

Memory & Relaxation Enhancement using Meditation as an Intervention: A Psychological and Physiological study

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

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



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DECLARATION


I hereby certify that the work which is presented in dissertation entitled, "**Memory & Relaxation Enhancement using Meditation as an Intervention: A Psychological and Physiological study**", in partial fulfillment of the requirements for the award of the degree of Master of Engineering in Electronic Instrumentation and Control, submitted to Electrical & Instrumentation Engineering Department of Thapar University, Patiala is as authentic record of my own work carried under the supervision of Dr. Mandeep Singh. It refers other researcher's works which are duly listed in the reference section. The matter contained in this dissertation has not been submitted neither in part nor in full to any other degree to any other university or institute except as reported in text and references.

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
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ABSTRACT

Meditation is a practice of inner awareness. It is widely practiced around the world for mental and spiritual well-being. In the past, a lot of research has been done to observe the effect of meditation on the cognitive abilities of human beings. Through our research we are validating the fact that meditation has a positive effect on the working memory of a person. In this research, fourteen participants have been selected and are made to perform memory related psychological tasks. EEG has been recorded for the participants for their physiological assessment. These participants are then divided into 2 groups: 1) Meditators' group, which has undergone guided meditation for 15 days and 2) Control group, which has undergone no intervention during the duration of fifteen days. Both the groups have been made to undergo the same tasks after 15 days of intervention. It has been observed that post-meditation memory task performance for meditators improved whereas it decreased for the control group. The mean memory span of DSPAN task in meditators' group improved from 7 to 8.1428 whereas it remained same for the control group. In case of mean memory span of task CORSI in improved from 0.351 to 0.44 whereas in control group the mean memory span reduces from 0.195 to 0.11. It was observed from physiological assessment that EEG alpha band power .Also the meditators are found to be more relaxed post-meditation while performing the task. This leads to the conclusion that taking meditation as an intervention improves performance as well as relaxation.

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LIST OF ABBREVIATION

ADHD- Attention Deficit Hyperactivity Disorder
APGR- Appearance, Pulse, Grimace, Activity, Respiration
BCI- Brain Computer Interface
D-span- Digit Span
ECG- Electrocardiography
EEG- Electroencephalography
FFT- Fast Fourier Transform
FDS- Forward digit span
fMRI- Functional magnetic resonance imaging
GRE- Graduate Record Examination
GSR- Galvanic Skin Response
GUI- Graphical User Interface
HMD- Head Mount Device
HRV- Heart Rate Variability
In- Inion
IQ- Intelligence Quotient
LAN- Local Area Network
NIS- Near Infrared Spectroscopy
Ns- Nasion
PCPT- PEBL Continuous Performance Task
PEBL- Psychology Experiment Building Language
PEPPE- Prevention and Early intervention Programme for Psychoses
PET- Positron emission tomography
PSD- Power Spectrum Density
RDS- Reverse Digit Span Test
TM- Transcendental Meditation
VR- Virtual Reality

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1.1 MEMORY

Memory is our ability to encode, store, retain and subsequently recall information and past experiences. It acts as a connection between the past and present. The past experiences decide our present behaviour [1].

We can make use of our memory by recalling, recognition and relearning[2]. To recall or remember something is to revisit the information. For example the name of the capital which we have already learned is recalled during exams. Recognition can be understood as finding a correct piece of information out of several. In other words we tend to compare our old experience with the new one for similarities. This case is same as multiple choice questions. Relearning is studying the same information over again. This leads to strong neural connections in brain.

1.2 MEMORY RECALL CYCLE

Memory model was proposed by Atkinson and Shiffrin in 1968, as a cyclic information transfer model. The model explains the flow of information which may be used in human beings to retain information in their brain. The figure 1.1 depicts the flow of information at various stages in memory.

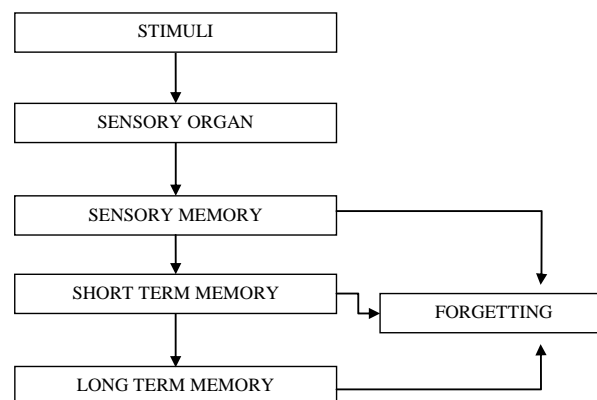


Figure 1.1: Memory recall cycle model

We have various sensory organs such as eyes, ears, skin nose and tongue, each of these organs is sensitive to specific type of physical stimuli for example eyes are sensitive to light. The sensory

organ converts the physical stimuli in equivalent electrical form. The electrical signal reaches the sensory memory where the information is encoded. The encoded information is then passed on to buffer memory. If this information is important then only it is sent to short term memory, else it is discarded. The information which are very important get stored in long term memory for very long time. The information residing in short term memory can be passed on to long term memory directly or by phonological rehearsal [3].

1.3 CLASSIFICATION OF MEMORY

Human memory is classified in three broad categories, sensory memory, short term memory or working memory and long term memory. The figure 1.2 depicts the sub classification of these three categories of memory[3].

Sensory memory stores the signals processed by the sensory organs. Each sensory organ has its own distinct sensory memory in brain. The signals will only be stored if we are paying attention to them. These signals are passed on to next memory i.e. short term memory. The retention time for sensory memory is about few milliseconds and that of short term memory is about less than a second. We can retain information in our short term memory for longer duration of time by rehearsing it. The retention capacity of short term memory is defined as the number of information items retained when presented only once. The average memory span is seven plus minus two [4].

The other type of memory is long term memory; the information stored in this memory may last for infinite time. The important information encoded by short term memory is passed on to this memory. The better way to retain information in long term memory is by association with previously acquired data.

Long term memory is further classified as explicit and implicit memory on the basis of recollection.

Explicit memory involves conscious effort where as implicit memory comes naturally.

Episodic memory and semantic memory are subdivision of explicit memory; episodic memory has our past experience and semantic memory has the information of the concepts we have learnt in past both requires conscious effort during recollection.

Procedural memory is implicit memory and it comes automatically e.g. driving a car involves co ordination of various organs and we do that effortlessly.

Other way of classification of memory is verbal and non verbal working memory.

Verbal memory involves retention of words, numbers and verbal items. People utilize left side of brain to process verbal information. Left side of the brain has the ability to generate and understand speech. This is not a generalized case people may process verbal information as a visual data involving right side of the brain [5]. Retention of verbal information for a longer period involves phonological loop i.e. rehearsing information in brain [3].

Non verbal memory involves visual and spatial aspect of information storage [6].

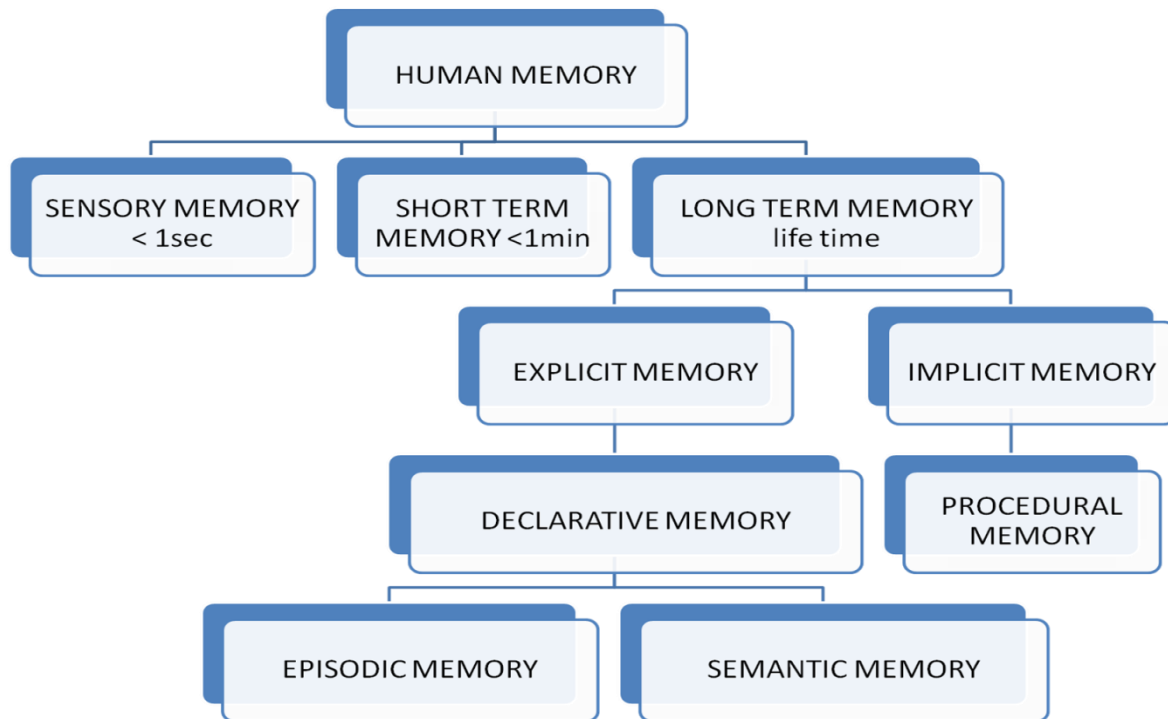


Figure 1.2: Classification of memory

1.4 RELATIONSHIP BETWEEN ATTENTION AND WORKING MEMORY

Working memory closely related to attention. It has been said that attention is an object of working memory. Working memory is a dynamic memory and it stores information for very brief interval of time. There are a large number of signals generated by our sensory organs and only one of the signals is attended by our working memory. The higher the signal strength the higher will be its chance to be gain access to working memory. Attention mechanism plays a vital role in competitive selection process which determines the access of information to working memory [7]. The figure 1.3 depicts a model of attention mechanism.

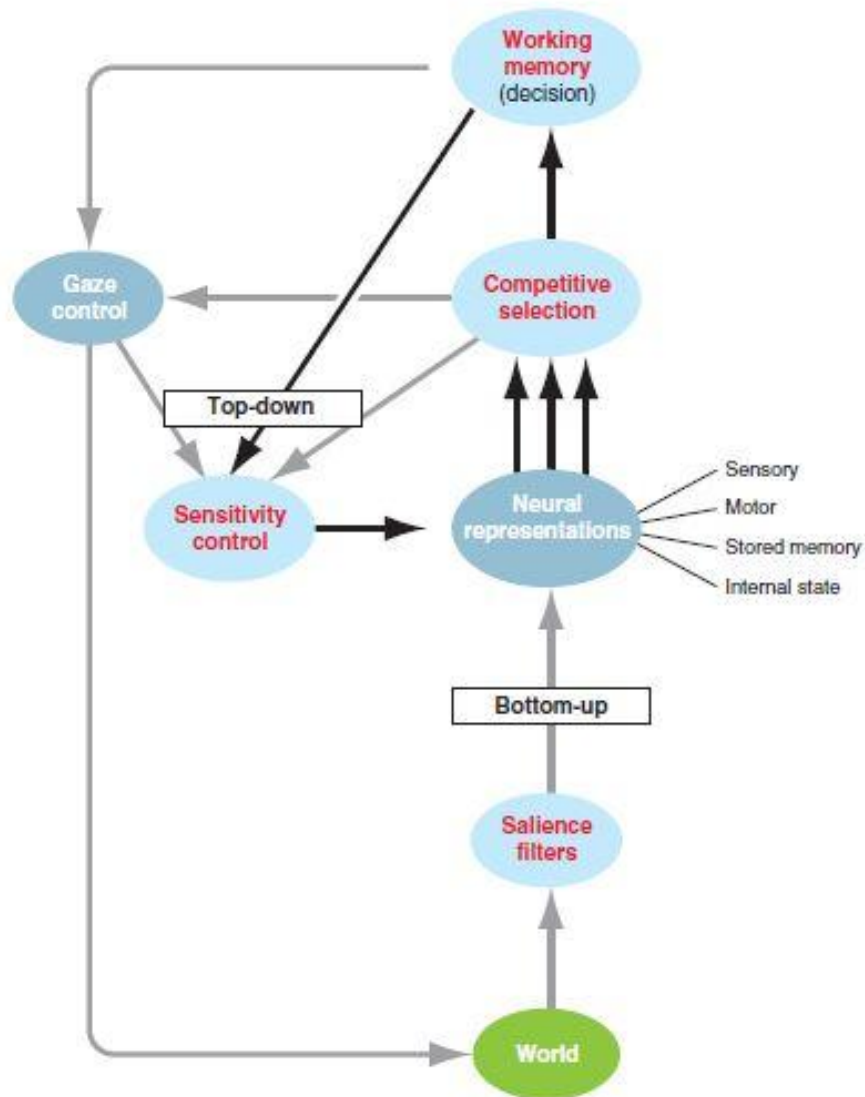


Figure 1.3: Attention mechanism[7]

The stimulus generated by the world can be of varied form. These stimuli can be strong enough to access the memory. The saliency filter has its role in selection of important stimuli.

