced artifacts are caused by the potential difference between the cornea and retina, which is quite large compared to cerebral potentials. When the eyes and eyelids are completely still, this cornea-retinal dipole does not affect EEG. However, blinks occur several times per minute, the eyes movements occur several times per second. Eyelid movements, occurring mostly during blinking or vertical eye movements, elicit a large potential seen mostly in the difference between the Electrooculography (EOG) channels above and below the eyes. An established explanation of this potential regards the eyelids as sliding electrodes that short-circuit the positively charged cornea to the extra-ocular skin.

2.5.5.2 Environmental Artifacts: In addition to artifacts generated by the body, many artifacts originate from outside the body. Movement by the patient, or even just settling of the electrodes, may cause electrode pops, spikes originating from a momentary change in the impedance of a given electrode. Poor grounding of the EEG electrodes can cause significant 50 or 60 Hz artifact, depending on the local power system's frequency. A third source of possible interference can be the presence of an IV drip; such devices can cause rhythmic, fast, low-voltage bursts, which may be confused for spikes.

2.5.5.3 Artifact Correction: Recently, independent component analysis techniques have been used to correct or remove EEG contaminants. These techniques attempt to "unmix" the EEG signals into some number of underlying components. There are many source separation algorithms, often assuming various behaviours or natures of EEG. Regardless, the principle behind any particular method usually allow "remixing" only those components that would result in "clean" EEG by nullifying (zeroing) the weight of unwanted components. Fully automated artifact rejection methods, which use ICA, have also been developed [17-20].

CHAPTER 3

LITERATURE REVIEW

Cognition is a term denoting the mental processes involved in gaining knowledge and intellectual capacity, including knowing, arbitrating, memorising, and problem-solving. These are higher-level functions of the brain and involve imagination, perception, language and planning. Cognition is the methodical term for mental processes. It states to the awareness, procurement, and memorization of information of humans. More precisely, it refers to the thinking, knowing, remembering, judging and problem-solving abilities of humans. Cognition is studied in various disciplines such as psychology, philosophy, linguistics and computer science. There is a connection between the two terms: Sports and Cognition. The ability to make decisions while in the mid of high enactment sporting competition. The connection must be strong enough to maintain the dependability of the athlete to work mentally and physically. Cognition is a very vital aspect to be considered for a sports person because athletes must be able to make splitsecond decisions under the pressures of activity or competition. Quite often this necessary skill is left to chance, relying on the skill of the sportsman or athlete. Keeping in mind this point of view, the research has tried to put forward some ideas and concepts to help a sports person develop his cognitive skills on the field. This chapter tells about what other researchers have done till now in this field.

Many researchers have been carried out in this regard. For instance, researchers attempting to conclude the cognitive abilities associated with successful sport performance have examined the relation between various types of sports and the attentional style.

Crystal D. Oberle [21] worked upon the basketball players. He began the experiment with a demographic questionnaire related to the involvements of the players followed by a Group Embedded Figures Test (GEFT). The results showed that although the experienced players were better than the non-players but they were also more distracted by a defender

attempting to block the shot from the front. This suggested that the experienced players may possess a field-dependent attentional style.

Claudio Babiloni *et al.* [22] studied the frontal cerebral rhythms of the two hemispheres of 12 golfers. Electroencephalographic (EEG) recordings have been characteristically engaged in studies of closed motor skills such as golf, archery.

Isabelle Legault *et al.* [15] assessed the capacity of older participants to improve their tracking speed thresholds in a dynamic, virtual reality environment using MOT training. Results showed that this capacity is significantly affected by healthy aging but that cognitive training (MOT in this case) can efficiently reduce age-related effects in older individuals. The MOT task was first introduced by **Pylyshyn** and colleagues to determine how people track multiple elements.

Brickenkamp (1981) [7] created the original version of d2 test in Germany. (As a part of cognitive assessment D2 test has been used in this research. The d2 Test of Attention is a neuropsychological measure of selective and sustained attention and visual scanning speed. It is a paper and pencil test that asks participants to cross out any letter "d" with two marks around above it or below it in any order. The surrounding distracters are usually similar to the target stimulus, for example a "p" with two marks or a "d" with one or three marks.

Adam Moore and Peter Malinowski [8] investigated the link between meditation, self-reported mindfulness and cognitive flexibility as well as other attentional functions. The research worked upon a group of mediators who experienced mindfulness meditation. The tests used were D2 test and endurance test. The D2 Test of Attention is a neuropsychological measure of selective and sustained attention and visual scanning speed.

Marina G. Falletti *et al.* [23] used cogstate computerized battery for cognitive assessment experimentation. The detection of human cognitive behaviour requires careful development of certain cognitive batteries. These cognitive batteries are used for assessing the mental abilities of an individual. Cogstate is one such battery. The cogstate

computerized cognitive tests are valid and reliable in many different clinical and social settings. This study uses this battery as one of the ways to assess the cognitive abilities.

Marina G. Falletti et al. [24] examined the change in group performance using this computerized test battery. Another aim of the study was to examine how many times the battery needed to be completed before performance becomes consistent. The results illustrated that when brief test-retest intervals were used (i.e., 10 minutes), performance became consistent or stabilized after the second assessment. Practice effects were also observed on some of the tasks at a one-week test-retest interval.

A Collie, D Darby and P Maruff [25] conducted a number of computerized cognitive assessment tests for athletes having sports related head injuries. A number of computerised cognitive assessment tests and test batteries have been developed over the past two decades. These batteries offer major scientific and practical advantages over conventional neuropsychological tests which make them ideal for the assessment of cognitive function in sportspeople.

Ganesh R. Naik and Dinesh K. Kumar [26] gave an overview on ICA. In signal processing, ICA is a computational method for separating a multivariate signal into additive subcomponents. This is done by assuming that the subcomponents are nonGaussian signals and that they are statistically independent from each other.

Neep Hazarika et al. [27] classified the EEG signals using wavelet transform. The electroencephalogram (EEG) is widely used clinically to investigate brain disorders. However, abnormalities in the EEG in serious psychiatric disorders are at times too subtle to be detected using conventional techniques.

Jonathan D. Mouton and Crystal D. Oberle [28] also adopted various techniques to assess attentional styles of people varying in experience in team and sports. Electroencephalographic (EEG) recordings have been routinely employed in such studies for closed motor skills such as golf [29-31], archery [32].

Christopher M. Janelle *et al.* [33] observed the electroencephalographic recordings to study the attention of the player during rifle shooting. Not only sports, dance activity can also be studied by such techniques. Another research was carried out to assess the dance performance using neurofeedback [34]. The study by **Jocelyn Faubert and Lee Sidebottom** [35] concentrated on athletes for their cognitive training.

Do-Won Kim *et al.* [36] also made a research to study the selective attention. This selective attention was studied for auditory stimuli given to the subject. The participants were instructed to close their eyes and concentrate their attention on the auditory stimulus. The instructions were provided through the speakers during the inter-stimulus interval.

Carlos Escolano *et al.* [37] concentrated on the working memory for their research. The research revolved around neurofeedback training. Multiple Object Tracking (MOT) is widely used as an intervention for sports persons. It is seen that the capacity of older participants improves their tracking speed thresholds in a dynamic, virtual reality environment using MOT training [38]. **George A. Alvarez and Steven L. Franconeri** [39] also conducted two experiments including moving objects as a part of MOT to test for visual attention.

Moving on to the analysis of electroencephalographic rhythms, the study analyses the rhythms using wavelet package. Wu Ting *et al.* computed the feature extraction of EEG signals using wavelet package decomposition (WPD) [40]. Similarly, another study also made use of wavelet to classify emotions. This research also classified the results using K nearest neighbour (KNN) and Linear Discriminant Analysis (LDA) classifiers [41].

CHAPTER 4

METHODOLOGY

4.1 Protocol

(a) Participants

19 healthy graduates (12 of them were in training group and rest 7 in the control group) in technology participated. All participants were given a detailed, written summary of the experimental procedures. None of the participants reported neurological or psychiatric disorders or previous head injury that might affect the experiment. It was also confirmed that all subjects had normal or corrected normal vision and normal hearing.

(b) Preparation of participant for EEG

Participants sat on a comfortable armchair in the front of monitor. Subjects were explained them about complete procedure, that is, hardware (EEG system), data acquisition, and all the tests to be carried out, as a result of which subject became familiar with the experiment. The scalp of subject is prepared by light abrasion to remove dead cells. Details of data acquisition using EMOTIV are explained in section 4.2.1.

(c) Tests conducted for pre-intervention cognitive assessment

The subjects were made to perform the tests of the cognitive test battery-cogstate. The cogstate computerized cognitive tests are valid and reliable in many different clinical and social settings. The tests used in this research are: identification task, Groton maze, Groton maze learning test, international shopping list task and two back memories.

The next trial includes *D2 test*. The d2 test of attention is a neuropsychological measure of selective and sustained attention and visual scanning speed. Here again, subjects were asked to mark the particular symbols of „p“ and „d“ as early as possible. The calculations were computed in accordance to the performance of the subject in this test. Details of cogstate and d2 test are explained in section 1.2.1 and 1.2.2.

(d) *Intervention*

„Multiple Object Tracking“ is used as intervention in the study. The subject was presented with *MOT task* and then MOT created by UNITY software. The subject was made to play the MOT task for 40 minutes daily (for 15 days).

(e) *Signal Processing and feature extraction*

The pre and post data required was analysed and then compared to observe the changes due to training. The raw data acquired was initially filtered. The frequency range was selected between 2 to 43 Hz as this covers almost whole range of an EEG signal. This is followed by Independent Component Analysis (ICA) of the signal. ICA was used for finding underlying factors or components from multivariate (multi-dimensional) statistical data. The eye artifacts and muscle artifacts were removed from the resulting signal. This procedure was carried out using EEGLAB toolbox. The final data thus obtained was analysed using frequency analysis. This frequency analysis was done using Wavelet transform. Different ranges of EEG signal- alpha (α), beta (β), theta (θ) are computed by programming in MATLAB. Energy, entropy and power of all the components are calculated individually. Classification of trained and control group was done using Support Vector Machine (SVM) and Linear Discrimination Analysis (LDA) classifiers.

