



**Faculty of Cognitive Sciences and Human Development**

**The Effect of Neurofeedback Training on Mild Cognitive Impairment  
Elderly in Kuching Area**

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## **DECLARATION**

The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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## **ABSTRACT**

Neurofeedback training (NFT) is a self regulation technique that helps individual learns to control or change their brain activity. This study aimed to apply neurofeedback to enhance the cognitive performance in elderly with Mild Cognitive Impairment (MCI). Using Quantitative Electroencephalography (QEEG) to record and analyzed the brain rhythms patterns of elderly before and after neurofeedback, this study then focused on alpha wave in the neurofeedback training as it was positively associated with cognitive performance decline in elderly. Ten subjects were selected through convenience and purposive sampling after administration of MMSE and other instruments and then were assigned to experimental (NFT) and control group (no NFT). With 15 sessions of alpha neurofeedback, increase in alpha absolute power was rewarded while simultaneous suppression of theta and beta2 were done in experimental group. Results showed that after completion of neurofeedback, all subjects in experimental group learn to increase their alpha absolute power while mixed result was recorded for suppression of theta and high beta either at individual, inter and intra group level. Increase in absolute power in pre and post QEEG in inter (within group) and intra (between group) group level were significant in alpha rhythms except for at location T3T4 in intra group analysis. Cognitive enhancement was measured in terms of working memory (Digit Span & Arithmetic) & processing speed (Symbol Search & Coding) components test of WAIS-IV. Cognitive results in individual level revealed that pattern of increase and decrease of score was regular in experimental group with all of them shown increment in DS, AR and SS while for CD only 2 had lower score in post CD. In control group, the pattern of changes was not regular with few had increment in certain test than and some did not had changes in score at all. At grouped level, significant increment observed in DS and SS in experimental group only. These

results suggest that MCI elderly could learn to increase specific components of EEG activity that such enhanced activity may facilitate in working memory and processing speed enhancement.

**Keywords:** Neurofeedback training, quantitative electroencephalogram (QEEG), mild cognitive impairment (MCI), elderly, cognitive enhancement

## ***Kesan “Neurofeedback” Ke Atas Warga Tua Yang Mempunyai Kecelaan Kognitif Ringan***

### **ABSTRAK**

*“Neurofeedback” ialah satu teknik pengawalan sendiri yang membolehkan seseorang individu untuk mengawal atau mengubah aktiviti gelombang otaknya. Kajian ini bertujuan untuk menambahbaik prestasi kognitif warga tua yang mempunyai kecelaan kognitif (MCI) dengan menggunakan “neurofeedback”. Dengan bantuan “Quantitative Electroencephalogram” (QEEG) untuk merekod serta menganalisis gelombang otak warga tua sebelum and selepas “neurofeedback”, kajian ini memfokuskan kepada gelombang alpha kerana ianya berkait rapat dengan fungsi kognitif dalam kalangan warga tua. Sepuluh subjek yang dipilih melalui “convinence” dan “purposive sampling” selepas ditapis melalui MMSE dan instrumen lain dan seterusnya dibahagikan kepada kumpulan eksperimen dan kawalan. Semasa 15 sesi “neurofeedback”, kekuatan mutlak gelombang alpha dinaikan manakala gelombang theta dan beta2 dikurangkan untuk subjek kumpulan eksperimen. Selepas tamat sesi neurofeedback, semua subjek kumpulan eksperimen menunjukkan peningkatan kekuatan mutlak alpha di peringkat individu dan berkumpulan. Untuk theta dan beta2, keputusannya tidak seragam untuk kedua-dua peringkat. Peningkatan pada kekuatan mutlak pada QEEG pertama dan kedua adalah signifikan untuk gelombang alpha untuk analisis dalam kumpulan dan antara kumpulan (kecuali pada T3T4). Perubahan kognitif telah diukur menggunakan ujian komponen WAIS-IV yang merangkumi ujian “working memory” (“Digit Span” & “Arithmetic”) & “processing speed” (“Symbol Search” & “Coding”). Kenaikan atau penurunan pada skor adalah seragam untuk kumpulan eksperimental dengan kesemua subjek menunjukkan peningkatan pada DS, AR dan SS manakala untuk CD hanya dua dari lima menunjukkan penurunan skor di peringkat individu. Di peringkat kumpulan eksperimen, hanya DS dan*

*SS menunjukkan peningkatan signifikan. Keputusan kajian menunjukkan bahawa warga tua yang mempunyai kecelaan kognitif boleh menaikkan gelombang komponen EEG; alpha dan seterusnya perubahan tersebut mungkin sekali membantu memberi perubahan positif kepada “working memory” dan “processing speed”.*