Top down sensitivity control improves the quality of information. This can be understood with an example if we are looking at an object and it is important to us. The eyes will orient towards the target and working memory will enhance the information about the object [7].

2.1 MEMORY ENHANCEMENT

Memory enhancement may be defined as increase in information storage capacity of human. Better memory is decided not only by its capacity but also from other parameters like response time and associability with past experience. There are various methods through which memory can be enhanced.

The procedure to qualitatively measure the enhancement comprises assessment of memory before and after intervention. The intervention aimed at improving the memory abilities. Intervention may be given for several days and can be in the form of drugs, meditation, odor, color, videogames, or any other kinds of stimuli. The parameters obtained from pre and post assessment are compared to analyse the effect of intervention. The time line for enhancement assessment is shown in figure 2.1.

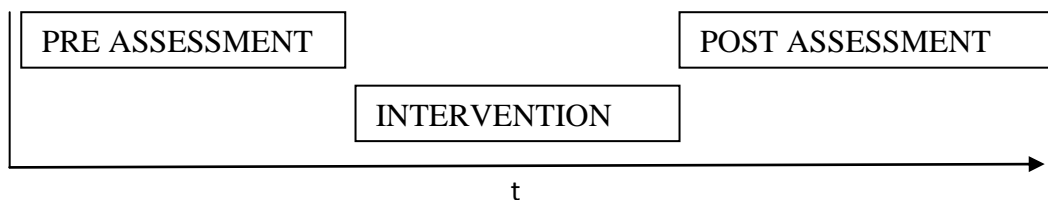


Figure 2.1: Time line for memory Enhancement Procedure

2.2 DIFFERENCE BETWEEN ENHANCEMENT AND THERAPY

Intervention can be used for two purposes; the first one is to cure someone of pathological condition, whereas the other purpose could be to improve some system [8]. For example memory stimulant drugs such as anabolic steroids are used by the sick patients as a cure to their neurological disorder but the athletes can have it for enhancement [9]. Other example is reconstruction surgery widely known as plastic surgery. It helps the patients with damaged and deformed bodies to regain their confidence, but in current scenario people undergo cosmetic surgery such as Botox injection to improve their appearances.

2.3 CLASSIFICATION OF MEMORY ENHANCEMENT TECHNIQUES

Memory can be enhanced through different ways some of them are prevalent in society from more than 1000 of years. There are two broad classes of memory enhancement techniques: conventional and unconventional. Unconventional techniques involve relatively new techniques such as medicinal effect on cognition and gene alteration.

2.3.1 CONVENTIONAL

There are various conventional ways through which cognitive abilities can be enhanced. They are classified in three different category, these are education, mental training and enriched environment [10] .

1) EDUCATION

In our education system we come across various activities which stimulate our various cognitive abilities. It tends to update our “mental software” which involves in managing various cognitive domains: mathematics, reading, writing and understanding language, problem solving in particular subject etc. This type of mental software will enhance our mental load handling capacity by clever encoding, organization and processing of information [11] . From Wikipedia education is said to be passed from one generation to another through teaching, research or training of group of people. Also there is transfer of skills, habits and knowledge which one has acquired through learning. Education can be any experience that has effects on the way one thinks, feels or acts. Education is commonly separated into five stages starting from preschool, primary school, secondary school, college, university or apprenticeship [12]–[14] .The education system by default enhances cognitive abilities. However for a particular task, special efforts may be made to improve the speed or efficiency of performance.

2) ENRICHED ENVIRONMENT

Enriched environment is another conventional technique by which we can enhance one’s cognitive abilities. Enriched environment stimulates the brain by its multidimensional environment [15]–[18].

One of the latest enriched environments is virtual reality environment [19]. In this environment a head mount device is provided and people experience the virtual word as if it is real. The human

visionary system can see and understand the world in three dimensions. Most of our display units generate two dimensional images. But due to advancement in opto-electronics now a three dimensional virtual environments can be created before the eyes. There are various concepts of physics and biology which could not be visualized easily and repetitive live demonstration of these concepts may not be possible. This VR technology enables individual to understand and learn the concept easily.

3) MENTAL TRAINING

There are various forms of mental training by which cognitive enhancement can be done.

Even general mental activity, “working the brain muscle” can improve performance [20] as well as long-term mental health [21], while relaxations techniques help regulate the activation of brain[22].

Video gaming is yet another mental training technique to improve cognitive abilities. Gaming is good mental exercise. Persons playing fast paced games have better vision perception, attention and cognition. Video games are used in various fields like education, physical exercise, entertainment and cognitive training [23].

Another form of mental training consists of learning strategies to memorize information (i.e. memory techniques). “The method of loci” is one such strategy. In this method the individuals utilize the visualization power to organize and recall information. The method involves a person to imagine layout of shops, any building or any geographical place. Then they were asked to walk from one room to other room while depositing imaginary objects that may evokes natural association to the subject even though she is memorizing. During retrieval, subject will recollect their experience and the objects they thought of. As this method relies on memorizing and recollecting the content, it is used in tackling brain’s spatial memory and navigational system to remember objects . In basic term, it is a method of memory enhancement which uses visualization to organize and recall information.

Meditation is also one of the conventional practice through which cognitive abilities can be enhanced. Meditation practice affects many cognitive abilities. Its effect on memory and attention has been reported in many researches. Mediation practice has been used to reduce stress and anxiety.

2.3.2 UNCONVENTIONAL

There are certain techniques such as drugs, gene therapy, odour and food supplements which can enhance cognitive abilities; nearly all of these techniques are considered to be in experimental stage [10].

1) DRUGS

There are certain drugs which when used in proper amount can enhance cognitive abilities. Nootropic is one of the drugs which can improve cognitive abilities like memory, attention and concentration.

Modafinil drug was developed and used for the treatment of excessive lethargy. It was successfully used to cure sleep disorder. Now research has been done to see its effect on normal adults to check whether it improves higher cognitive abilities like memory and executive function[24], [25].

Nootropic works by improving the brain's oxygen supply, by stimulating nerve growth, or by altering the availability of the brain's supply of neurochemicals (neurotransmitters, enzymes, and hormones). Nootropics formulations have been used in ayurvedic system since ages. Some examples for enhancing memory are almonds, ginger, tulsi, ambla, Indian tulip tree etc [26]. These being conventional may not be considered under this category. These will provide a long term effect. However, some of the unconventional drugs which are used to improve memory are Ritalin and Adderall which provide short term effects. These are commonly used by college students to improve grades and provide an edge over their classmates [27]. These methods of cognitive enhancement are legally not approved as they form a type of cheating, just in the same manner as doping for sports persons is banned. Some drugs which are used for treating Alzheimer's disease and other cognitive deficits also improve cognition in healthy individuals. US Food and Drug Administration has already approved a number of these drugs, including donepezil (Aricept®), rivastigmine tartrate (Exelon®), galantamine HBr (Reminyl®), and memantine (Namenda®). Modafinil is also being tested for use by military and has shown improvement in simulator performance by helicopter pilots [25].

Other supplements like caffeine and nicotine also improves cognitive abilities [10], [11], [28]. In case of caffeine tiredness reduces, while with nicotine a complex interaction with memory and attention occurs. Caffeine is being used traditionally as a stimulant for providing alertness.

2) GENE THERAPY

Gene therapy or gene modification is a technique which inserts genes with special traits directly into cell. It is used to cure or prevent disease instead of using drugs or surgery. This can be used to enhance cognitive abilities in healthy individuals. The research on rats and mice had demonstrated that gene modification can enhance memory. The NR2A subunit of NMDA (N-Methyl-D-aspartic acid) is linked with low plasticity of brain (or neuroplasticity is the ability of brain to change based on new experience). While normal animal is maturing, synthesis of NR2B is replaced by NR2A; hence memory is low in adult animals. The research genetically modified the mice to produce more of the NR2B subunits. The NR2B “Doogie” mice showed improved memory performance. It was assessed on both acquisition and retention capabilities of memory[10].

3.1 MEMORY ASSESSMENT

Memory assessment is a technique which is used to assess the information retaining capacity of a person. Memory can be assessed through two different ways

- 1) Memory assessment task
- 2) Physiological assessment

3.1.1 PSYCHOLOGICAL ASSESSMENT

In this type of assessment, participants will be asked to complete memory assessment tasks like numbers recall, word series, spatial changes etc. that require active memory skills. There are certain standard software that are used for cognitive assessment like Psychological Experimental Building Language (PEBL), PsychoPy, Prevention and Early Intervention Program for Psychoses (PEPP), CANTAB etc. PEBL is a C programming based open source platform in which we can make custom made task as well as run experiments already designed according to Psychological assessment procedures. Some of the memory tasks are discussed below [29], [30][31].

3.1.1.1 VERBAL MEMORY TASK

The tasks are used to check the verbal information retention capacity of participants. Some tasks involves learning of certain special characters, letters, names, numbers etc. all these information comes under verbal category and it has been seen that certain area of brain is responsible to handle this type of information.

1) D-SPAN MEMORY TASK

In this assessment task a series of numbers appears on the screen one after the other. The participant has to learn the digits in the order appeared on the screen. After a brief interval time, participant has to punch the digits in the same order as they learned it. For every two consecutive right responses the length of digits increases by one. And if there are two wrong responses in succession the task will end. The task GUI is shown in figure 3.1.

The maximum length of digits retained by the participant is taken as its memory span.

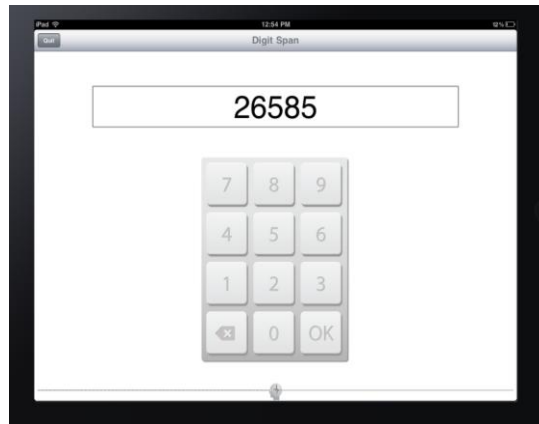


Figure 3.1: Task Digit span [32]

2) STERNBERG

Sternberg comes in category of short term verbal memory. The objective of this task is to check that how many letters a participant can remember and recall accurately. The task starts with a fixation point appearing in the middle of the screen for 5 seconds just after a single character appears and stays for 2.5 sec, the participants was required to learn this character, after that 3.5sec is provided for retention of the character then stimuli, single character appears on the screen for 2sec and the participant is asked to respond by pressing Key L if the character learned appears on the screen else A [23].

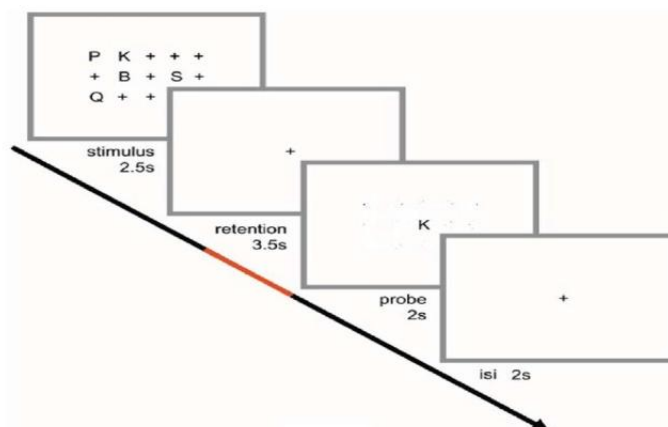


Figure 3.2: Memory Task Sternberg [23]

The same task is repeated with five characters. The time line for various slides which will occur on the computer screen is shown in figure 3.2 for Sternberg task.

For every correct response a score of one is awarded. The stimuli appear for 18 times on the screen.

3.1.1.2 NON VERBAL MEMORY TASK

The tasks involved in this category are different to verbal memory task. The participants require to memorize the spatial changes occurred on the screen and then after a brief interval of time has to recollect the information. The other name for these types of task is visual spatial memory task.

1) CORSI

In this test nine blue coloured square blocks will be randomly placed on the computer screen figure 3.3, one block per second will get illuminated with a yellow colour and the participant has to memorize the trail. After the completion of trail the participants has to recreate the trail by pressing these blocks in the same order as they appeared on screen. This test evaluates their visual spatial memory.