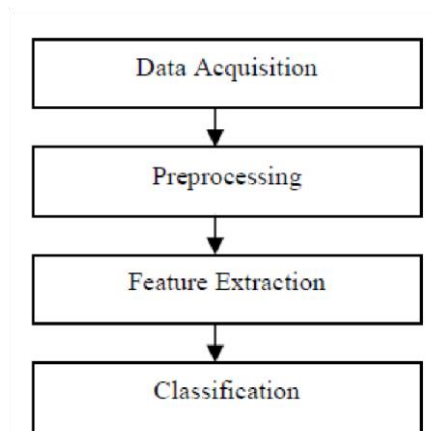


Figure4.1: Flow chart for signal processing

For computing physiological results, the parameters like beta/theta ratio of power and power of alpha band of various channels. FC5 and FC6 selected and computed for its beta/theta ratio for selective attention and F3, F4, O1 and O2 and computed its upper alpha band power for working memory. Details of components of signal processing are explained in section 4.3.

(f) Statistical analysis of data

This is done for pre and post data using SPSS software. One tail paired type t-test is computed.

(g) Tests conducted for post-intervention cognitive assessment

As a part of post-intervention tests, same tests of cogstate and d2 test are performed and lastly comparison between both is done.

4.2 Data Acquisition

EEG data is recorded using EMOTIV EPOC having 10 channels [42]. The electrodes are placed according to international 10-20 system. EEG data is acquired while the person plays MOT during pre and post-intervention procedures. The subject is also made to perform cogstate and D2 tests as a part of pre and post-intervention experimentation. The sampling rate at which data is acquired is 128 Hz.

4.2.1 EMOTIV

EMOTIV offers a multi-channel EEG system for acquiring of EEG data. The EMOTIV EEG, a high multi-channel, resolution, wireless portable EEG system to assess raw EEG data. The research has been conducted with EEG by licensing a test bench. The EMOTIV EEG neuroheadset connects wirelessly to PCs running Windows, Linux, or MAC OS X.



Figure 4.2: Subject wearing EMOTIV

14 EEG channel names based on the International 10-20 locations are: AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4. Based on the latest developments in neurotechnology, EMOTIV EPOC is a high resolution, multi-channel, wireless neuroheadset. The EPOC uses a set of 14 sensors plus 2 references to tune into electric signals produced by the brain to detect the user's thoughts, feelings and expressions in real time. The EPOC connects wirelessly to PCs running Windows, Linux, or MAC OS X [43].

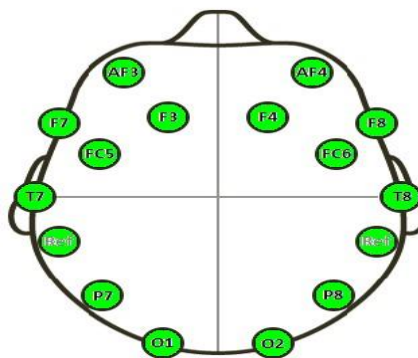


Figure 4.3: EMOTIV sensor map

The colours of sensors indicate the following features:

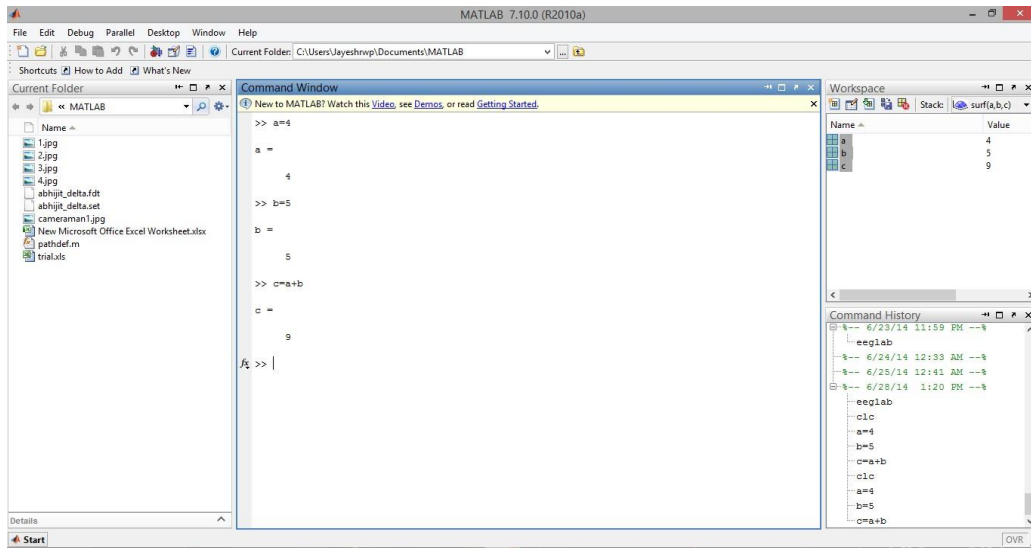


Figure 4.5: The MATLAB environment consisting of the MATLAB desktop

MATLAB's built-in functions offer excellent tools for data analysis, signal processing, linear algebra computations, numerical solution, optimization of normal differential equations (ODE's), quadrature, and numerous other sorts of scientific computations. There are numerous functions for 2-D and 3-D graphics, as well as for animation. The user however is not limited to the built-in functions; he can inscribe his own functions in the MATLAB language.

There are several optional toolboxes accessible from the developers of MATLAB. These toolboxes are collection of functions written for special applications such as symbolic computation, image processing, signal processing, control systems, neural networks, etc. [44]

4.3.1.2 EEGLAB

EEGLAB is an interactive MATLAB toolbox for processing EEG, EMG and other electrophysiological data employing independent component analysis (ICA), artifact rejection, time/frequency analysis, event-related statistics, and several useful modes. First developed on Matlab 5.3 under Linux, EEGLAB runs on Matlab v5 and higher under Linux, UNIX, Windows, and Mac OS X (Matlab 7+ recommended).

EEGLAB provides interactive Graphic User Interface (GUI) permitting users to adaptable and interactively process their high-density EEG and other dynamic brain data using ICA and/or Time/Frequency Analysis (TFA). EEGLAB also combines extensive tutorial and help windows, plus a command history function that eases user's transition from GUI-based data examination to construction and running batch or custom data analysis scripts. EEGLAB offers a large number of methods for picturing and modelling event-related brain dynamics, both at the level of individual EEGLAB datasets and/or across a collection of datasets brought together in an EEGLAB 'study set' [45].

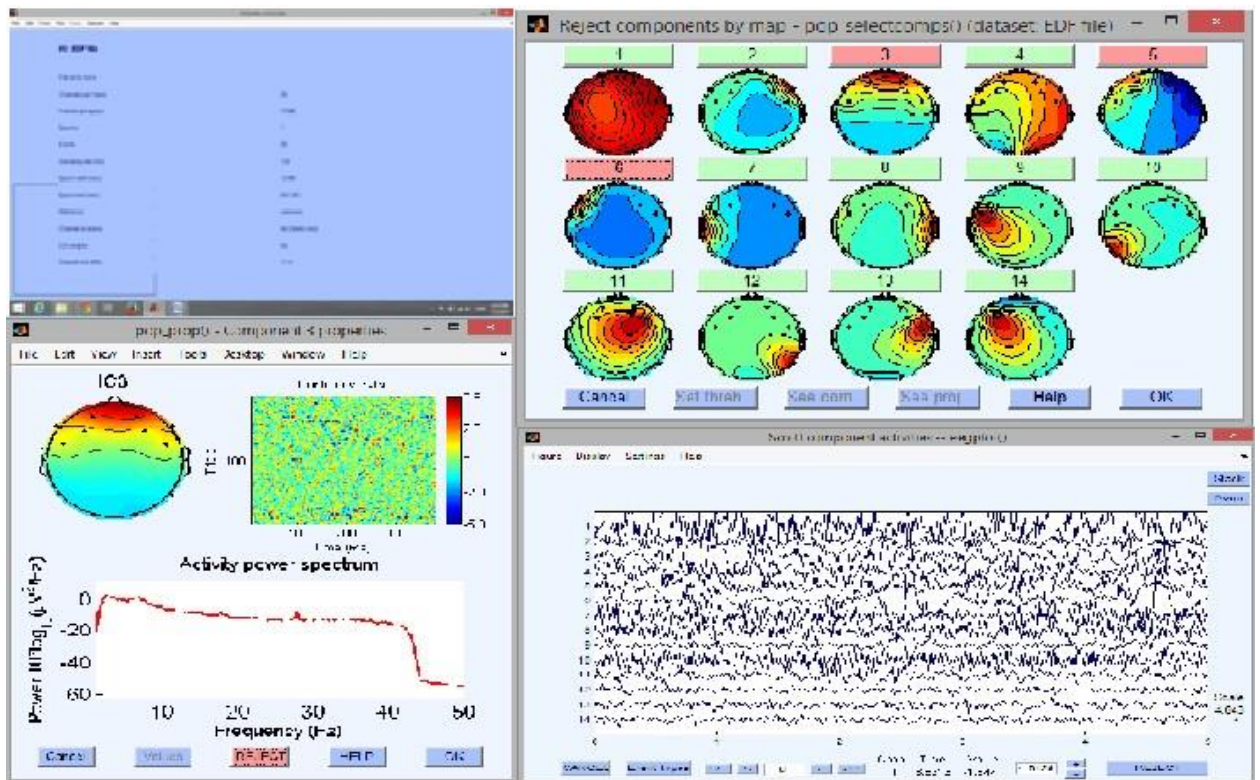


Figure 4.6: EEGLAB windows

Artifacts and Noise Removal

EEG signal is small compared to the amplitude of common artifacts (eye, muscle, mains power frequency radiation). Clean signals are dependent on low scalp/electrode

impedance, differential amplifiers, and filtering. Several kind of noises exist in the signal. These noises may arise due 50 Hz power line interference, movement or breathing by the subject. To remove noises, a filter is used first. The research makes use of window sinc FIR filter available in EEGLAB. Next, ICA is applied for artifact removal [46].