**Kata kunci:** *Neurofeedback, quantitative electroencephalogram (QEEG), kecelaan kognitif ringan, warga tua, perubahan kognitif*

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## LIST OF ABBREVIATIONS

|         |                                              |
|---------|----------------------------------------------|
| AD      | Alzheimer's disease                          |
| ADHD    | Attention deficit hyperactivity disorder     |
| AMCI    | Amnesic mild cognitive impairment            |
| AP      | Absolute power                               |
| APNA    | Asia Pacific Neurofeedback Association       |
| AR      | Arithmetic                                   |
| ARCD    | Age related cognitive decline                |
| BF      | Biofeedback                                  |
| CAMCOG  | Cambridge Cognitive Examination              |
| CD      | Coding                                       |
| CONT    | Control                                      |
| CSF     | Cerebrospinal fluid                          |
| DS      | Digit Span                                   |
| EEG     | Electroencephalography                       |
| EXP     | Experimental                                 |
| FDG-PET | Fludeoxyglucose positron emission tomography |
| FMRI    | Functional Magnetic Resonance Imaging        |
| GAD-7   | Generalized Anxiety Disorder 7               |
| ICA     | Independent Component Analysis               |
| MCI     | Mild cognitive impairment                    |
| MMSE    | Mini Mental State Examination                |

|          |                                                                     |
|----------|---------------------------------------------------------------------|
| MRI      | Magnetic resonance imaging                                          |
| NF       | Neurofeedback                                                       |
| NFT      | Neurofeedback training                                              |
| NIA-AA   | National Institutes of Health (NIH) and the Alzheimer's Association |
| PAF      | Peak alpha frequency                                                |
| PHQ-9    | Patient Health Questionnaire-9                                      |
| PS       | Processing speed                                                    |
| PSI      | Processing Speed Index                                              |
| QEEG     | Quantitative electroencephalography                                 |
| RCI      | Reliable change index                                               |
| s-LORETA | Standardized low resolution brain electromagnetic tomography        |
| SMR      | Sensory motor rhythms                                               |
| SPSS     | Statistical Package for the Social Sciences                         |
| SS       | Symbol Search                                                       |
| WAIS-IV  | Wechsler Adult Intelligence Scale-IV                                |
| WM       | Working memory                                                      |
| WMI      | Working Memory Index                                                |

## LIST OF SYMBOLS

|                 |           |
|-----------------|-----------|
| $\mu\text{V}^2$ | Microvolt |
| Hz              | Hertz     |

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.0 Introduction**

The purpose of this research is to apply alpha neurofeedback (NF) protocol to enhance the cognitive performance in elderly with mild cognitive impairment (MCI). To achieve the goals of this research, electroencephalography or widely known as EEG; a non-invasive real time methods used to view and recording brain activity before applying neurofeedback (NF) training. Quantitative EEG or QEEG is a collection of quantitative approach designed to process EEG signals. Neurofeedback is one of neurotherapy methods for modifying brain function based on human brain neuroplasticity ability (Kropotov, 2010) in various condition including cognitively impaired elderly. Mild cognitive impairment (MCI) refers to a transitional stage between normal aging and dementia, specifically Alzheimer's disease (AD) in which mild cognitive loss is detectable through neuropsychological test but it is not capable enough to affect the individual's ability to carry out everyday activities (Ganguli et al., 2004; Kelley and Petersen, 2007; Petersen et al., 2001). MCI elderly has shown to display a decline in a few cognition aspects specifically in working memory and processing speed (Saunders and Summers, 2011). Application of neurofeedback in this study was applied on elderly with mild cognitive impairment because the brain activity of elderly showed a decrease in high frequency bands; particularly alpha (Luckhaus et al., 2008) while increase in low frequency bands; notably theta (Jelic et al., 2000). Extensive information on reasons to conduct this research is written in the next section of this chapter which including background of study, problem statement, objectives, operational definition and lastly on the significance of study.