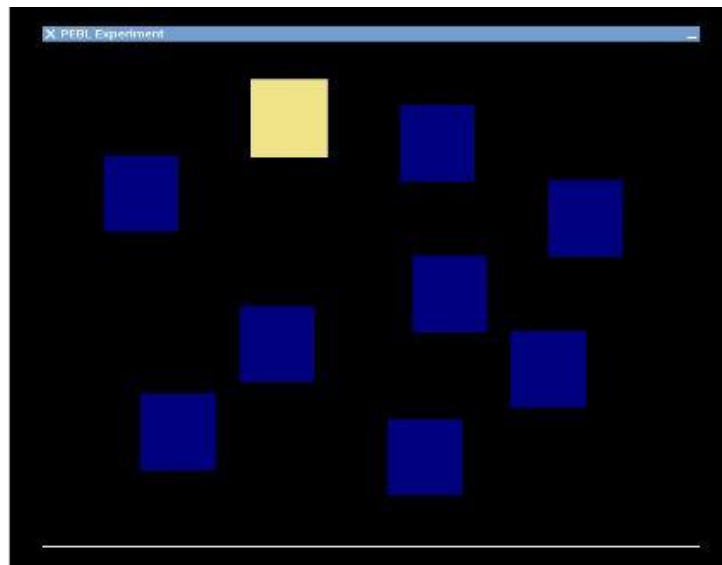


Figure 3.3: Task Corsi [33]

3.1.2 PHYSIOLOGICAL ASSESSMENT

Memory assessment can also be done by using Physiological methods like Electroencephalography (EEG), Electrocardiography (ECG), Galvanic skin response (GSR),

Heart rate variability (HRV) etc. [34]. EEG is conventionally used to detect pathological conditions like sleep disorder, epilepsy [35]–[39], but nowadays it is also being used to detect and quantify emotions [38]–[40]. EEG is recorded by placing electrodes over the scalp of the subject[41]. EEG signals are conditioned by applying various de-noising filters and then various spectral features are extracted for frequency bands of different ranges like delta, theta, alpha, beta, and gamma [35], [36], [38] . It is found that activity of different lobes of brain increases as per the task performed. [42], [43]. The identification of various sites in human brain which handles specific memory task are identified using EEG signals [42]–[45].

4.1 NEURAL CORRELATE

Neural correlate is the relationship between the bodily experience and Electro-Neuro-Biological state. This area of study has led to establish a relationship between neural activity and cognitive variables. The neural correlate of motor planning was one of the important studies in the development of brain computer interface. This device translates the motor signals generated in the brain for artificial actuators.

4.2 WORKING MEMORY

Memory is used to store and recall information. Memory is classified into three types: sensory memory, short term (or working memory), and long term memory. Sensory memory is a sensory signal buffer and every sensory organ has its own unique buffer. It can hold information for about a few milli-seconds. Working memory have limited storage capacity, it can hold seven plus minus two items for about a few seconds but this time can be varied by rehearsing the information in brain. Various researchers have reported changes in Brain wave rhythms during working memory task.

Also it has been found that the working memory load and the prolonged practice of some tasks have a significant influence on the EEG rhythms.

Joshua Jacobs et. al. studied that memory retrieval and decision making in correlation with theta activity. During retrieval, power of left-parietal theta oscillations increased in relation to how well a test item was remembered, and theta in central regions correlated with decision making. The study also showed how these oscillatory dynamics complemented event-related potentials [6], [46].

Ole Jensen and Claudia D. Tesche showed that frontal theta activity in humans increases in a working memory task. The research showed brain oscillations in the theta band are involved in tasks related to working memory. The activity in the theta band increased with the number of items retained in working memory. The results suggested that theta oscillations generated in frontal brain regions play a significant role in working memory tasks [47], [48].

Bornali Kundu et. al. in their study found that delay time in ERP are different for different memory capacities. EEG activity in frontal region is observed during delayed-recall task supports that the frontal area is for short term memory [49].

Pega Zarjam et.al. classified the cognitive load on the basis of spectral features. They found that out of 32 EEG electrodes of 10-20 system a few are enough for classification. The spectral features like spectral entropy and spectral energy calculated for delta band tends to decrease with increasing load over channels FP1, FP2, O1, AF3 and in all 32 channels respectively. A decrease in entropy with increasing load implies more predictability and less irregularity [42], [43], [50]–[52].

Pablo. F. Diez et. al. utilized periodogram for classification of EEG signals. Mean power and root mean square power are calculated for delta theta alpha and beta band of EEG over electrodes F3, F4, C3, C4, P3, P4. They results suggests that root mean power is a better parameter for classification [53].

Takayasu Ando et. al. in their FMRI study on brain activation during visual memory task showed that activity in pre frontal region area is significantly higher when subjects were performing higher memory load task than lower one. They also discussed about the reduction in brain area activation and increased activity after one week training suggesting the neural plasticity aspect [54].

Grace Hwang et. al. analyzed that verbal and non verbal memory task induces oscillatory activity in frontal and occipital regions of brain. The verbal task involves sub vocal rehearsal and they found enhanced beta activity during the inter-stimuli interval [6].

Markus Näpflin et. al. analyzed that for the same subject when performed the same task again after a gap of year there is less variation in spectral parameter of EEG. The shape of the power spectra remained same but there is variation in peak and mean power values. [44].

Alan Gevins et. al. in their study found that alpha activity tends to decrease with increase in working memory load irrespective to the type of memory task performed (verbal and non-verbal), whereas the activity in alpha and theta band increases after practice over frontal midline. There is increase in theta in both cases i.e. task difficult and practice, it suggests that more efforts are

required to perform task over an extended session but in alpha it can be inferred that less resources are required when one acquires skills [55].

Jaime F. Delgado Saa et. al. discussed the classification of EEG signal based on the basis of power spectrum density for BCI application to control the wheel chair for mentally impaired persons. PSD tends to improve the classification accuracy [56].

Kai Keng Ang et. al. in their study on classification of memory load for BCI used near infrared spectroscopy(NIS). The 1 back and 3 back tasks were performed as a memory load task. It was found that the high density near infrared spectroscopy data collected over pre frontal region could classify the memory load and ideal condition [57].

B. Schack et. al. in their study related to phase relationship between theta and gamma EEG rhythms occurred during memory task found that there is a linear relationship between the memory workload and EEG activity over pre frontal regions of brain [58].

Julie Onton et. al. analyzed frontal midline activity during visual working memory task and it was observed that the (5-7 Hz) theta activity increases while performing the task. Also it was observed that lower beta (12-15 Hz) activity was higher during memorizing period of trails than during ignored letter trials [59].

B. Schack et al. in their study found that upper alpha and theta play an important role in memory related work. It was observed that there was increase in theta over prefrontal regions of brain. They also observed that there was load dependent increase in upper alpha over occipital electrode site O2 [60].

5.1 MEDITATION

Meditation (dyaan) is a thoughtless state. In this state the mind is at rest and it attains a state of consciousness. One can achieve the state through practice. The practices involve self regulation of mind and body.

5.2 TYPES OF MEDITATION

Meditation as described above is a thoughtless state and it can be achieved through different practices. The meditation techniques are broadly classified as focused attention and open monitoring meditation.

Focused attention meditation can further be classified in accordance to the object used to be focused on for example breath, heart beats, pulse etc.

5.2.1 MINDFULNESS MEDITATION

Mindfulness meditation is also referred to as Open Monitoring (OM). This type of meditation practices involve allowing any thoughts, feelings, or sensations to arise while maintaining a specific attentional stance: awareness of the phenomenal field as an attentive and non attached observer without judgment or analysis. The Examples of OM meditation are Zen, Vipassana, and the western adaptation to mindfulness meditation. Vipassana meditation is Buddhist meditation. The ultimate aim of OM meditation is to stay only in the self monitoring state (i.e. clear reflexive awareness). In OM meditation a person does not focus on any object, rather she is aware of every moment and everything [61], [62].

5.2.2 CONCENTRATIVE MEDITATION

This type of meditation techniques involve focusing on specific mental or sensory activity. The person can focus on repeated sound, an imagined image, candle flame, body sensation such as breath, Heart-beat, pulse, etc. It involves an individual to focus on only one object and if they lose their attention they have to bring it back. Therefore it is referred to as Focused Attention

(FA). The Examples of this type of meditation are yogic meditation and the Buddhist sanatha meditation in which the yogis focus on the sensation of breath[63]. In FA meditation the quality of attention has to be maintained. For example, while focusing on any imagined image, suddenly attention diverges to pain in knee. At this stage person will release the distraction and has to restore attention back to focusing point. Transcendental Meditation (TM) is also considered as concentrative meditation according to some researchers. Transcendental meditation practice involves repeated recitation of mantra. The mantra is very specific as far as this meditation is concerned [64], [65].

5.3 WHY MEDITATION?

Mediation is helpful in various ways. It has been reported by a number of researchers as one of the most effective practice to reduced stress. It is also used in many medical care centers around the world. A study related to effect of meditation was conducted in US and it was found that when meditation sessions were provided as a short course of behavior modification fewer people visited physicians [66]. Another study was conducted on people involved in insurance sector and it was statistically showed that the use of medical care was significantly less for meditators as compare to non meditators [61].

5.4 MEMORY ENHANCEMENT USING MEDIATION AS INTERVENTION

Memory is very important ability of an individual. Memory is classified in three categories these are short term memory, long term memory and sensory memory. Short term memory is also known as working memory. Working memory plays a vital role in day today life. For example if someone has a good short term memory they can easily memorize a ten digit mobile number. To enhance this capability meditation could be an inetrvention. Meditation has very health benefits also. It has been proven to reduce stress and anxiety. It can be used to enhance cognitive abilities. One of the cognitive ability is short term memory. A lot of research has been conducted to study the effect of meditation on working memory[67].

5.4.1 MINDFULNESS MEDITATION FOR WORKING MEMORY ENHANCEMENT

Marieke K. van Vugt et al. studied the effect of Sathipattana Sutra, a mindfulness meditation on working memory. The Subjects for this study were divided into two groups. The first group

performed mindfulness meditation for 10-12 hours daily, and second group was taken as control group. The subjects in each groups belongs to same age and has same educational background. The participants were assessed by delayed recognition task. It is a memory task. In the first 2 weeks, the participants focused mainly on their breath, and in the second 2 weeks, they opened up their attention and added practices that cultivated compassion and loving kindness. The pre and post intervention data were compared. The EZ-diffusion mode (a mathematical model) suggested that mindfulness training leads to improved information quality and reduced response conservativeness, with no changes in non-decisional factors [68].

Michael D. Mrazek et al. conducted a research on the effect of mindfulness meditation practice on Graduate Record Examination (GRE) score and working memory. They selected 48 students. These students were divided in two groups of 22 students each. The first group performed mindfulness exercise of about 10-20 minutes duration for two weeks. The second group didn't receive any intervention. In the Mindfulness exercises the participants were instructed to focus their attention to some sensory experience (e.g., sensations of breathing, tastes of a piece of fruit, or sounds of an audio recording). The meditation exercise also involved personalized feedback from the instructor. It was found that MT reduced mind wandering during and after both the assessment. It also improved both GRE reading-comprehension scores and working memory capacity [69].

Amishi P. Jha et al. studied the impact of Mindfulness Training (MT) on working memory. The Subjects selected for this study belonged to military background. They were divided into two groups. The first group was meditator group and the participants were instructed to performed meditation for 8 weeks, whereas the second group was taken as control group. The MT course was created by former U.S army officer. The course matched many features of Mindfulness Base Stress Reduction (MBSR). The course involved 24 hr of class instruction over 8 weeks, with weekly 2-hr meetings (on average) and a full-day silent retreat. It was found that the response time for visual memory task improved in meditators who have undergone extensive training [62].

5.4.2 CONCENTRATIVE MEDITATION FOR WORKING MEMORY ENHANCEMENT

Sarina J. Grosswald et al. studied the effect of Transcendental Meditation technique to reduce stress and anxiety as a means of sinking symptoms of ADHD. Subject taken in this study were students ages 11-14, they practiced it twice daily in school. Results showed statistically significant reductions in stress, anxiety, and improvements in ADHD symptoms and executive function. Stress is known to reduce working memory. Since meditation helps in reducing stress, working memory enhancement is the natural consequence of practising meditation [70].

CHAPTER 6

PROBLEM DEFINITION

Memory is our ability to encode, store, retain and subsequently recall information and past experiences in the human brain. It acts as a connection between the past and present. We can make use of our memory by recalling, recognition and relearning. Electrical changes take place in the brain while performing memory based tasks. In our research we are trying to study these changes in electrical activities while performing memory tasks. We are also trying to validate that meditation has a positive effect on cognitive abilities like working/short-term memory. We will study the effects of meditation on the working memory through various psychological memory based tasks and by acquiring EEG while performing these tasks.

We can summarize our problem definition as:

1. To study the effect of meditation on performance of memory based task
2. To study the related effect of meditation on relaxation by observing EEG alpha band power

CHAPTER 7

PROPOSED METHOD

Memory correlation with EEG activity involves the assessment of human memory through Psychological memory task and acquisition of EEG data during task. Also to study the effect of meditation involves the comparison between the pre intervention and post intervention Psychological and physiological data. The proposed methodology for the research is as follow.

7.1 SELECTION OF PARTICIPANTS

All the participants selected for this research should be engineering students engaged in undergraduate or postgraduate degree courses. None of the participant should have any history related to psychological or neurological illness. The subjects should be briefed about the procedure, purpose and method of the experiment before starting experiment. All the participants should voluntarily participate in the study. All experiments should be conducted in the Laboratory of Thapar University.