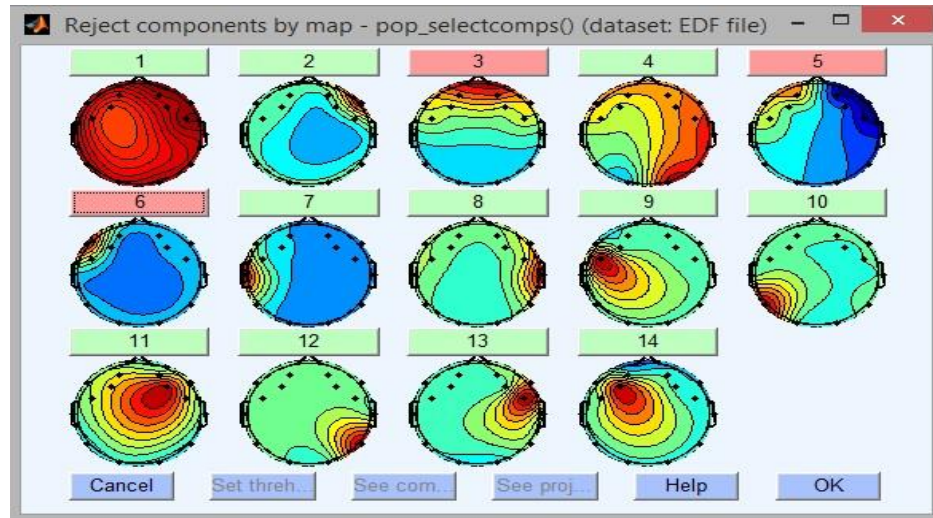


Figure 4.7: Topography before removal of artifact: 3, 5 and 6 is artifact

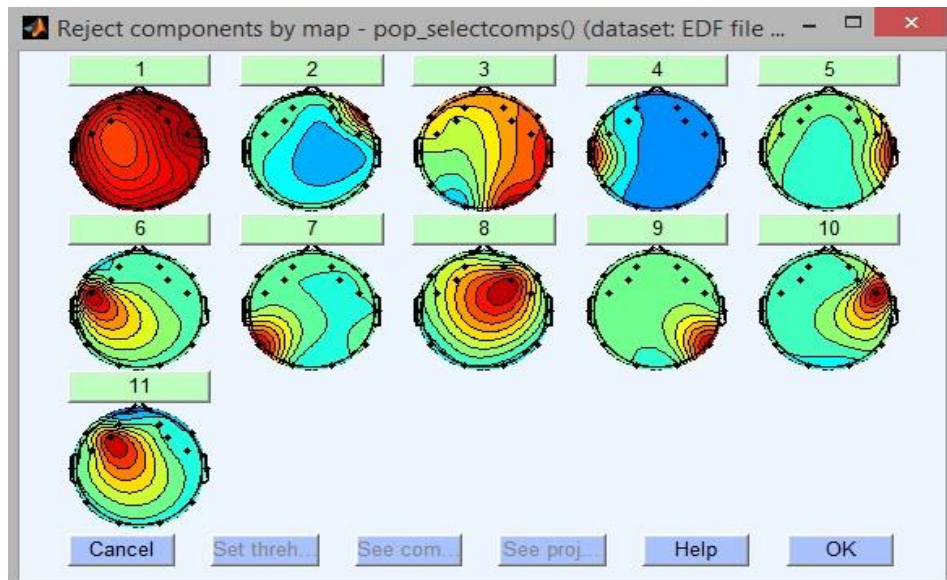


Figure 4.8: Topography after removal of artifact by running ICA

4.3.1.3 SPSS Software

SPSS is a software package used for statistical analysis, also known as "IBM SPSS Statistics". Companion products in the same family are used for survey authoring and deployment (IBM SPSS Data Collection), collaboration and deployment (batch and automated scoring services) and data mining (IBM SPSS Modeler), text analytics. SPSS (originally, Statistical Package for the Social Sciences, later modified to read Statistical Product and Service Solutions) was released in its first version in 1968 after being developed by Norman H. Nie, Dale H. Bent and C. Hadlai Hull. SPSS is among the most widely used programs for statistical analysis in social science. It is used by market researchers, health researchers, survey companies, government, education researchers, marketing organizations and others. The original SPSS manual has been described as one of "sociology's most influential books". In addition to statistical analysis, data management (case selection, file reshaping, creating derived data) and data documentation (a metadata dictionary is stored in the data file) are features of the base software. SPSS was released in its second version in 1972 and its company name is INDUS Nomi.

Statistics included in the base software:

- a. Descriptive statistics: Cross tabulation, Frequencies, Descriptive, Explore, Descriptive Ratio Statistics
- b. Bivariate statistics: Means, t-test, ANOVA, Correlation (Bivariate, partial, distances), Nonparametric tests
- c. Prediction for numerical outcomes: Linear regression
- d. Prediction for identifying groups: Factor analysis, cluster analysis (two-step, Kmeans, hierarchical), Discriminant [47].

4.3.2 Steps for Signal Processing

4.3.2.1 Pre-processing: Filtering of data (Band Pass Filter)

EEGLAB software is used for carrying out signal processing. For filtering the signal, bandpass filter is used which is selected from window since FIR filter and required range of the filter is set, *i.e.*, 2 to 43 Hz. The order of the filter is taken to be 212. A low pass filter helps to pass only low frequency signals and similarly a high pass filter passes high frequency signals, so instead of employing both, a band pass filter is used which passes the required band of signals. A band pass filter filters a Band Pass filters without distorting the input signal or introducing extra noise that are 3dB below the maximum centre or resonant peak while attenuating or weakening the others outside that range. It is the combination of low pass and high pass filter where low pass filter is followed by the high pass filter.

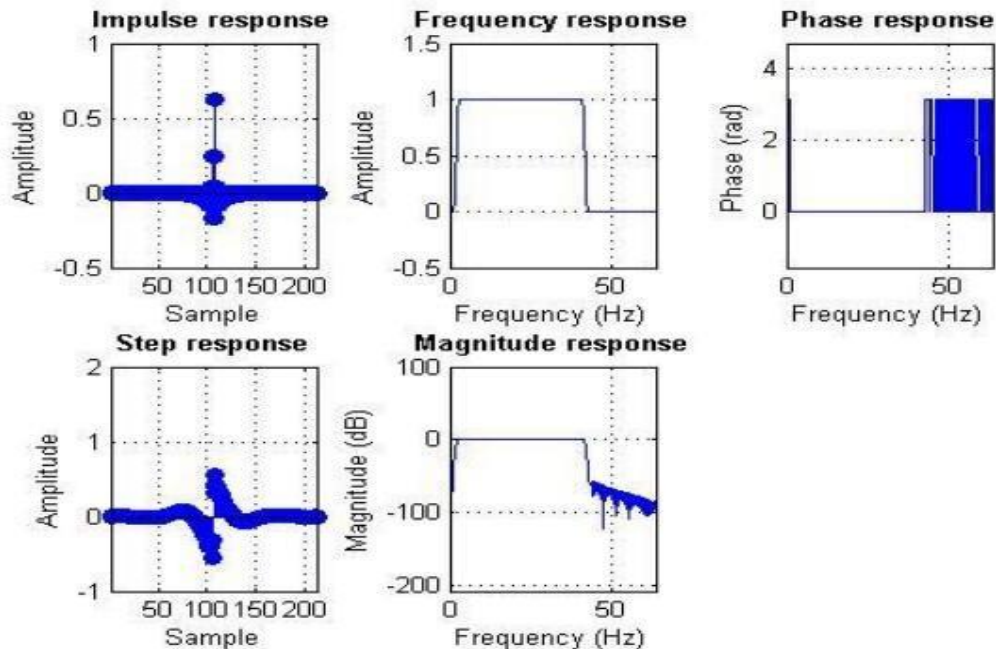


Figure 4.9: Filter response Plot

4.3.2.2 Independent Component Analysis

ICA is an essential part of signal processing used for separating multivariate signal into its subcomponents which are additive in nature. It is a method for finding underlying factors or components from multivariate (multi-dimensional) statistical data. ICA is different from

other methods as it finds the components that are both statistically independent and non-Gaussian. ICA is a computational method for separating a multivariable signal into additive subcomponents supposing the mutual statistical independence of the non-Gaussian source signal.

Origin of ICA

Imagine that you are in a room where two people are speaking simultaneously. You have two microphones which are held at different locations. The microphones give you two recorded time signals, which can be denoted by $x_1(t)$ and $x_2(t)$, with x_1 and x_2 the amplitude, and t the time index. Each of these recorded signal is a weighted sum of speech signals emitted by the two speakers, which is denoted by $s_1(t)$ and $s_2(t)$. It could be expressed as:

$$x_1(t) = a_{11}s_1 + a_{12}s_2$$

$$x_2(t) = a_{21}s_1 + a_{22}s_2$$

where a_{11} , a_{12} , a_{21} and a_{22} are some parameters that depend on the distances of the microphones from speakers. Two speech signal $s_1(t)$ and $s_2(t)$ can now be estimated, using only the recorded signals $x_1(t)$ and $x_2(t)$. This is called the cocktail-party problem.

Definition of ICA

To define ICA, „latent variables“ model is used. Assume n linear mixtures x_1, \dots, x_n of n independent components

$$x_j = a_{j1}s_1 + a_{j2}s_2 + \dots + a_{jn}s_n, \text{ for all } j$$

In the ICA model, assume that each mixture x_j and each independent component s_k is a random variable and not a proper time signal. The observed values $x_j(t)$, e.g., the microphone signals in the cocktail party problem, are then a sample of this random variable. Also it is assumed that both the mixture variables and the independent components have zero mean: If this is not true, then the observable variables x_i can always be centred by

subtracting the sample mean, which makes the model zero-mean. Vector-matrix notation can also be used instead of the sums like in the previous equation. Let x denote the random vector whose elements are the mixtures x_1, \dots, x_n , and likewise s denotes the random vector with elements s_1, \dots, s_n . Let us denote by A the matrix with elements a_{ij} . Generally, bold lower case letters indicate vectors and bold upper-case letters denote matrices. All vectors are understood as column vectors; thus x^T , or the transpose of x , is a row vector. Using this vector-matrix notation, the above mixing model is written as $x = As$

This equation is called independent component analysis, or ICA model. Sometimes the columns of matrix A is needed, denoting them by a_j the model can also be written as

$$x = \sum_{i=1}^n a_i s_i$$

The ICA model is a generative model, which means that it describes how the observed data are generated by a process of mixing the components s_i . The independent components are latent variables, meaning that they cannot be directly observed. Also the mixing matrix is assumed to be unknown. All what is observed is the random vector x , and both A and s must be estimated using it. This must be done under as general assumptions as possible.