## **1.1 Background of Study**

Elderly of the age of 60 and above make up of 7.7% of the whole population in Malaysia and this number is expected to multiply up to 14.7% by 2030 (World Population Prospects, 2010). Cognitive performance of elderly will decline with age and this make them more susceptible to get age related cognitive impairment disease such as mild cognitive impairment and even worse it may lead to dementia (Baker et al., 2008; Rosdinom et al., 2011). The susceptibility for elderly to involve in such condition leads to various researches on how to slow down and combat the condition. Non-pharmacological approach such as neurofeedback training has caught researchers' attention to curb this problem. Neurofeedback training (NFT) is a self regulation technique that helps individual learns to control or change their brain activity (Frank et al., 2010) which has been proved to improve elderly cognitive performance (Angelakis et al., 2007; Becerra et al., 2012; Hanslmayr et al., 2005)

## **1.2 Problem Statement**

Mild cognitive impaired elderly constitute a high-risk population for developing dementia, in particular Alzheimer's disease (Manly et al., 2008; Petersen, 2004). With the yearly increasing number in AD cases worldwide, MCI has become a serious issue to be investigated further to find ways to at least slowing its progression to AD (Alzheimer's Association, 2018). Researchers has been doing extensive work in characterizing MCI by using multimodalities imaging methods to identify the brain anatomy & physiology, brainwaves patterns and also cerebrospinal fluid (CSF) for quantification of specific proteins. In terms of pharmacological treatment, MCI patients will use cholinesterase inhibitors, the same drug prescribed to AD patients and vitamins consumption such as vitamin B, Vitamin E, and Omega-3 fatty acids (Vega and Newhouse, 2014).Non-

pharmacological approach such as neurofeedback training has been seen as one of the promising approach to at least slowing down cognitive related problems in elderly (Becerra et al., 2012; Luijmes et al., 2016).

### **1.3 Objective**

#### **1.3.1 Main Objective**

To enhance the cognitive performance in MCI elderly with alpha protocol neurofeedback training.

#### **1.3.2 Specific Objective**

- i. To study the changes in absolute power of alpha, theta & high beta rhythms in EEG
- ii. To evaluate the changes in cognitive performance in terms of working memory components (Digit Span & Arithmetic) and processing speed (Symbol Search & Coding) after neurofeedback training

#### **1.3.3 Research Hypothesis**

Alpha protocol neurofeedback training will enhance cognitive performance in MCI elderly by targeting the parieto-occipital regions in the training and by focusing on up training alpha while suppressing theta and beta2 activities.

### **1.4 Conceptual and Operational Definition of Terms/Variables**

#### **1.4.1 Mild Cognitive Impairment**

Mild cognitive impairment (MCI) refers to a transitional stage between normal aging and dementia in which mild cognitive loss is detectable through neuropsychological test but it is not capable enough to affect the individual's ability to carry out everyday activities (Ganguli et al., 2004; Kelley and Petersen, 2007; Petersen et al., 2001). There are varieties

of neuropsychological test used to describe the cognitive loss in MCI elderly. This research conducted a test using Malay Mini Mental State Examination (MMSE) to measure impairment and MCI subjects is defined as elderly with a score of 20 – 26 (Ibrahim et al., 2009; Razali et al., 2012).

#### **1.4.2 Dementia – Alzheimer’s Disease (AD)**

Dementia is an overall term that describes a wide range of symptoms associated with a decline in memory or other thinking skills severe enough to interfere with daily life. Memory loss and inability to pay attention are examples of symptoms of dementia. Alzheimer's is the most common type of dementia which contributes to 60- 80 % of dementia cases (Alzheimer’s Association, 2018).

#### **1.4.3 Elderly**

The World Health Organization (WHO) defines elderly as people aged 60 years and above (World Health Organization, South East Asian, 2018) . The elderly population is expected to increase from 1.05 million in 1990 to 3.26 million in 2020, showing an increase of 210%.(Mafauzy, 2000).

#### **1.4.4 Electroencephalography (EEG) and Quantitative Electroencephalography (QEEG)**

Electroencephalography (EEG) is a non-invasive neuroimaging method used to record electrical activity of the brain. Quantitative EEG or QEEG is a collection of quantitative approach designed to process EEG signals. High spatial and temporal resolution of EEG becomes one of the reasons of renaissance of EEG nowadays (Kropotov, 2010).

#### 1.4.5 Brain Waves/Rhythms Frequency

Brain waves or rhythms are electrical signals of the brain recorded by EEG. They are divided into five different categories according to frequency bands, namely, delta (below 4Hz), theta (4-8Hz), alpha (8-12 Hz), beta (12 – 30Hz) and gamma (beyond 30 Hz). Alpha can be further categorized into lower alpha (8 – 9 Hz) and upper alpha (10 -12 Hz) (Petsche et al., 1997) and this study referred alpha as alpha unselective band as alpha with frequency of 8-12 Hz and upper alpha is defined at frequency of 10 – 12 Hz. Beta are divided into three sub-waves which are with beta1 at 13 – 16 Hz, beta2 at 16 – 20 Hz and beta3 at 20 -28 Hz (Rangaswamy et al., 2004).