7.2 PREPARATION OF PARTICIPANTS FOR EEG

Participants should be instructed about the experimental procedure. They should be instructed to have their scalp properly washed and dried before the EEG acquisition. They should sit before the laptop at a comfortable distance on the chair. The electrodes should be placed on the scalp. It should be made sure that the electrode gel is making a firm contact between the electrode plate and scalp.

7.3 EEG DATA ACQUISITION

Baseline reading

EEG data should be acquired for the baseline condition first. There should be two sets of baseline reading.

- 1) The participant should close their eyes for two minutes for first baseline EEG reading.
- 2) After the first baseline reading, the participant should open their eyes and stay relaxed for two minutes during which second EEG baseline reading shall be acquired.

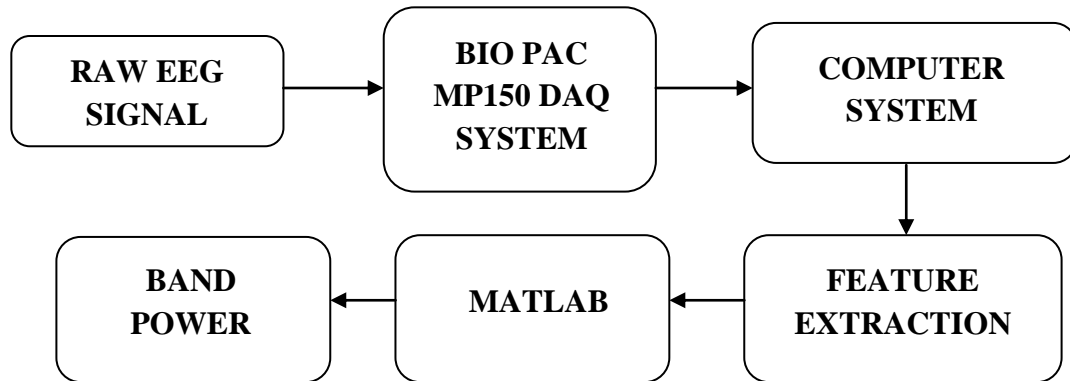


Figure7.1: Data acquisition steps

Physiological assessment during task

EEG reading should be acquired while participants perform their tasks. The block diagram of the assessment procedure is shown in figure 7.1.

7.4 STATISTICAL ANALYSIS OF DATA

Analysis of data shall be done using one tail paired type t-test and correlational studies shall also be made. Details of both are given in section6.3.

7.5 INTERVENTION

Meditation audio should be provided to each participant of meditator’s group. They should do the meditation everyday for 15 days.

7.6 EEG DATA SHALL BE ACQUIRE WHILE PERFORMING COGNITIVE TASKS FOR POST ASSESSMENT

Post assessment shall be done to find the improvements after intervention. In post assessment EEG data shall be acquired while performing working memory.

8.1 EEG SIGNAL

One of the ways through which physiological memory assessment can be done is through analysis of EEG signals. Electroencephalography (EEG) refers to the recording of brain's spontaneous electrical activity. Brain's electrical activity is induced by the collective firing of billions of neuron. Figure 8.1 depicts the various parts of neuron.

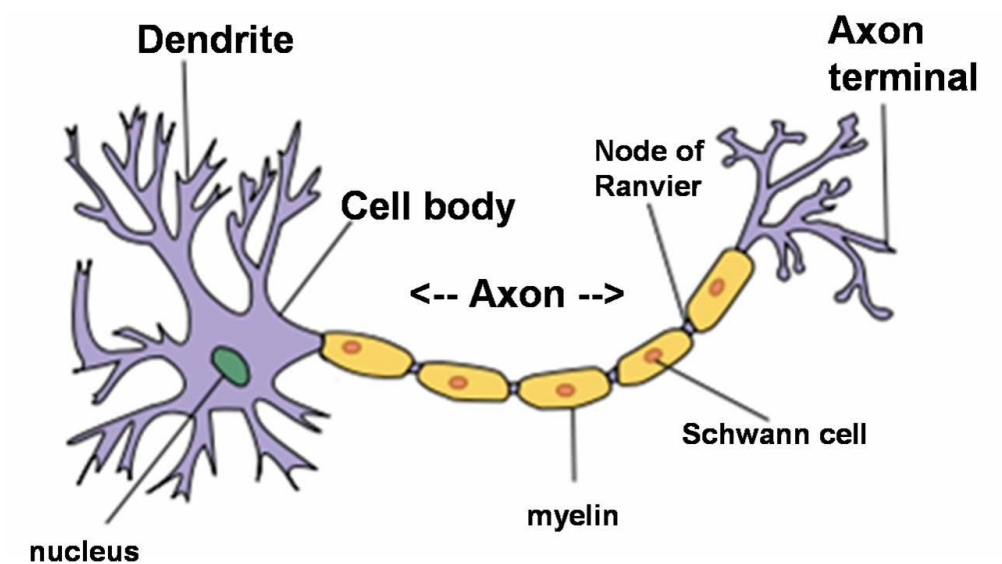


Figure 8.1: Basic Neuron structure

The time domain EEG signal can be converted into frequency domain. The figure 8.2

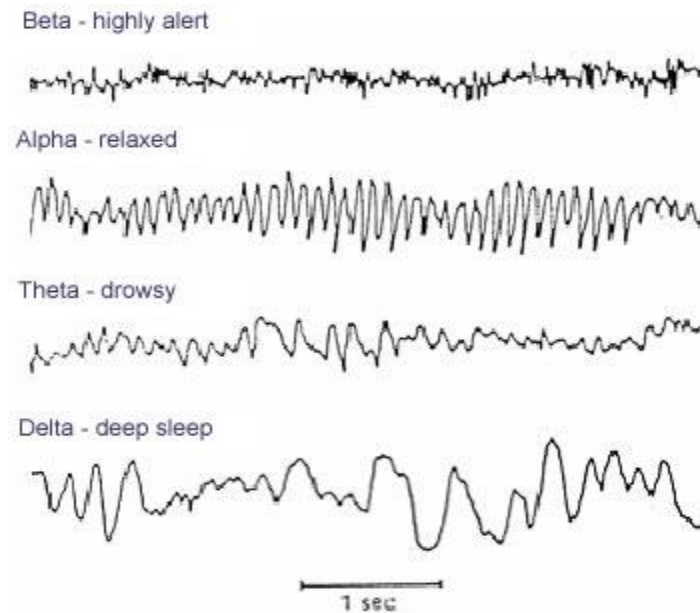


Figure 8.2: Brain Rhythms

depicts the various bands of EEG activity. The frequency bands are

- 1) Delta (0.5-4 Hz)
- 2) Theta (4-8 Hz)
- 3) Alpha (8-13 Hz)
- 4) Beta (13-30 Hz)

8.2 10-20 SYSTEM

EEG is recorded by placing the electrodes on the scalp. The electrodes are placed on the head in accordance to 10-20 international electrode placement system. There are two reference position nasion and inion. Inion is the projection of the occipital bone whereas nasion is the intersection of the frontal bone and two nasal bones of the human skull. The entire distance between the two reference points are divided into six segments as 10%-20%-20%-20%-20%-10%. The electrode positions are depicted in the figure 10.

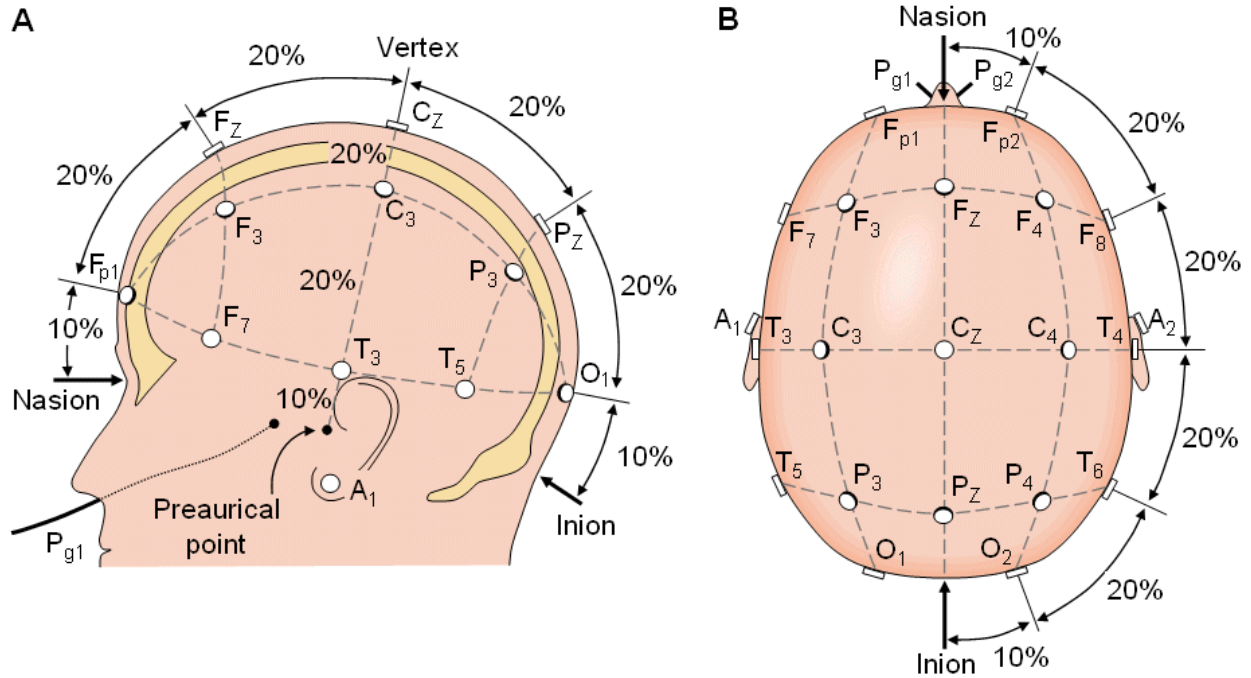


Figure 8.3: 10-20 system of EEG electrode placement

8.3 DATA ACQUISITION HARDWARE

EEG data is acquired through BioPac MP150 EEG 100c data acquisition system shown in figure 8.4. The hardware unit comes with a computer based software program to control its operation. The analog data is converted into digital format by MP150 and the software can perform the task like storage, analysis and retrieval of EEG data.



Figure 8.4: MP150 BioPac system

The acquired data is transmitted to the computer through Ethernet cable. There can be at most 16 EEG 100c channels that can be attached to MP150 system. The EEG data can be acquired at an acquisition frequency of 1 KHz or higher. The sampling and acquisition frequency can be

controlled through software. The EEG data is generally sampled at a frequency of 500 Hz. The six electrode position are shown in figure 8.5 where scalp electrodes were placed

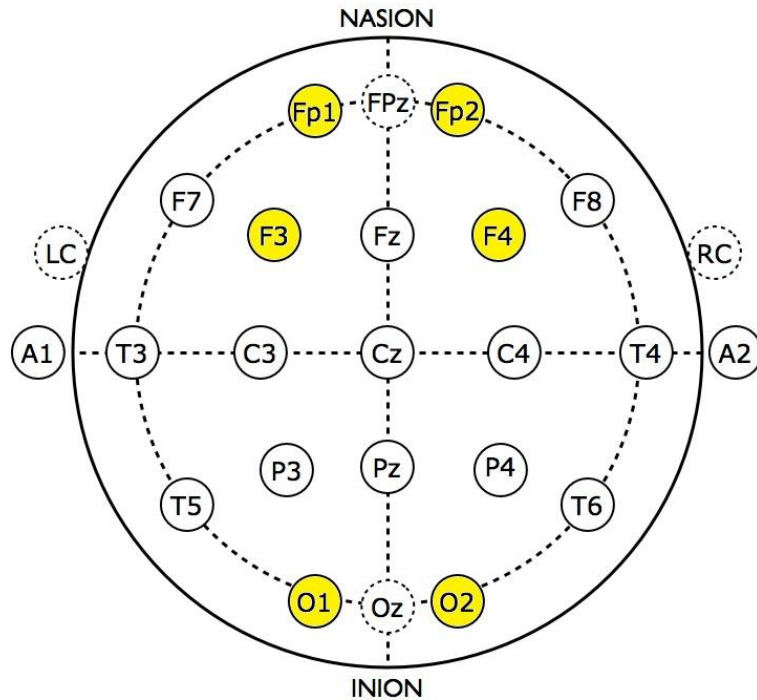


Figure 8.5: Marked electrodes for recording

8.3.1 SIGNAL CONDITIONING AND FEATURE EXTRACTION

AcqKnowledge software is used not only to collect data but also to extract features. This software program is compatible with windows 7 operating system. The graphical user interface is point and click type. There are in built programs to calculate various features of EEG like power spectrum density, entropy, mean etc. It can also perform complex tasks such as digital filtering or fast Fourier transformations. The tasks are easy to choose from drop down menu item. There is inbuilt comb filter in MP150 which is used for signal conditioning. The comb filter can be applied to the data in real time to filter the noise introduced in the signal. The filter is set at 50 Hz to remove noise due line frequency. The feature extracted is power spectral density and it was computed using hamming window in ACQknowledge software. The steps involved in the acquisition setting in ACQknowledge software are as follows:

Step 1: Open the ACQknowledge software. The interface is shown in figure 8.6

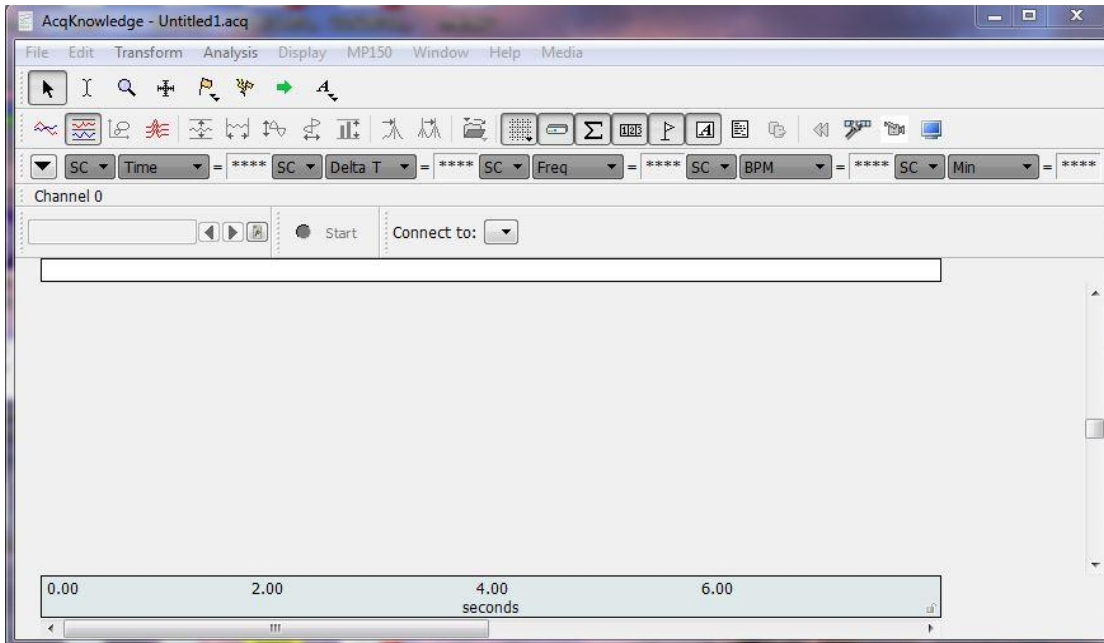


Figure8.6: ACQknowledge interface

Step 2: Click the MP150 icon to set up channels as shown in figure 8.7

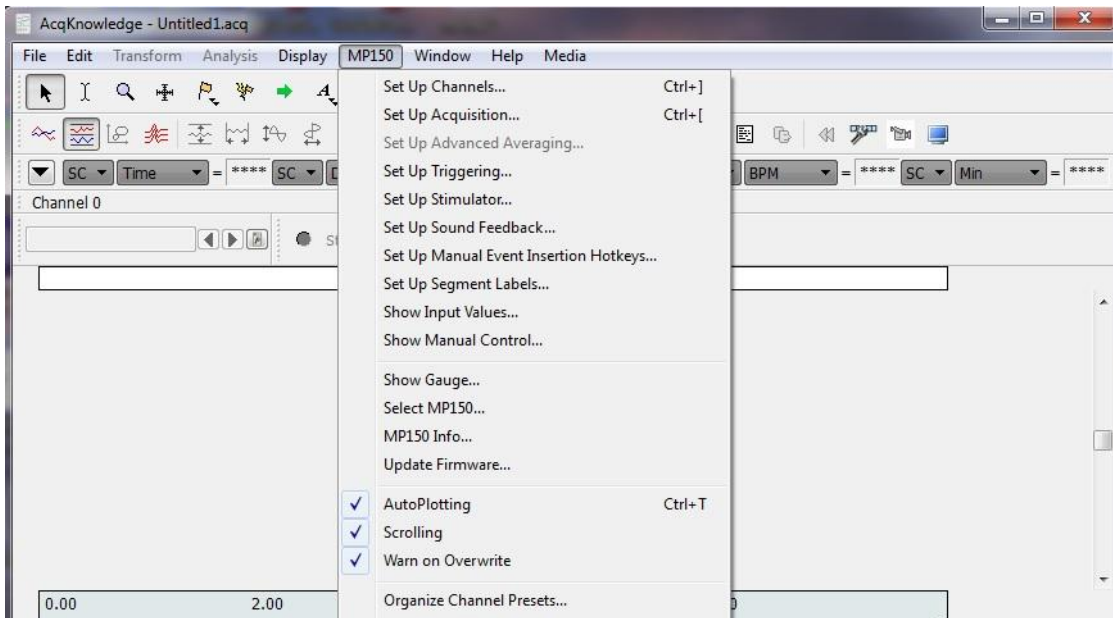


Figure 8.7: Drop down menu for setting up channels

Step 3: Add analog channel by clicking on add new module as shown in figure 8.8
Select EEG 100c hardware.

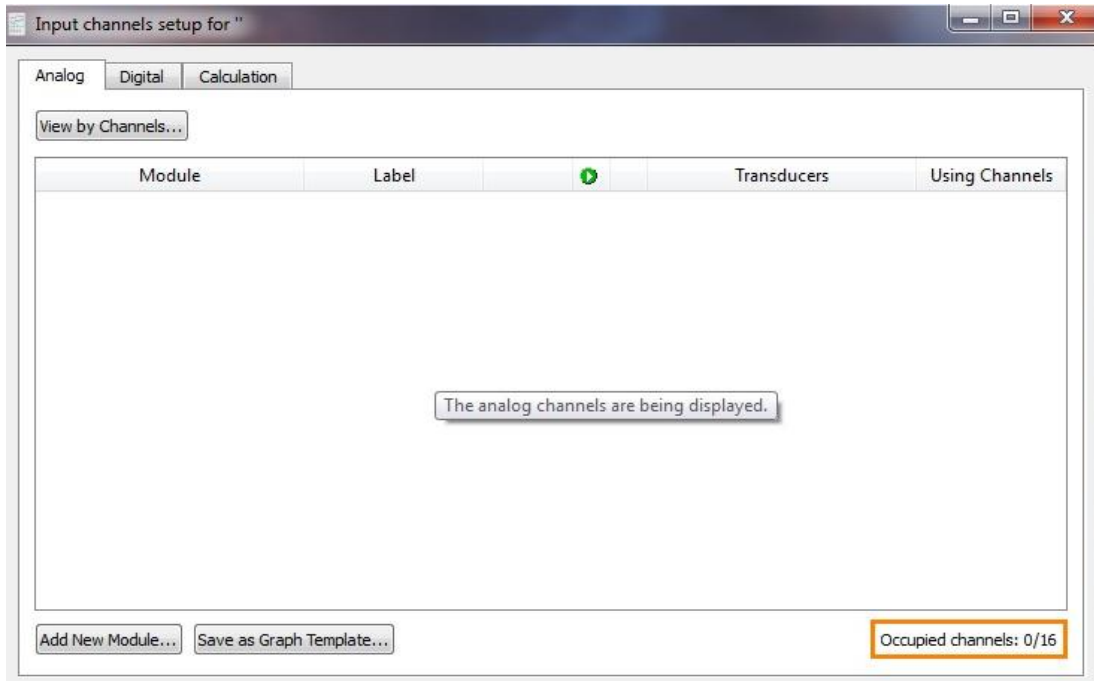


Figure8.8: EEG module and channel selection

Step 4: Set the configuration of EEG100c hardware as shown in figure 8.9
The setting in the software should be same as that on hardware.

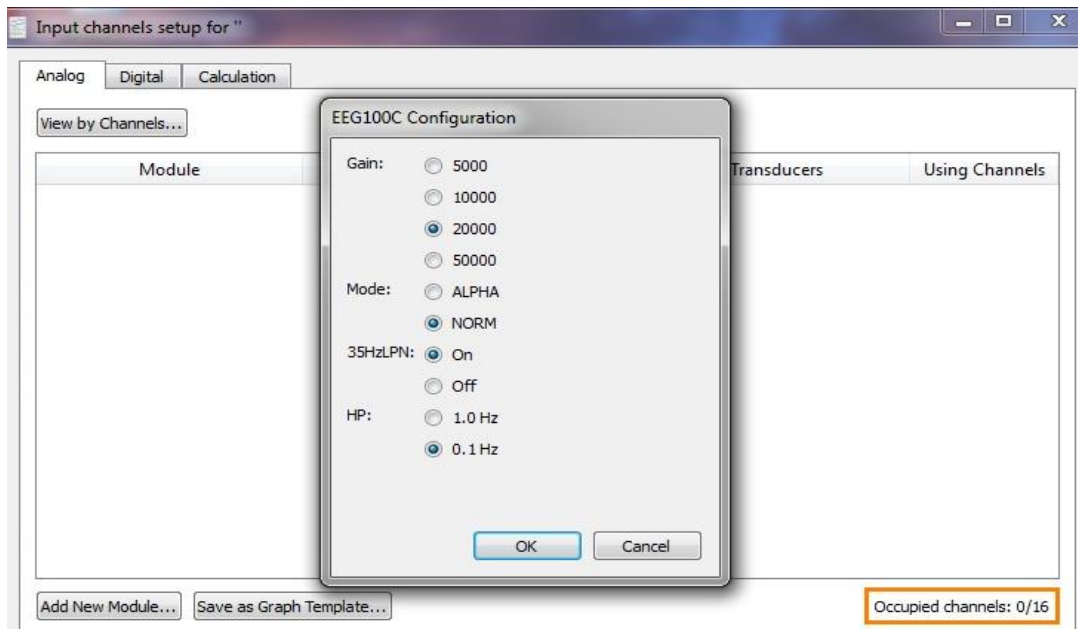


Figure8.9: Data acquisition configuration setting

Step 4: Click on calculation icon as shown in figure 8.10 to add comb filter on acquired data in real time.

Select the existing EEG channel to apply comb filter on it.

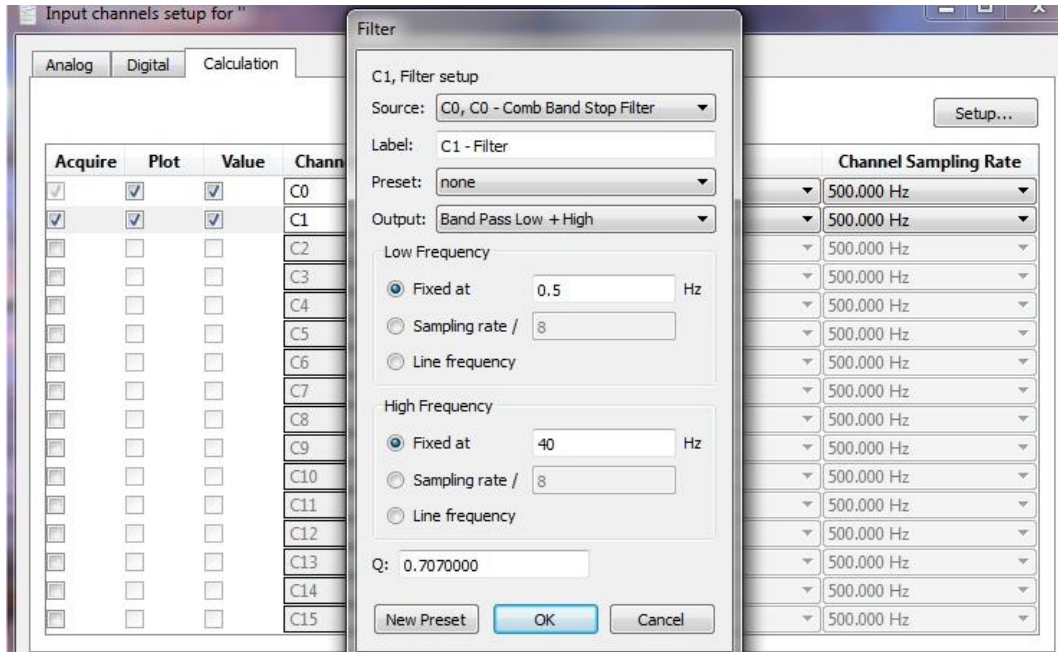


Figure 8.10: Comb filter set up

The figure 8.11 show the effect of comb filter. This filter removes the power line noise.