ICA is very closely related to the method called blind source separation (BSS) or blind signal separation. A “source” means here an original signal, i.e. independent component, like the speaker in a cocktail party problem. “Blind” means that very little is known, if anything, on the mixing matrix, and makes little assumptions on the source signals. ICA is one method, perhaps the most widely used, for performing blind source separation.

ICA removal using EEG

Severe contamination of EEG activity by blinks, eye movements, heart, muscles and line noise is a serious problem for EEG interpretation and analysis. One of the methods to remove such contaminations or artifacts is ICA. It is assumed that the signals are acquired are mixtures of activities of EEG rhythms and the artifacts.

ICA decomposition

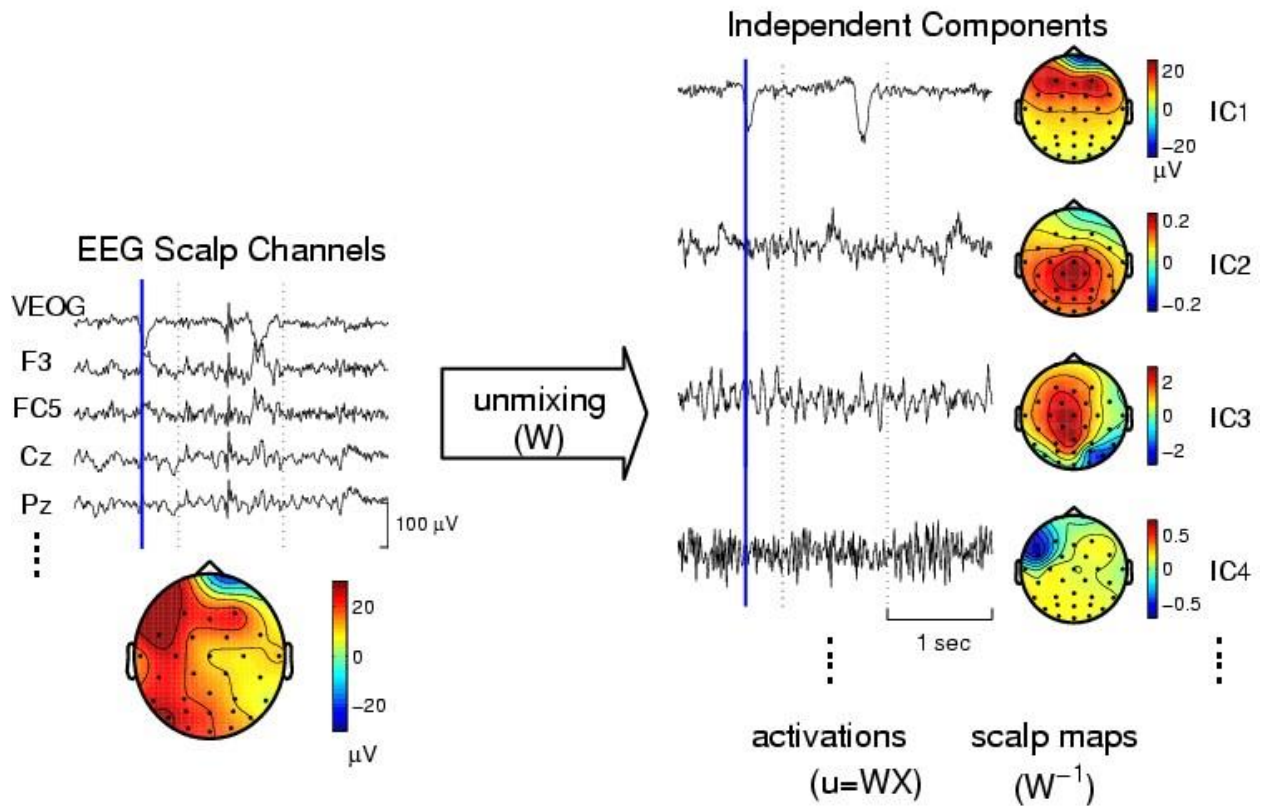


Figure 4.10: Schematic illustration of the procedure of ICA

In EEG analysis, the rows of the input matrix, X , are EEG signals recorded at different electrodes and the columns are measurements recorded at different time points. ICA finds an „unmixing“ matrix, W , which decomposes or linearly unmixes the multi-channel scalp data into a sum of spatially and independent components. The rows of the output data matrix, $U = WX$, are time courses of activation of the ICA components. The columns of the inverse matrix, $\text{inv}(W)$, give the relative projection strengths of the respective components at each of the scalp sensors.

The activations the matrix of unmixed component are given by

$$W = \text{weights} * \text{sphere}; \text{Activations} \\ = W * \text{data};$$

and the inverse weight matrix or the mixing matrix is

$$W_{inv} = \text{inv}(W);$$

$$\text{Projection} = W_{inv}(:,i) * \text{activations}(i,:);$$

The projection of the i th component is the outer product of i th row of the component activation, $\text{activations}(i,:)$, with the i th column of the inverse matrix, $W_{inv}(:,i)$.

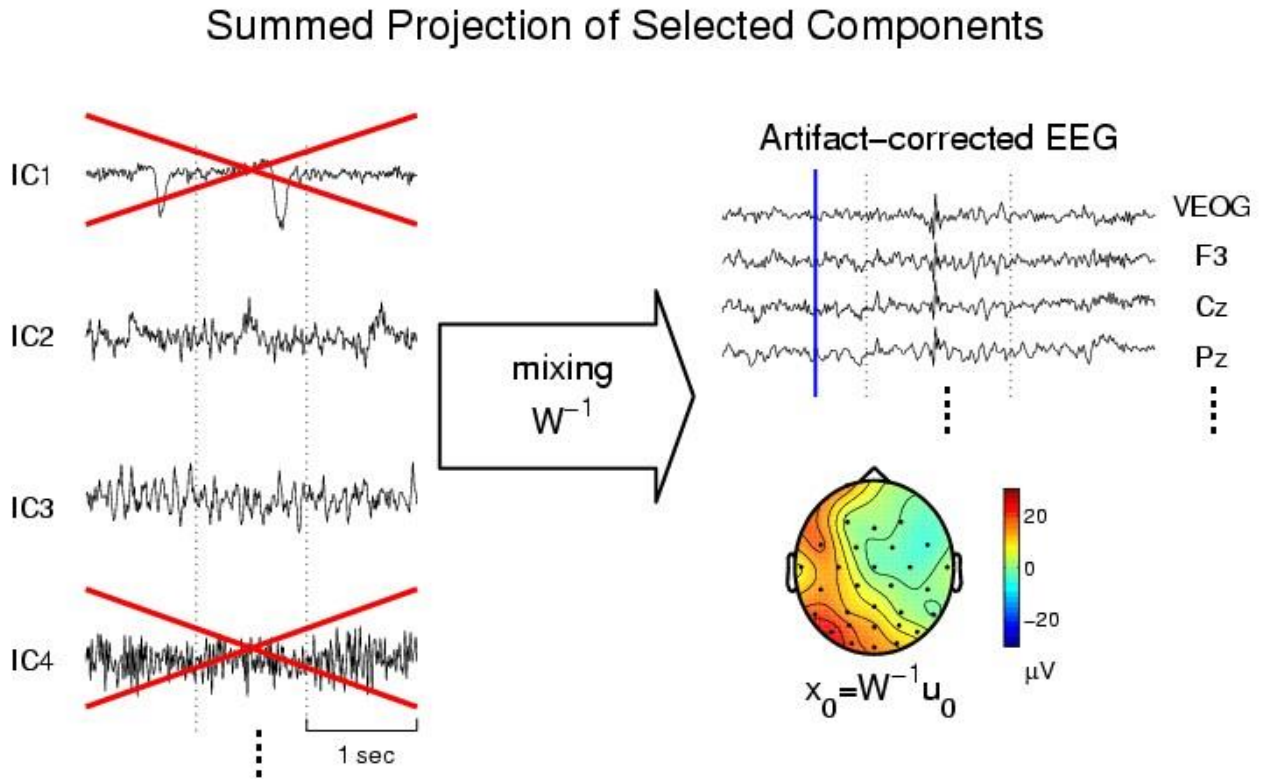


Figure 4.11: Summed projection of selected components in ICA

Artifact-free event-related brain signals were obtained by projecting the sum of selected non-artifactual ICA components back onto the scalp, $\text{clean_data} = W_{inv}(:,a) * \text{activations}(a,:)$;

Removing blink and muscle artifacts

The figure below depicts a 3 seconds portion of the acquired EEG and its ICA component activations, the scalp topographies of four selected components, and the artifact-corrected

EEG signals which is attained by removal of four selected EOG and muscle noise components from the data. The eye movement artifact at 1.8 sec in the EEG data is isolated to ICA components 1 and 2 (left middle). The scalp maps (right middle) indicate that these two components account for the spread of EOG activity to frontal sites.

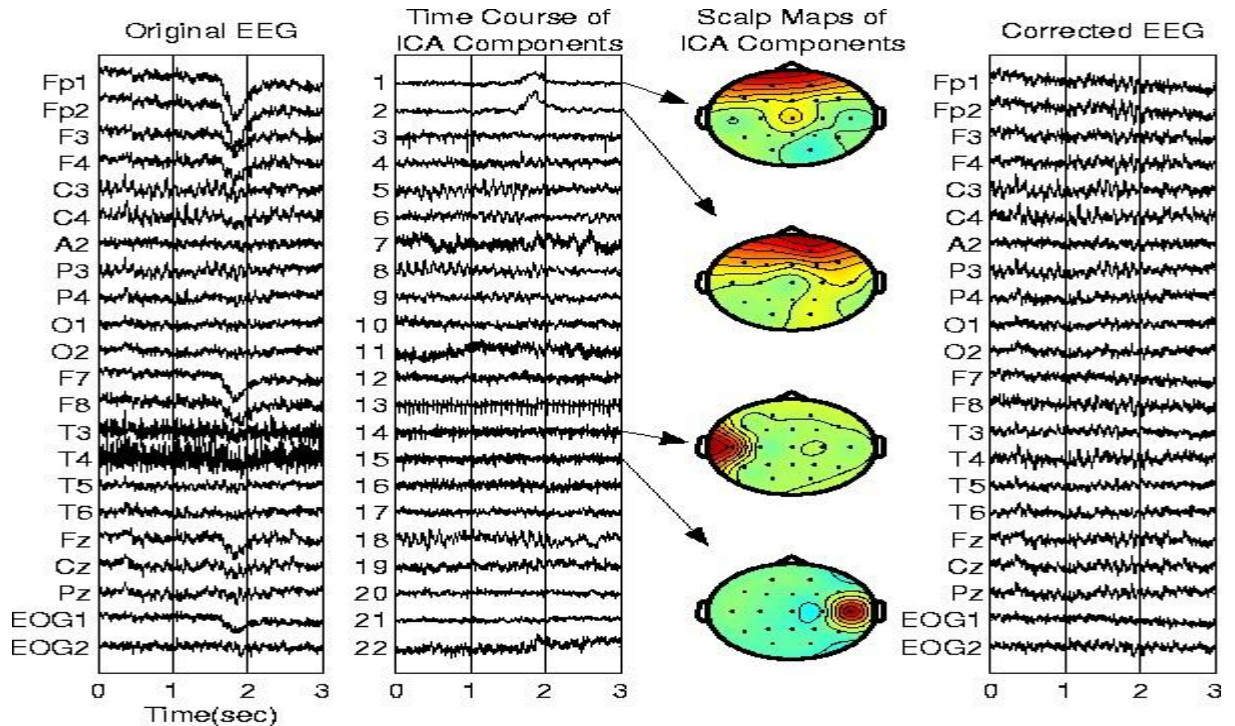


Figure 4.12: Blink and muscle artifact removal by ICA

Eliminating the four artifact components whose scalp maps are shown above, and projecting the remaining components back onto the scalp channels produced artifactcorrected EEG data (right) free of these artifacts [48-49].

4.3.2.3 Wavelet Transform

A wavelet is a waveform of a very limited duration that has an average value of zero. It starts from zero, increases, and then decreases gets back to zero. Wavelets have advantages over traditional Fourier methods which are used for analysing physical situations where the signal contains discontinuities and sharp spikes. Wavelets were developed independently

in the fields of quantum physics, electrical engineering, mathematics and seismic geology. Wavelets can be joined, using a "shift, multiply and sum" technique called convolution, with portions of an unknown signal to extract information from the unknown signal. It can be stated that a wavelet is a mathematical function used to divide a given function or continuous-time signal into different scale components. A wavelet transform is the demonstration of a function by wavelets. The wavelets are scaled and translated copies (known as "daughter wavelets") of a finite length or fast-decaying oscillating waveform (known as the "mother wavelet") [50].

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

$$W_f(\tau, s) = \int_{-\infty}^{\infty} f(t) \varphi_{\tau, s}^*(t) dt$$

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

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

Wavelet transforms can be classified as

- Discrete wavelet transforms (DWTs)
- Continuous wavelet transforms (CWTs)
- Fast wavelet transform (FWT)
- Wavelet packet decomposition (WPD)

Almost all practically useful discrete wavelet transforms use discrete-time filter banks. These filter banks are called the wavelet and scaling coefficients in wavelets nomenclature. These filter banks may contain either finite impulse response (FIR) or infinite impulse response (IIR) filters [51-52].

Discrete Wavelet Transform

Usually time and frequency domains have been considered for analyses of EEG signals. The discrete wavelet transform (DWT) is an active tool for Time-Frequency analysis of signals.

Discrete wavelet transform (DWT) is a spectral analysis technique used for analysing non-stationary signals, and provides time-frequency signals. Wavelet transform is a spectral estimation technique in which any general function can be expressed as an infinite series of wavelets. The decomposition of the signal results in a set of coefficients are called wavelet coefficients. Decomposition of the signal analysis depends on the high-pass and low-pass filter. Wavelet transform uses a different window size, which allows the wavelet to be stretched or compressed depending on the frequency of the signal. DWT analyses frequency bands with dissimilar resolution by means of multi-level decomposition into a coarse frequency band. This results in excellent feature extraction from sub-bands of the non-stationary EEG signals. In simple words, a discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled.

Daubechies families

Ingrid Daubechies invented what are called compactly-supported orthonormal wavelets which made discrete wavelet analysis achievable. The names of the Daubechies family wavelets are written in the form dbN, where N is the order, and db the surname of the wavelet. The figure below shows some members of Daubechies family.

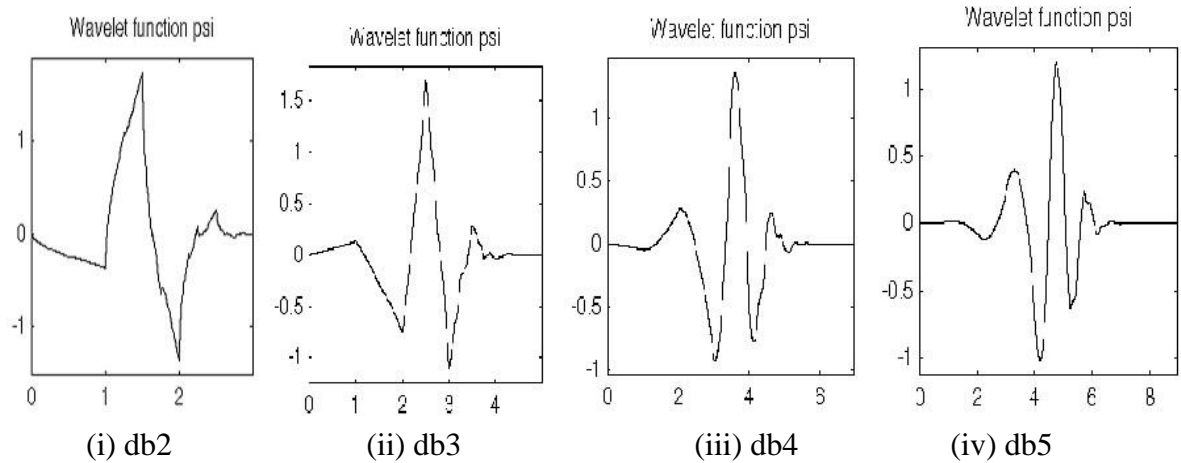


Figure 4.13: Daubechies Family

The research makes use of Daubechies wavelet „db4“ which is used to decompose the signal by wavelet decomposition at 5 levels and „sqrtwolog“ is used to calculate the threshold [53]. From the wavelet coefficient, different frequency bands of EEG are reconstructed as follows: Theta (4-8 Hz) = [4.56 7.125]

Alpha (8-13Hz) = [7.125 12.25]

Beta (13-25 Hz) = [12.25 22.5]

4.3.3 Feature Extraction

The pre and post data required was analysed and then compared to observe the changes due to training. The raw data acquired was initially filtered. The frequency range was selected between 0.4 to 35 Hz as this covers almost whole range of an EEG signal. This is followed by ICA of the signal. ICA was used for finding underlying factors or components from multivariate (multi-dimensional) statistical data. The eye artifacts and muscle artifacts were removed from the resulting signal. This procedure was carried out using EEGLAB toolbox. The final data thus obtained was analysed using frequency analysis. This frequency analysis was done using Wavelet transform. Different ranges of EEG signal- alpha (α), beta (β), theta (θ) are computed by programming in MATLAB.

Energy, entropy and power of all the components are calculated individually. Classification of trained and control group was done using Support Vector Machine (SVM) and Linear Discrimination Analysis (LDA) classifiers.

The parameters derived for the EEG acquired are: Energy, Power (POWER) and Entropy. All these parameters were extracted by using MATLAB R2010a (EEGLAB Toolbox).

1. **Energy:** The energy of the signal is defined as the sum of squared modulus of the sample values of any signal.

$$E = \sum_{n=0}^{N-1} |X|^2$$

where X is the samples values in each sub-bands and N is the total number of samples.

2. **Power:** The power is the amount of power per unit frequency as a function of frequency. Power is computed by squared modulus of the Fourier transform of the time series of the signal.

$$\max(\omega) = \frac{1}{n} |X(\omega)|^2$$

The beta/theta ratio and alpha band values are estimated from the power of each EEG subbands can be considered as feature for classification.

3. **Entropy:** Entropy is a numerical measure of the randomness of a signal.

$$(e) = - \sum_1^n X^2 \log(X^2)$$

Entropy can act as a feature and used to analyze psychological time series data such as EEG data.

4.3.4 Classification

After extracting the important features from the signal. The next step is classification. Classification basically is used to reduce the dimensionality of the available large data.

Several classes are defined and the input data is allocated or classified into its corresponding class according to the value of its feature vector.

Classification tools can be of two types: supervised learning tools and unsupervised learning tools. In case of supervised learning tools, first of all, the tool has to be made familiarized with the type of input data means some of the data from the input data is fed to that tool for training of the tool according to the feature vectors of the input data. After training process is completed, the test data means the full input data (which needs to be classified) is fed to the tool and it gets classified.

But in case of unsupervised learning tools, there is no need for prior training of the tool or no need to make the tool familiarize with the input data. The input data (which needs to be classified) can be directly fed to the tool and it gets classified into different classes according to the feature vectors.

There are several available classification tools and two of them are used in this research which is Support Vector Machine (SVM) classifier and Linear Discriminant Analysis (LDA) classifier [54-55]. These are described as follows:

4.3.4.1 Support Vector Machine

In machine learning, support vector machines (SVMs) are supervised learning models with associated learning algorithms that analyse data and recognize patterns for classification and regression analysis. The basic SVM takes a set of input data and predicts, for each given input, which of two possible classes forms the output, making it a non-probabilistic binary linear classifier. Given a set of training examples, each marked as belonging to one of two categories, a SVM training algorithm builds a model that assigns new examples into one category or the other. A SVM model is a representation of the examples as points in space, mapped so that the examples of the separate categories are divided by a clear gap that is as wide as possible. New examples are then mapped into that same space and predicted to belong to a category based on which side of the gap they fall on [56].