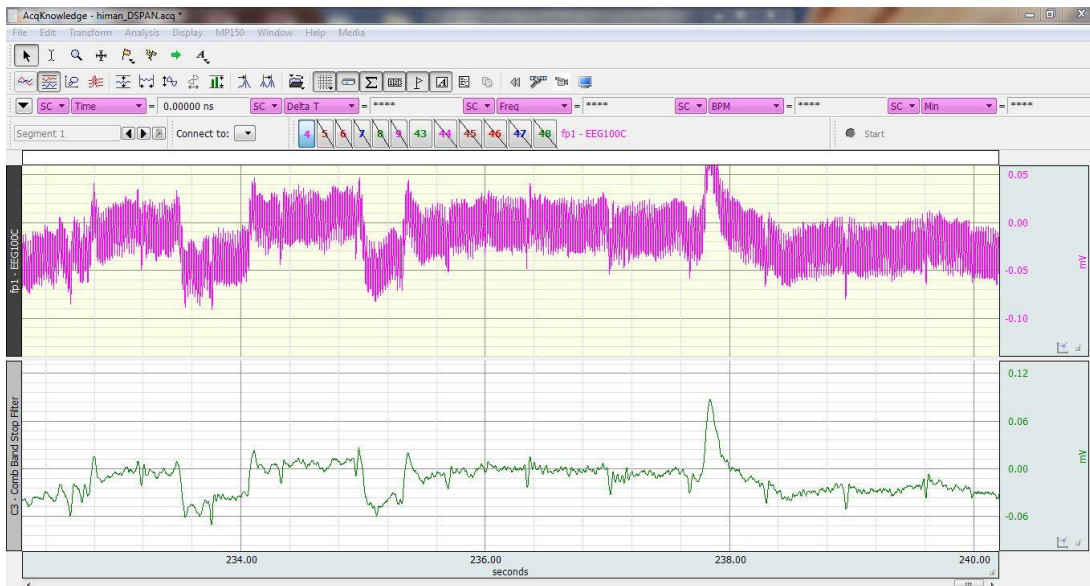


Figure 8.11: Power line noise removal by Comb filter

Step 5 The feature are calculated using inbuilt analysis programs. Click on analysis and select power spectral density as shown in figure 8.12

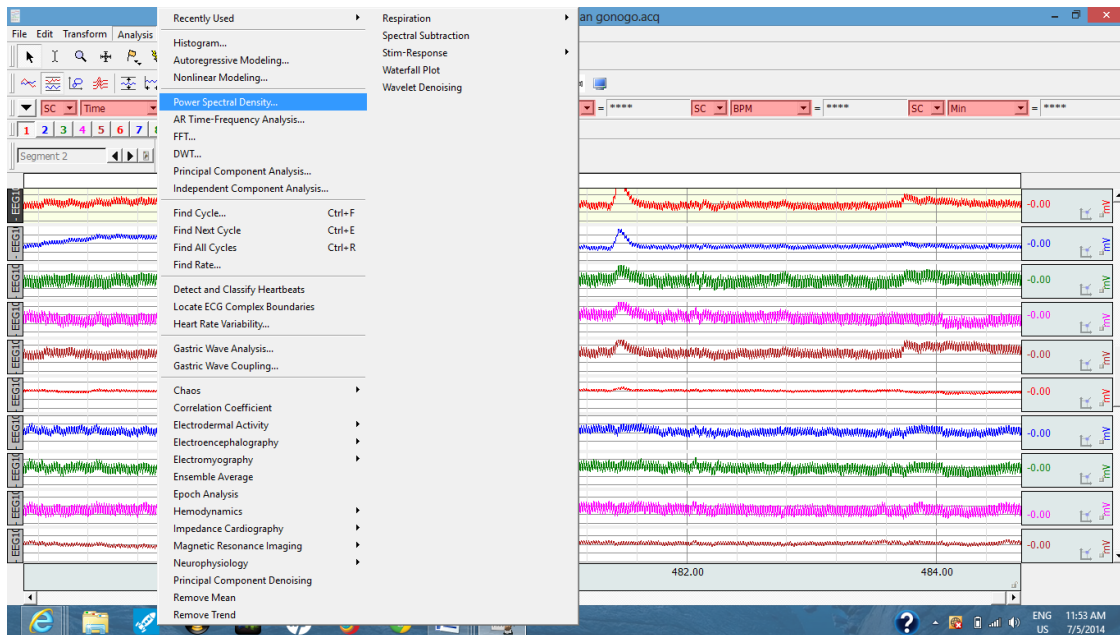


Figure 8.12: Drop down list for feature extraction from EEG signal

Step 6: Click on window and select hamming window to calculate the power spectrum density. The default setting for power spectrum density is shown in figure 8.13

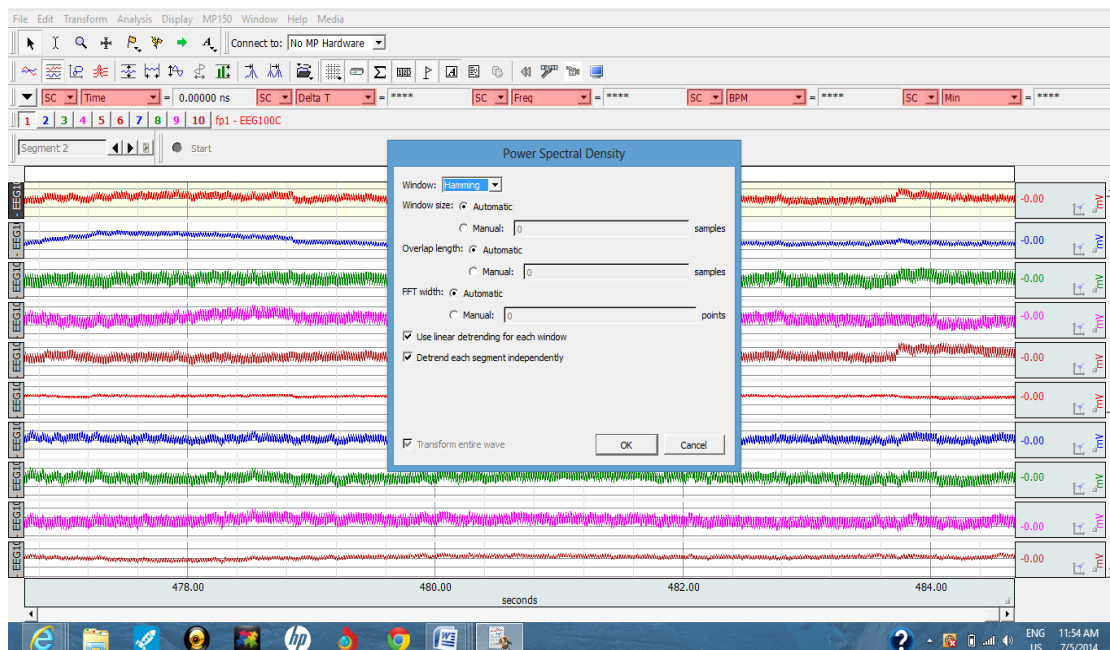


Figure 8.13: Power spectrum density calculation settings

Step 7: To save the power spectrum density file as shown in figure 8.14 , Click on file then save as excel file

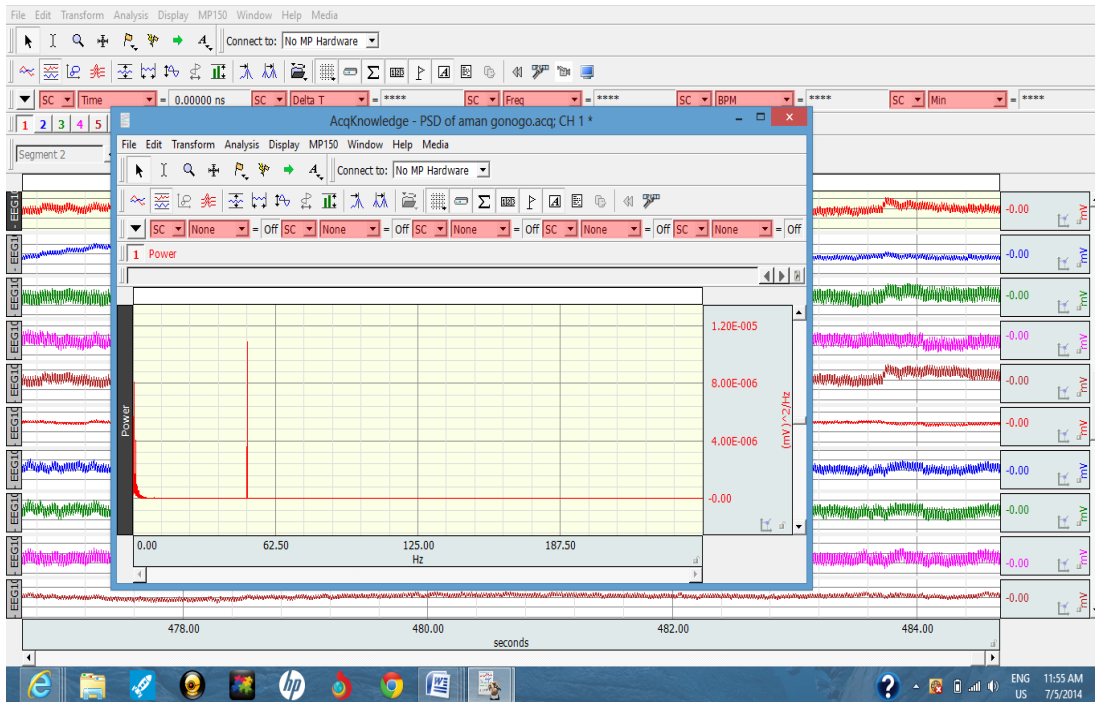


Figure 8.14: Power Spectrum density calculation

Step 8 The excel file is used to calculate power for various band. The power spectrum density excel file is shown in figure 8.15

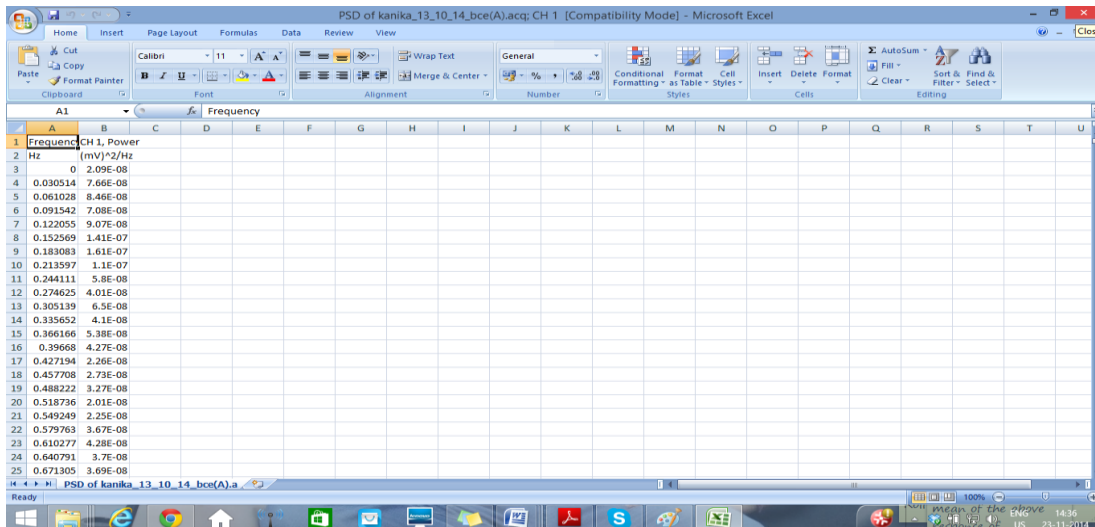


Figure 8.15: Power spectrum density excel file

Step 9: The excel file of power spectrum density generated from ACQknowledge software was imported in MATLAB for further processing

Power for various bands i.e.

- 1) Delta (0.5-4 Hz)
- 2) Theta (4-8 Hz)
- 3) Alpha (8-13 Hz)
- 4) Beta (13-30 Hz)

were calculated. The formula utilized for the calculation of EEG band power is given in equation 8.1.

$$\text{power} = \frac{\sum \frac{\text{mv}^2}{\text{Hz}}}{\text{no of samples}} \times \text{frequency range} \quad (8.1)$$

The MATLAB generates a excel file consisting of EEG band power shown in figure.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	4.88E-08	8.75E-09	1.11E-08	7.67E-09									
2	5.71E-08	4.33E-09	7.61E-09	3.64E-09									
3	1.43E-08	3.44E-09	7.61E-09	3.66E-09									
4	1.51E-08	3.73E-09	7.68E-09	3.72E-09									
5	1.38E-08	3.59E-09	8.1E-09	3.19E-09									
6	1.14E-08	4.2E-09	1.53E-08	5.22E-09									
7	1.32E-08	4.75E-09	1.11E-08	4.49E-09									
8	3.96E-09	2.75E-09	1.77E-09	3.76E-09									
9	1.4E-08	3.32E-09	5.49E-09	5.78E-09									
10	1.22E-08	5.07E-09	5.77E-08	7.51E-09									
11													
12	delta	theta	alpha	beta									

Figure 8.16: EEG band power

8.4 PSYCHOLOGICAL ASSESSMENT USING PEBL and

The three tasks were performed during psychological assessment of memory.

The tasks are DSPAN, CORSI and Sternberg.

Memory span for Corsi is automatically generated at the end of the task and is given equation 8.2.

$$\text{Memory span of Corsi} = \frac{\text{Startlength} + \text{Total Correct}}{\text{Trials Per Length}} \quad (8.2)$$

Memory span for Dspan is the maximum length of digits correctly recalled by the participant.