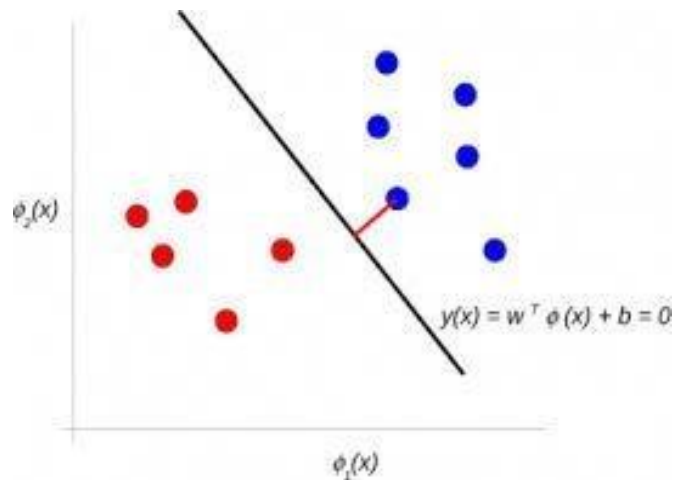


Figure 4.14: SVM Classifier

4.3.4.2 Linear Discriminant Analysis

Linear Discriminant analysis (LDA) and Fisher's linear Discriminant are methods used in pattern recognition, statistics, and machine learning to discover a linear combination of features which characterizes or separates two or more classes of objects or events. The consequential amalgamation may be used as a linear classifier, or for dimensionality reduction before later classification. LDA is related to principal component analysis (PCA) [57].

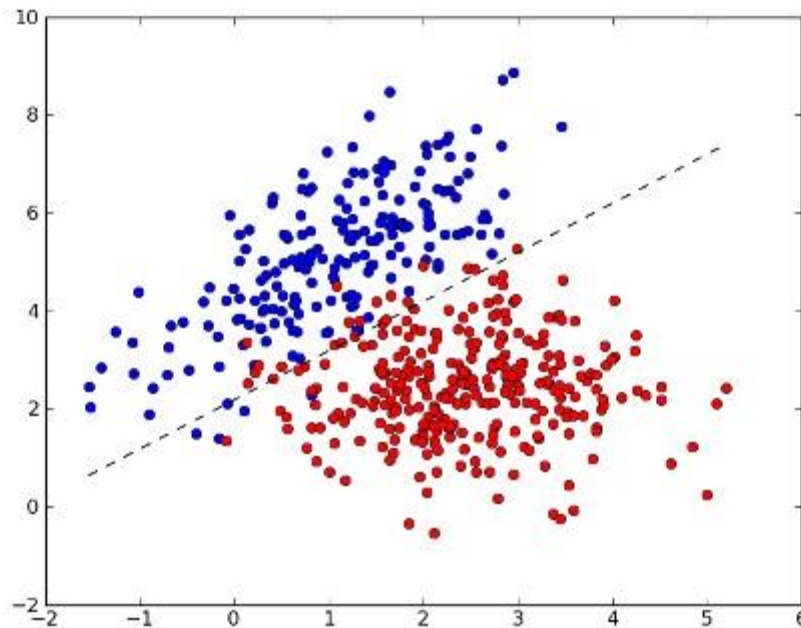


Figure 4.15: LDA classifier

Linear Discriminant Analysis easily handles the case where the within-class frequencies are unequal and their outcomes have been judged on randomly generated test data. This approach maximizes the ratio of between-class variance to the within-class variance in any particular data set and hence guaranteeing maximal separability. The use of Linear Discriminant Analysis for data classification is applied to classification problem in speech recognition.

RESULTS AND DISCUSSION

The results were computed both physiologically and psychologically. During the performance of tests (cogstate and D2), physiological parameters (EEG) were recorded.

4.1 Physiological Results

Parameters like beta/theta ratio of power and power of alpha band of various channels were investigated. FC5 and FC6 were selected and computed for its beta/theta ratio for selective attention. F3, F4, O1 and O2 were computed for its upper alpha band power for the working memory.

Table 5.1: Beta/theta power ratio for selective attention (channels FC5 and FC6)

Sr. No.	For Training Group (Beta/Theta Ratio)			
	For channel 4(FC5)		For Channel 11(FC6)	
	Pre	Post	Pre	Post
1	0.01638	0.05164	0.0174	0.09335
2	0.026596	0.14688	2.16766	0.12547
3	0.11917	0.128445	0.523429	0.146381
4	0.079985	0.13156	0.15915	0.179385
5	0.08498	0.1031	0.9954	0.13801
6	0.02412	0.06114	0.01067	0.06193
7	0.0276	0.080546	0.672382	0.05982
8	0.08735	0.3892	0.142651	0.11681
9	0.05928	0.09442	0.088036	0.2641
10	0.1184	0.1945	0.09019	0.1213
11	0.022689	0.2797	0.018611	0.013276
12	0.078985	0.09742	0.083036	0.09635
	For Control Group (Beta/Theta Ratio)			
13	0.20136	0.09946	0.4465	0.14799
14	1.853153	0.24699	3.57426	0.3134
15	0.030194	0.029529	2.2596	0.138967

16	0.06333	0.047957	0.04908	0.12744
17	0.05613	0.002677	0.04853	0.003472
18	0.8094	0.1088	0.9136	0.12285
19	0.037255	0.024301	0.1294	0.029336

The graphs showing the results of selective attention are as follows:

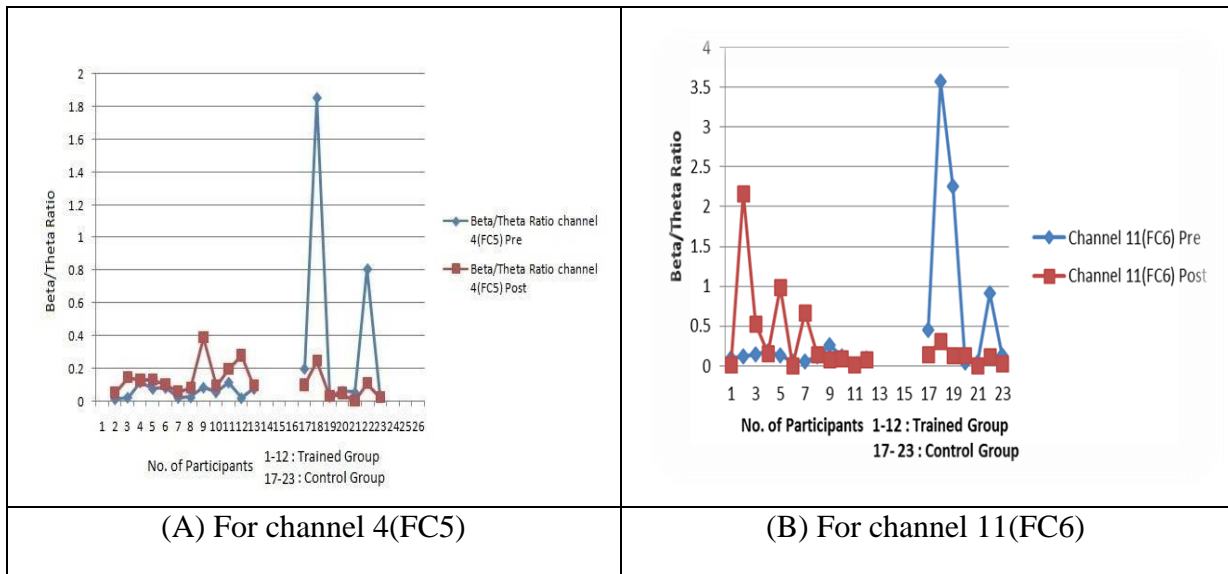


Figure 5.1: Beta/Theta Power Ratio for Training and Control group

Figure 5.1 represents the parameter beta/theta ratio of power for each participant of trained and control group. This graph shows this parameter for channels FC5 and FC6. It is observed that beta/theta ratio increases after appropriate intervention or by training provided to the sports persons using MOT. When computed statistically using t-test, the value came out to be $p=0.021433$ and $p=0.01218$ for FC5 and FC6 respectively which are significant.

The outcomes and graphical results of working memory are:

Table 5.2: Alpha band power for working memory (channels F3, F4, O1 and O2)

Sr. No.	For Training Group (Alpha)							
	For channel 3(F3)		For channel 12(F4)		For channel 7(O1)		For channel 8(O2)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	24.62956	26.51665	19.61565	67.10631	13.80037	24.8668	12.70531	18.24675
2	2.603904	19.19547	4.16522	21.81498	91.07207	691.1861	7.292314	43.91057
3	0.949499	16.26913	3.198127	4.976673	1.632219	4.976673	3.095339	4.976673
4	2.685716	35.62214	11.40556	38.41717	0.626592	20.74615	3.301953	15.4407
5	7.659799	167.3878	11.31071	307.6373	2.932579	52.12149	2.388415	36.81871
6	31.99031	103.1914	157.8171	3.995227	132.4984	0.301216	129.8693	0.542884
7	1.2537	190.1756	1.8217	70.81407	2.1543	39.13673	3.5676	36.61457
8	8.843246	11.46775	9.050108	22.97839	2.005277	7.605951	7.400578	15.68977
9	56.14826	1780.963	13.7592	57.16825	3.401262	81.44227	5.708567	187.0496
10	7.190708	67.11099	21.59776	90.36268	0.160418	86.57436	0.704679	67.44439
11	0.994286	1143.386	1.31087	1101.815	0.630114	1304.178	0.343171	1022.424
12	1.632219	4.976673	0.949499	16.26913	8.843246	11.46775	0.626592	20.74615
	For Control Group (Alpha)							
13	49.78739	9.085526	38.88812	13.67232	8.327196	6.179809	9.994537	3.315519
14	34.75324	15.90297	262.3825	32.23931	49.74861	10.54063	49.05078	39.84059
15	1.300266	0.835406	9.140444	3.752043	1.582508	0.550231	0.688587	0.231655
16	7.670584	4.00021	7.75357	5.394209	8.723481	1.880257	8.043792	2.282678
17	488.5475	2.963922	89.87202	5.476739	79.2765	1.085309	70.41092	0.500721
18	68.72994	1353.625	102.3011	1319.65	74.4867	1278.905	80.64478	1135.199
19	206.2262	12.82259	331.3036	21.47491	409.9053	3.96175	336.1986	3.418149

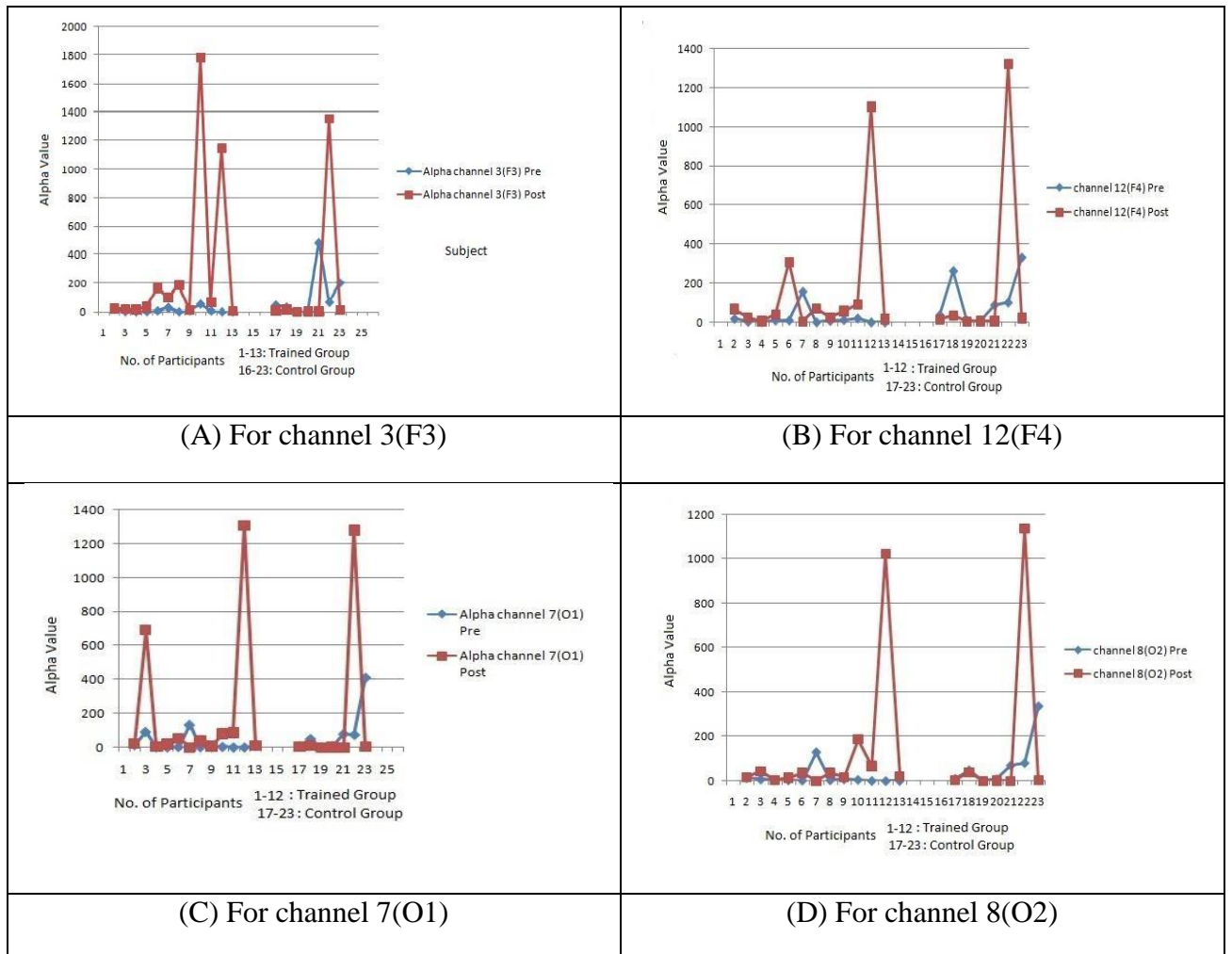


Figure 5.2: Alpha Power for Training and Control group

It is inferred from Figure 5.2 that alpha band power increases during post intervention procedure for both frontal channels (F3 and F4) and occipital channels (O1 and O2) in case of trained group. The opposite is observed for control group. The results have been proven statistically using t-test. For channel F3, the value came out to be 0.057928. For F4, it is 0.173687. Channel O1 gave 0.08068 and for channel O2, it is 0.108338 which is significant.

4.2 Psychological Results

The psychological records of cogstate battery are described below by using the resultant graphs

Table 5.3: Cogstate values for Identification Task, Groton Maze Chase Task, Groton Maze Learning Test Recall and Groton Maze Learning Test

Sr. No.	For Training Group (Cogstate Variable)							
	Identification Task		Groton Maze Chase Task		Groton Maze Learning test Recall		Groton Maze Learning test	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	2.701741	2.671636	1.599307	1.66054	2	4	32	51
2	2.655492	2.512341	1.133296	1.433083	1	3	39	35
3	2.735825	2.620559	1.56604	1.6	4	6	40	44
4	2.767417	2.671636	0.799867	0.933291	3	4	36	45
5	2.69341	2.63641	1.366484	1.432951	3	4	38	42
6	2.661388	2.548875	0.999833	1.49925	1	4	39	42
7	2.722423	2.656344	1.132842	1.19972	10	13	40	50
8	2.671636	2.530327	1.19988	1.329322	3	6	39	51
9	2.800455	2.635891	1.366348	1.44321	12	14	42	63
10	2.75336	2.72681	0.93296	0.933291	0	3	16	21
11	2.823954	2.793811	1.466471	1.522355	4	6	42	50
12	2.929161	2.91029	0.932867	1.05666	1	6	29	31
	For Control Group (Cogstate Variable)							
13	2.734985	2.865171	1.43319	1.699673	3	8	46	31
14	2.74584	2.742101	1.966054	1.866356	2	4	51	45
15	2.67814	2.768782	0.89994	0.973304	7	3	51	23
16	2.532796	2.684726	0.899933	0.799787	1	3	25	30

17	2.584398	2.651836	1.366348	1.46608	5	8	37	54
18	2.651836	2.584398	1.366348	1.46608	0	8	40	33
19	2.527539	2.768867	1.699673	1.233046	6	4	29	45

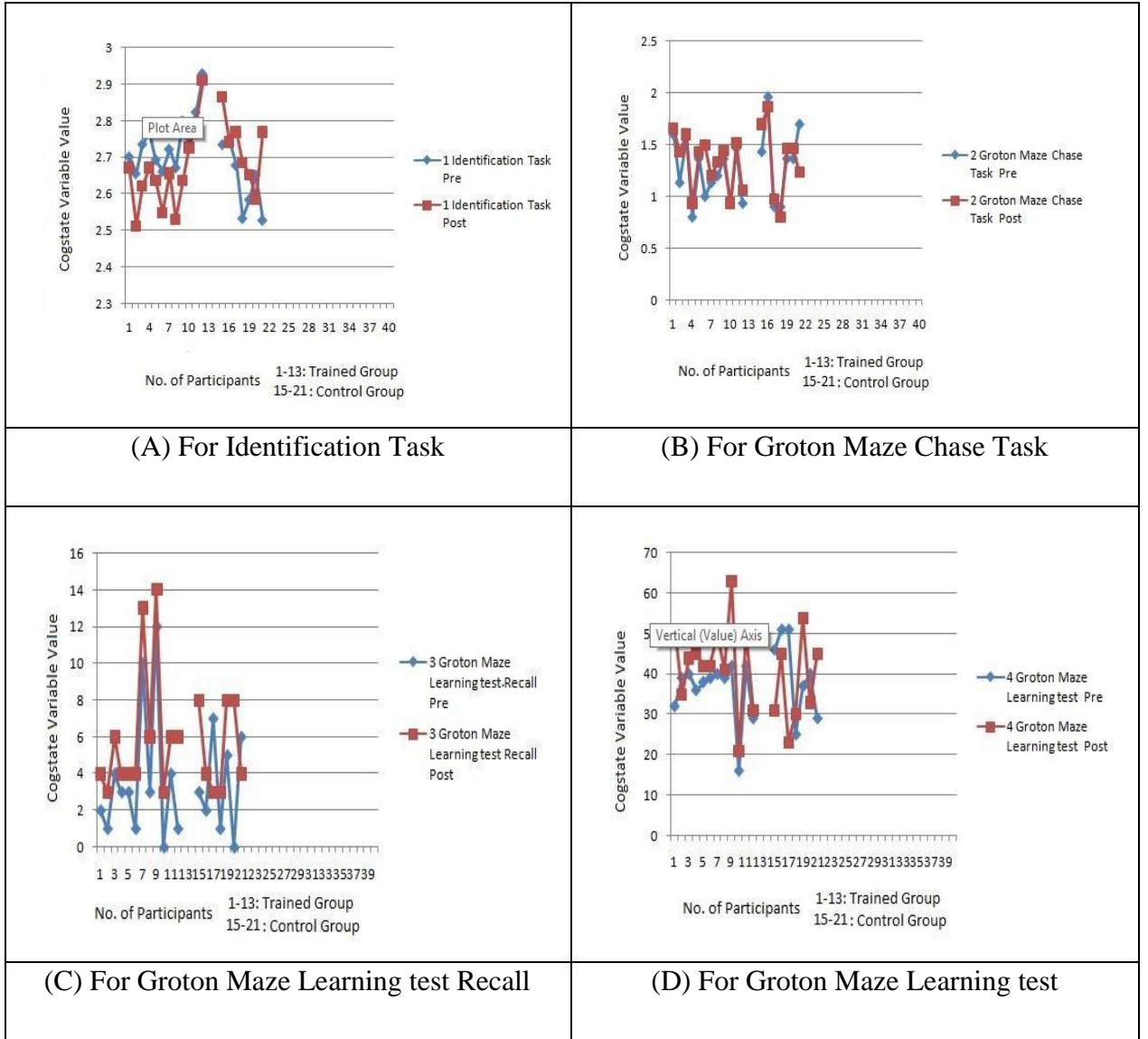


Figure 5.3: Cogstate Variable for Training and Control group Table 5.4: Cogstate values for International Shopping List Task, International Shopping List Recall, Two Back Memory