In Sternberg task a score of 1 is awarded for every right response. There are two sets of Sternberg task. The task first generates score1 and the second one score2. The maximum score1 of ten can be scored by the participant in first Sternberg task whereas in Sternberg second task the maximum score is eighteen.

For the calculation of enhancement the change in memory span is calculated. Then percentage in memory span is calculated using equation 8.3.

Change in memory span = Post Intervention memory span – Pre Intervention memory span

$$\text{Percentage Change in memory span} = \frac{\text{Change in memory span}}{\text{Pre Intervention memory span}} \quad (8.3)$$

8.5 DATA ANALYSIS

Statistically data is analysed using t-Test and correl.

1) T-TEST

The t-Test is used to test the null hypothesis that the means of two populations are equal. This test are classified in two types one tail and two tail t-test. In the former type the mean of one population is known to be greater than the other. The test is applied to check the probability of this occurrence in the population, whereas in the later type there is no information known regarding the mean of the two populations. The other classification of t test is based on the data i.e. paired, one sample and two sample. In paired the population is same but there is some change for example the effect of medicine. In one sample t test the mean is provided and the sample of population is used to test for similarity.

2) PEARSON'S CORRELATION COEFFICIENT

The Pearson's correlation coefficient is calculated to find the relationship between the two data sets. To calculate the correlation coefficient the correl function available in excel was used. The data was arranged in two arrays. The correlation coefficient between the two data arrays was computed using the following equation 8.4.

$$r = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}} \quad (8.4)$$

Where r Pearson Coefficient, x_i is first vector, y_i is second vector, \bar{x}, \bar{y} are mean values.

A value of Pearson coefficient of $|0.1|$ to $|.3|$ represents poor correlation, $|.3|$ to $|.5|$ moderate and $|.5|$ to $|1|$ strong correlation.

CHAPTER 9

RESULTS AND DISCUSSIONS

9.1 CORRELATION BETWEEN MEMORY TASKS

In this research the results suggest that the memory tasks are different. There are two categories of memory tasks which are verbal and non verbal memory task. The verbal memory task involves learning of certain characters whereas in case of non verbal memory task the participants learn the spatial changes. In both the task memory is required. It may be a possibility that the performance of the participants varies among these tasks. We calculated coefficient of variance for each task. We also calculated the Pearson coefficient to find the correlation between the two tasks if any. A coefficient value of 0.5 and above depicts a strong correlation between the two entities. The table 9.1 depicts the performance parameters i.e. memory span/score for each participant. The table 9.2 depicts the coefficient of variance calculated for the data.

Table 9.1: Scores and Memory Span

Subject	Memory Span (Corsi)	Memory span (Dspan)	Sternberg score 1	Sternberg score 2
1	5	8	10	18
2	5	6	8	17
3	8	10	10	18
4	7.5	9	9	14
5	5.5	7	8	17
6	6.5	8	8	17
7	6.5	5	10	18
8	6.5	7	10	18
9	5.5	7	9	17
10	4.5	8	10	16
11	6.5	8	9	18
12	5	8	10	18
13	6	8	10	18
14	5	9	7	17

Table 9.2: Coefficient of variance

Tasks	Memory Span (CORSI)	Memory span (DSPAN)	Sternberg score 1	Sternberg score 2
Coefficient of variance	0.174595	0.164195	0.11234	0.065162

Table 9.3: Pearson coefficient for correlation between tasks

TASKS	Pearson Coefficient
Corsi – Dspan	0.305924

It can be inferred from table 9.3 that the correlation between the two tasks is weak. The coefficient value is less than 0.5 for the task DSPAN and CORSI. Therefore it may be concluded that the tasks are different.

9.2 CORRELATION BETWEEN EEG ALPHA BAND POWER AND MEMORY SPAN

In this research it was observed that the memory span obtained after the end of task bears a relationship with specific brain wave at a particular electrode. The table 9.4 and table 9.5 depicts the memory span and the EEG alpha band power. Pearson’s coefficient was calculated between the task memory span and the alpha EEG band powers at two electrodes O1 and O2.

Table 9.4: DSPAN task memory span and EEG alpha band power over occipital electrode

Subject Number	DSPAN Memory Span	ALPHA BAND POWER OCCIPITAL ELECTRODES (mV) ²	
		O1	O2
1	6	3.49E-09	2.26E-09
2	8	1.57E-08	1.92E-08
3	9	2.88E-09	5.01E-09
4	9	1.98E-09	5.47E-09
5	7	1.52E-08	1.04E-08
6	5	7.21E-09	2.39E-08
7	8	1.48E-08	1.28E-08
8	5	7.65E-09	1.6E-08
9	7	1.11E-08	2.07E-08
10	8	5.11E-09	1.34E-08
11	8	1.12E-08	1.5E-09
12	7	1.34E-08	1.55E-08
13	9	1.58E-08	7.18E-09
14	6	1.24E-08	1.53E-08

Table 9.5: CORSI task memory span and EEG alpha band power over occipital electrode

Subject Number	CORSI Memory Span	ALPHA BAND POWER OCCIPITAL ELECTRODES (mV) ²	
		O1	O2
1	7	5.06E-09	6.43E-10
2	5.5	3.23E-09	5.35E-09
3	7.5	4.8E-10	1.18E-09
4	5.5	2.27E-08	2.1E-08
5	6.5	9.32E-09	1.2E-08
6	6.5	7.79E-09	1.51E-08
7	6.5	7.66E-09	1.29E-08
8	5.5	1.45E-09	2.29E-09
9	6.5	9.11E-09	1.5E-08
10	6	5.75E-09	1.08E-09
11	4.5	5.88E-08	8.78E-09
12	5	3.78E-08	1.12E-08
13	7	9.12E-09	1.18E-08
14	6.5	1.55E-08	1.93E-08

The figure 9.1 shows the relation between the memory span of task DSPAN and EEG alpha band power. A Pearson’s coefficient of -0.50385 is observed and this value suggests that there is relation between the memory span and EEG alpha band power.

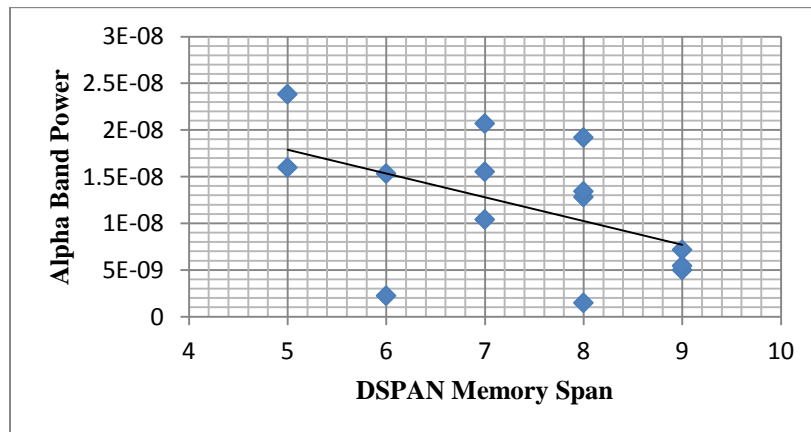


Figure 9.1: Relationship between EEG alpha band power and DSPAN memory span

The Pearson's coefficient calculated between the EEG alpha band power with the memory span of CORSI comes out to be -0.721. It is a high value of correlation. It may be concluded from this value that the memory span of task CORSI has a relationship with EEG alpha band power. The figure 9.2 shows the relationship between the two.

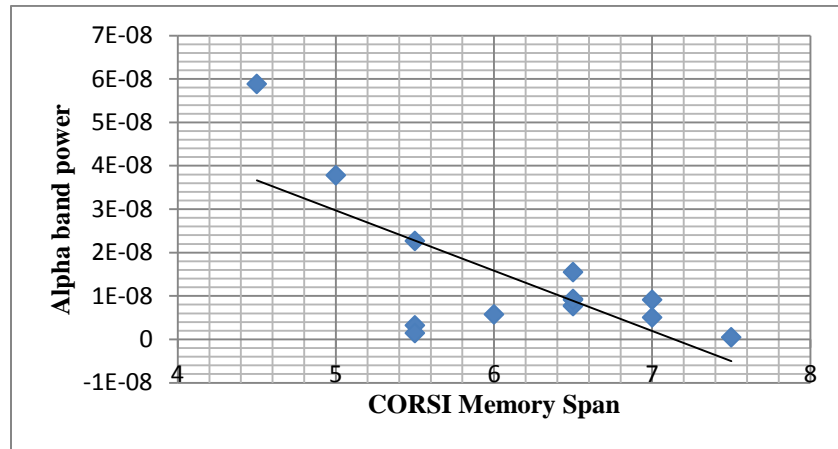


Figure 9.2: Relation between CORSI memory span and EEG alpha band power

9.3 NEURAL CORRELATE OF MEMORY

The neural correlate of memory is the relationship between the stimuli and EEG brain wave rhythms. It has been observed that there is a significant difference between the brain wave during relaxed state and during memory task. Also these brain wave changes may be more prominent at certain electrode locations. It is known that the memory resource is only allocated to a particular task if we are paying attention to it.

9.4 MEMORY ENHANCEMENT USING MEDITATION AS INTERVENTION

The memory is assessed using psychological and physiological assessment techniques. The psychological assessment has been conducted using DSPAN and CORSI. The both assessment task generate memory span at the end. The physiological assessment has been conducted using feature extracted from EEG signals. The EEG alpha band power for occipital electrodes has been calculated for the task and for baseline EEG reading. The table 9.6 depicts the memory span of task DSPAN along with alpha band power ratio. The table 9.7 depicts the memory span of task CORSI along with alpha band power ratio

Table 9.6: Pre and Post intervention results of DSPAN

S. No.	DSPAN							
	MEDITATOR				CONTROL GROUP			
	PRE		POST		PRE		POST	
	Alpha Ratio	Score	Alpha Ratio	Score	Alpha Ratio	Score	Alpha Ratio	Score
1	0.133119	8	0.224939	8	0.744712	6	0.369146	8
2	0.855259	8	0.919662	7	0.101173	10	0.121185	8
3	0.06585	5	0.288645	8	0.051655	9	0.122997	8
4	0.129104	7	0.1167	8	0.113395	7	0.103093	8
5	0.126343	7	0.043516	7	0.119035	8	0.031715	7
6	0.318529	8	0.60001	10	0.325468	8	0.091078	8
7	0.131394	6	0.626106	9	0.358453	8	0.220723	9
MEAN	0.251371	7	0.402797	8.142857	0.259127	8	0.15142	8

Table 9.7: Pre and Post intervention results of CORSI

S. No.	CORSI							
	MEDITATOR				CONTROL GROUP			
	PRE		POST		PRE		POST	
	Alpha Ratio	Score	Alpha Ratio	Score	Alpha Ratio	Score	Alpha Ratio	Score
1	0.092528	5	0.160295	6	0.641711	5	0.233291	5.5
2	1.168965	6.5	0.110696	7	0.168953	8	0.075603	7
3	0.067078	6.5	0.039347	6.5	0.012486	7.5	0.162553	7
4	0.088925	6.5	0.528094	6.5	0.169438	5.5	0.131586	5.5
5	0.16163	5.5	0.052358	5.5	0.081663	4.5	0.031819	4.5
6	0.567482	6.5	0.864475	6.5	0.108627	5	0.069971	6
7	0.315297	5	1.346833	6.5	0.183854	6	0.125988	6
MEAN	0.351701	5.9285	0.443157	6.357143	0.195247	5.9285	0.118687	5.9285

The figure 9.3 and figure 9.4 show the comparison between pre and post intervention mean memory span of DSPAN and CORSI memory task