Sr. No.	For Training Group (Cogstate Variable)
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	International Shopping List Task		International Shopping List Task recall		Two Back Memory	
	Pre	Post	Pre	Post	Pre	Post
1	28	32	9	14	1.235766	1.33315
2	20	24	6	8	1.395527	1.425818
3	25	31	10	11	1.570796	1.61057
4	24	32	8	12	0.874098	1.033315
5	21	32	8	11	1.107149	1.103315
6	26	29	11	12	1.089521	1.19461
7	30	36	12	15	1.199592	1.273674
8	30	37	10	11	1.133315	1.144834
9	25	30	11	30	1.220691	1.303655
10	30	35	12	14	1.57096	1.670096
11	31	34	10	12	0.986422	1.1319
12	29	32	10	11	1.264519	1.36719
	For Control Group (Cogstate Variable)					
13	26	23	9	11	1.133315	1.06057
14	27	32	14	11	1.395827	1.003346
15	31	29	9	6	1.133315	1.022133
16	25	31	11	12	1.395827	1.433315
17	27	24	12	11	1.230959	1.46899
18	20	24	11	9	1.230959	1.46899
19	24	20	9	6	1.277953	1.2736

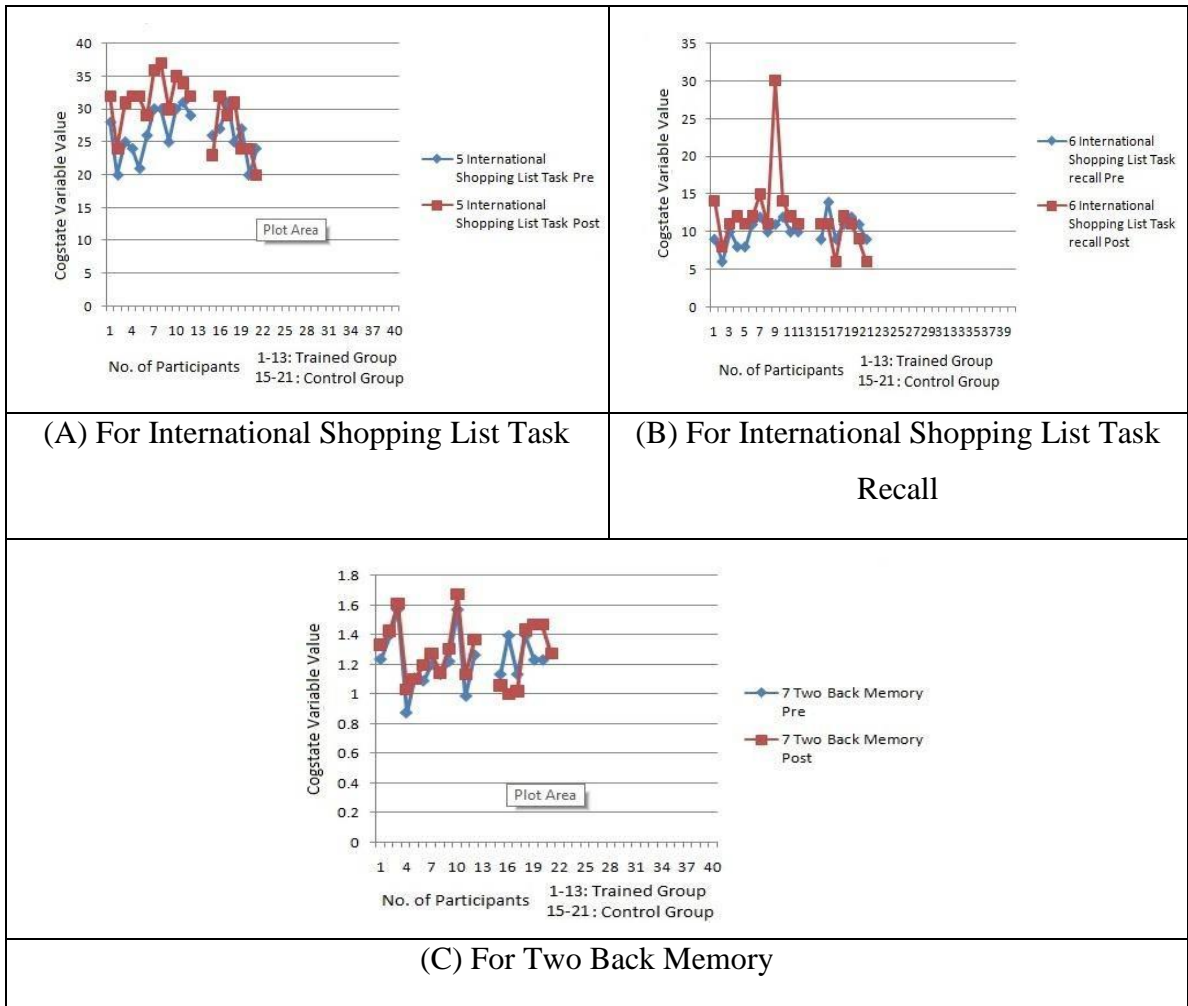


Figure 5.4: Cogstate Variable for Training and Control group

The cogstate battery returns some values according to the performance of the individual. These results for different tests are shown in the form of graphs. Figure 5.3 and 5.4 represent the cogstate returned values for identification task, groton maze chase task, groton maze learning test recall, groton maze learning test, international shopping list task, international shopping list task recall, two back memory of all the participants (trained and control group) for both pre and post intervention methodology.

After observing the graphs carefully, it is concluded that the performance of an individual is increased during post-intervention procedures. This gives rise to cognitive enhancement. The training provided to the individuals resulted in an increase in the performance of

various tests of the cogstate battery. Similarly, the outcomes of D2 test are shown as follows:

Table 5.5: Outcomes of D2 test for training and control group

Sr. No.	For Training Group (Concentration Performance)	
	Pre	Post
1	207	263
2	141	172
3	191	240
4	155	110
5	177	192
6	223	236
7	241	283
8	140	171
9	202	170
10	201	273
11	157	240
12	135	190
	For Control Group (Concentration Performance)	
13	240	276
14	217	220
15	210	190
16	250	246
17	192	170
18	170	175
19	179	177

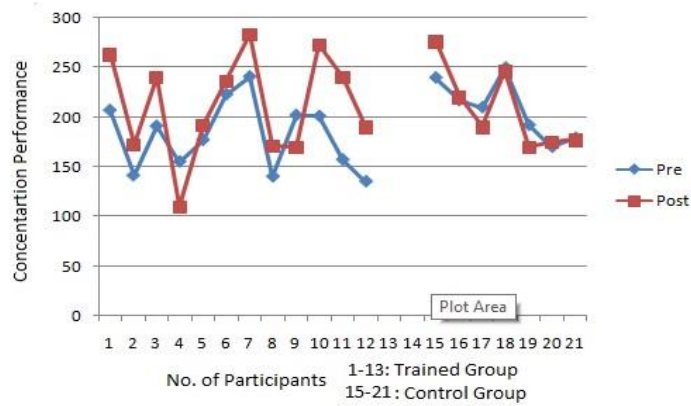


Figure 5.5: Graph showing the concentration performance during D2 task

D2 is a paper and pencil test and its outcomes are calculated as per the performance of the individual. Figure 5.5 shows those calculated values for each participant of trained and control group.

The outcomes of the D2 task showed that the level or degree of concentration of an individual increased after training. This ensured the enhancement in the cognitive abilities.

4.3 Classifiers' Results

The trained and control groups were calculated using SVM and LDA classifiers. These classifiers were used to calculate the accuracy of the experiment. Table I shows the selective attention accuracy using SVM was calculated to be 66.67% and with LDA it is 68.42%, whereas for working memory, it was calculated to be 55.56% (for F3, F4, using SVM), 57.89% (F3, F4, using LDA), 50% (for O1, O2, using SVM) and 52.63% (for O1, O2, using LDA).

Table 5.6: Accuracy obtained from SVM and LDA classifiers

Cognitive Ability	Electrodes Selected	SVM	LDA
Selective Attention	FC5, FC6	66.67%	68.42%
Working Memory	F3, F4	55.56%	57.89 %
	O1, O2	50%	52.63%

4.4 t-Test Outcomes

The pre and post intervention results were computed using t-test. The channels for working memory gave the t-test outputs as- for channel F3, the value came out to be 0.057928. For F4, it is 0.173687. Channel O1 gave 0.08068 and for channel O3, it is 0.108338. Similarly, the channels for selective attention were considered. Channel FC5 gave outcome 0.214335 and for channel FC6, it came to be 0.01218.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

The enhancement in the cognitive abilities has been observed through the quantitative results computed in the research. It has been detected that after providing suitable

intervention to the sports persons through MOT, their performances have been increased. This has been proved by analysis of EEG signals. Results point to the fact that during a task involving selective attention, beta/theta ratio of powers increases in channel FC5 and FC6 after intervention of 15 days through MOT. These results are obtained for almost every sports person of trained group (12 players). Opposite results are obtained for control group (players who were not exposed to any intervention) having 7 players. Not many improvements have been seen in their performances. Similar results are observed in case of working memory. Alpha band power increases for trained group in channels F3, F4, O1 and O2. Thus, pointing towards cognitive enhancement. These results have also been checked statistically using t-test. Enhancements have also been observed in psychological tests. The scores are found to be higher in post intervention tests in trained group. The channels for working memory gave the t-test outputs as- for channel F3, the value came out to be 0.057928. For F4, it is 0.173687. Channel O1 gave 0.08068 and for channel O2, it is 0.108338. Similarly, the channels for selective attention were considered. Channel FC5 gave outcome 0.214335 and for channel FC6, it came to be 0.01218. The selective attention accuracy using SVM was calculated to be 66.67% and with LDA it is 68.42%, whereas for working memory, it was calculated to be 55.56% (for F3, F4, using SVM), 57.89% (F3, F4, using LDA), 50% (for O1, O2, using SVM) and 52.63% (for O1, O2, using LDA).

Sports cognition has a bright future in upcoming time. With the use of such cognitive enhancement techniques, the enhancement of a sports player can be properly enhanced. In future, the study plans to apply these techniques with different interventions which are closely related to sports so as to increase the cognitive abilities which are highly required on the field. Thus, it can be stated that this is an easy approach for increasing the performance of a player which can be carried out efficiently.

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