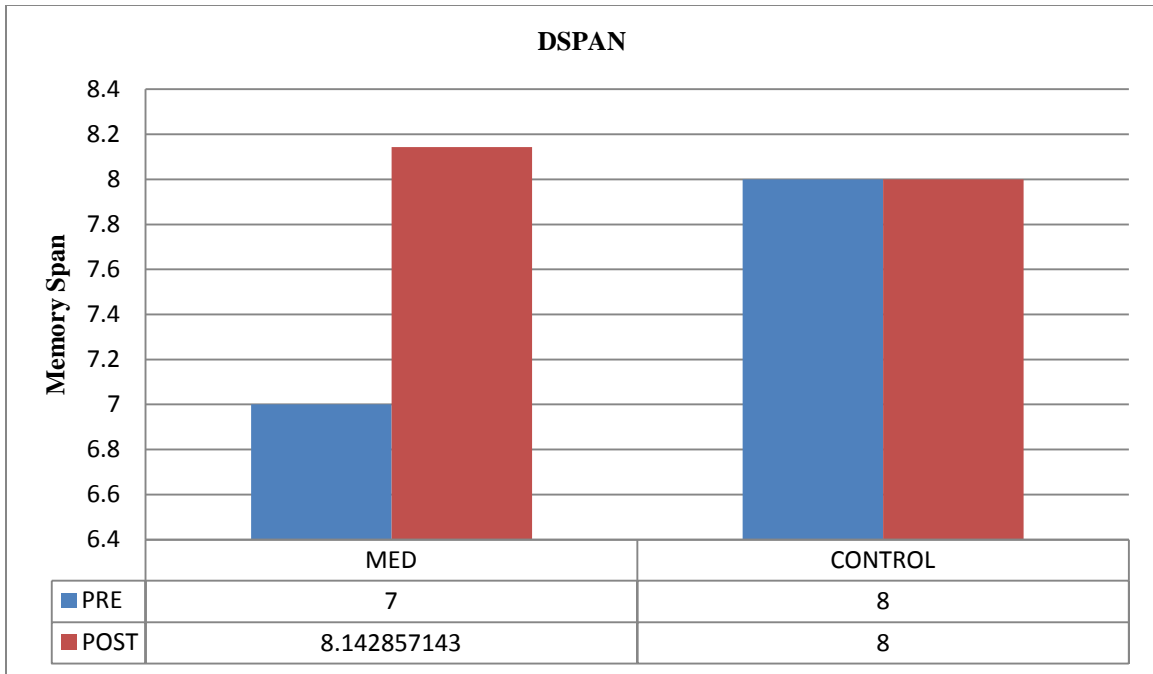


Figure 9.3: Comparison of pre and post intervention mean memory span of DSPAN

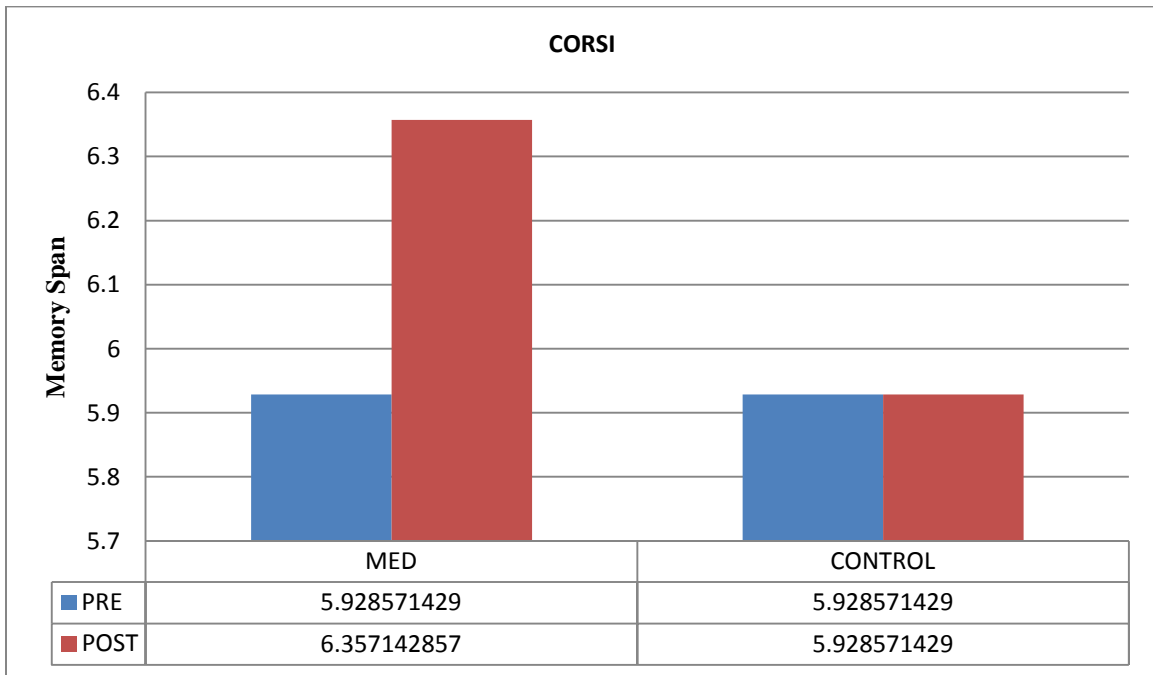


Figure 9.4: Comparison of pre and post intervention mean memory span of CORSI

The figure 9.5 and figure 9.6 show the alpha band power ratio for pre and post intervention of DSPAN and CORSI memory task

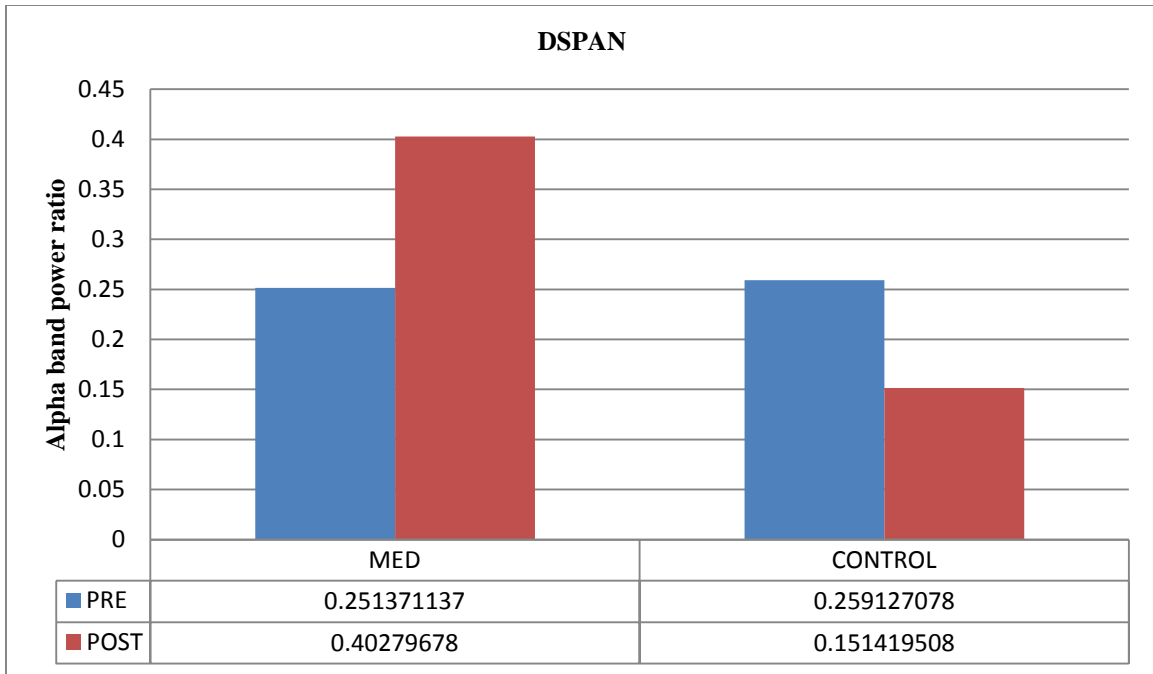


Figure 9.5: Comparison of pre and post intervention mean alpha band power ratio of DSPAN

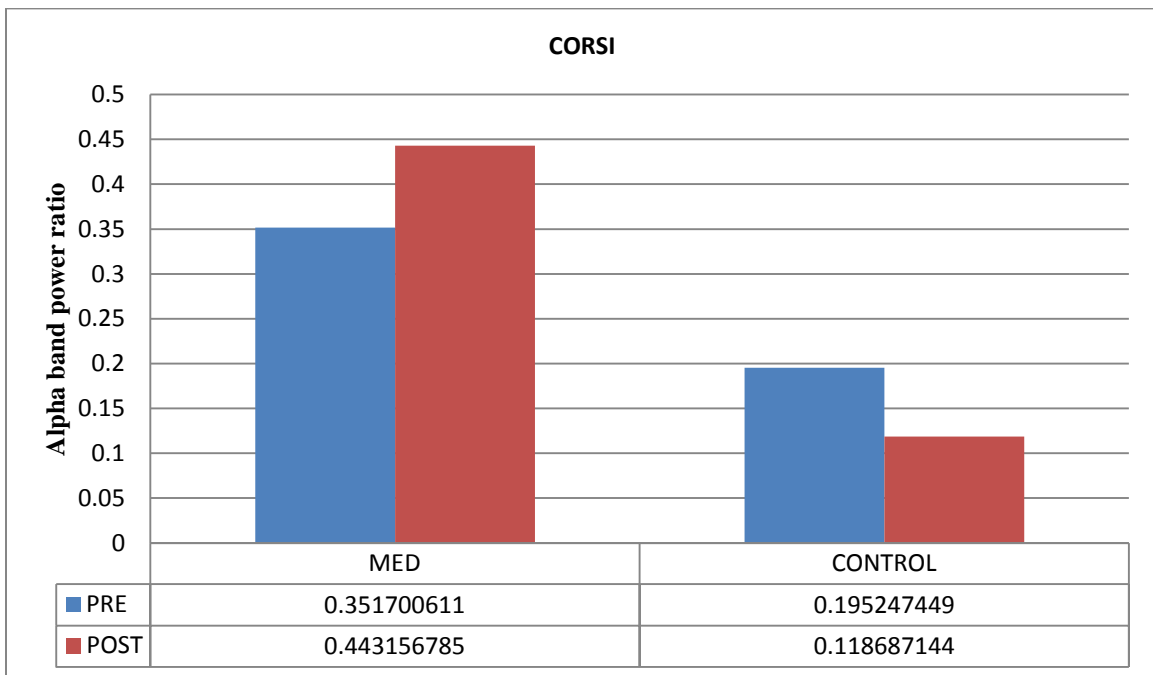


Figure 9.6: Comparison of pre and post intervention mean alpha band power ratio of CORSI

We have applied the T-Test in order to check whether our finding is statistical significant or not. We used one tail paired T-Test to compare the memory span of meditator group obtained during

pre and post intervention. The same test was applied for control group. The p values obtained are shown in table 9.8 and table 9.9.

Table 9.8: P-value using one tail paired T-Test between pre and post intervention memory span of Meditators

Memory Task	CORSI	DSPAN
P value	0.055608	0.051523

Table 9.9: P-value using one tail paired T-Test between alpha band of control group

Memory Task	CORSI	DSPAN
P value	0.5	0.5

Table 9.10: P-value using one tail paired T-Test between pre and post alpha band ratio of Meditators

Memory Task	CORSI	DSPAN
P value	0.358269	0.044064

Table 9.11: P-value using one tail paired T-Test between pre and post alpha band ratio of control group

Memory Task	CORSI	DSPAN
P value	0.134359	0.059248

There is a statistically significant improvement in memory span of participants of meditators' group for both the tasks, whereas memory deteriorates in control group. The mean memory span in case of DSPAN memory task increased from 7 to 8.142 whereas it remained same for control group. Also the mean EEG alpha band power has increased in case of meditators. The increased alpha band power is an indicator of relaxation so it may be concluded that the participants in meditators group were relaxed while performing the task.

The mean memory span obtained for the task CORSI in case of meditators group increased from 0.35 to 0.44 whereas the mean memory span has been observed to be decreased in control group. Also the mean EEG alpha band power of meditators group has increased. It has been reported that increase in alpha is an indicator of relaxation. So there is an improvement in memory task performance of participants belong to mediators' group and they were relaxed while performing the tasks.

10.1 CONCLUSION

In this research we have selected fourteen participants. The participants were divided in two groups of seven participants each. The memory span of the participants has been assessed using Psychological and physiological assessment techniques. The participants in the meditators' group made to undergo meditation for fifteen days. The following conclusions have been drawn from the results obtained.

- 1) We have calculated the Pearson's coefficient between the memory span of the participants obtained from the task CORSI and DSPAN. The coefficient value of 0.305924 has been observed. It may be concluded that the two tasks are not related and hence have to be performed to assess the various aspect of memory.
- 2) We have computed the Pearson's coefficient between the EEG alpha band power and memory span of tasks. We observed a negative relation between the memory span and EEG alpha band power. It may be concluded that higher the memory span lower will be the alpha band power.
- 3) It has been observed that there is a statistical significant improvement in the memory span in meditators' group, whereas the memory deteriorates in the control group. The mean memory span of the task DSPAN increased from 7 to 8.1428 in mediators group whereas in case of control group there is no change in memory span. In the second memory task CORSI it has been observed that there is increase in mean memory span from 5.928 to 6.357 whereas in case of control group there is no change in memory span.
- 4) It is know that the alpha band power is related to relaxation. A higher value of alpha band power is inferred as relaxed state of mind. It has been reported that practicing meditation leads to relaxed state of mind. We have observed an incremental change in alpha band power ratio along with improvement in memory span in meditators' group. The mean EEG alpha band power ratio has increased from 0.251 to 0.402 in meditators' group whereas it has decreased from 0.259 to 0.1514 in case of control group for DSPAN task. The mean EEG alpha band power ratio has increased from 0.351 to 0.443 in meditators' for CORSI task. It may be concluded that there is an improvement in performance of

memory task as well as the participants in meditators' group were relaxed while performing tasks.

10.2 FUTURE SCOPE

The current research has been conducted on healthy participants engaged in graduation and post graduation degree courses of engineering. The age group of participants is 20-25 years. In future this research can be conducted on different demographic groups such as people belong to different region, educational background ,age group etc. The research can also be conducted on large population size. We can also research on the possible effect of other interventions and meditation techniques on memory.

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