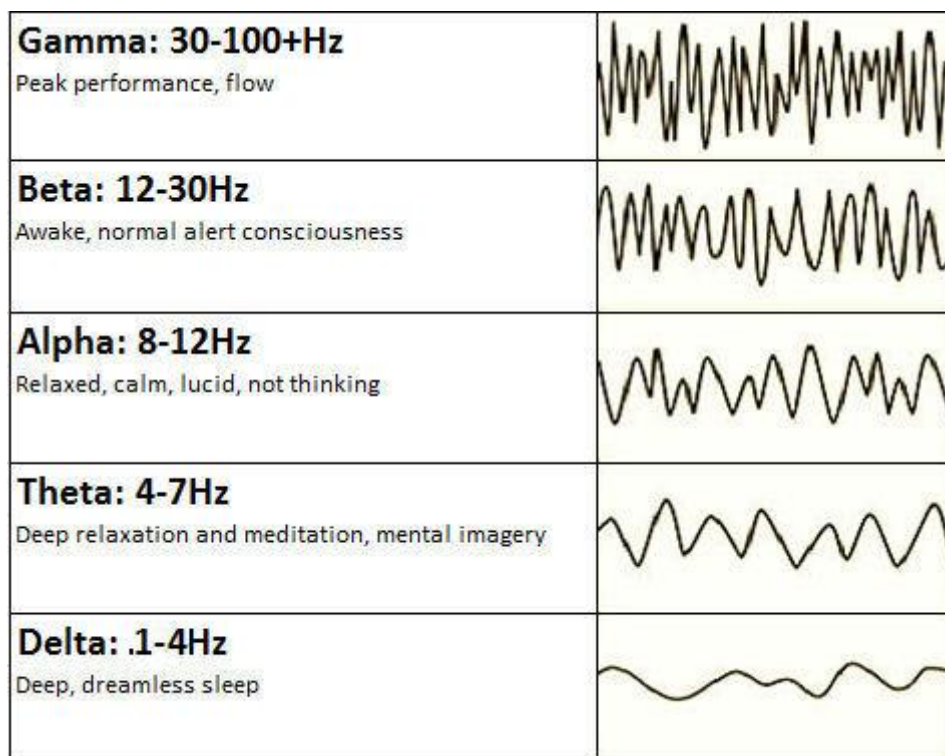


**Figure 1.1:** Brain waves of EEG (Source: Brainwave Frequencies Chart - Mind Body Vortex, 2017)

#### **1.4.6 Neurofeedback Training (NFT)**

Neurofeedback training is an operant conditioning self-regulation technique through which individual learns to change their brainwave activity. In this research, alpha neurofeedback training protocol is referring to up training/rewarding the alpha (8 – 12 Hz) and suppressing/inhibiting theta (4- 8 Hz) and beta2 (16 – 20 Hz).

#### **1.4.7 Cognitive Performance**

Cognitive performance is the ability to utilize the knowledge acquired by mental processes in our brains. Examples mental processes are the sleep-wake cycle, attention, perception, mood, emotion, appetite-satiety and memory. In this research, cognitive performance is referring to working memory performance and processing speed of Weschler Adult Intelligent Scale-IV (WAIS-IV). Measurement of the improvement in performance is operationally defined as post test score minus pre test score.

#### **1.5 Significance of Study**

Currently, an average Malaysian man is expected to live up to 71 years of age and a Malaysian woman up to 77.1 years of age. 7.7% of the whole population in Malaysia is comprised of the age of 60 and above comprised this figure is expected to climb up to 14.7% by 2030 (World Population Prospects, 2010). With the escalation of number in elderly population, it is predicted age-related disease which inflicting with cognitive function in adult such as mild cognitive impairment (MCI) or dementias will increase too (Mafauzy, 2000). An alarming fact is, it is forecasted that number of dementia cases in the developing world will increase by 100% between 2001 and 2040 (Rashid et al., 2012). It seems that the rate of dementia will increase from 9.4% in 2000 to 23.5% by 2050 in the population over 60 years of age (Nizamuddin, 2000). Hence, this study aims to apply

neurofeedback to enhance the cognitive performance in elderly with MCI to increase their quality of life during their aging period and even slowing down the risk of getting cognitive impairment related disease.

### **1.6 Limitation and Recommendation**

Through conducting the study and revising literature, there are a few limitations encountered and hereby I suggested recommendations to overcome or improve the existing study for the future research. The main limitation of this study is the small number of participants who are committed to participate until the end. Even though the number of people who passed the screening criteria was considered as enough but due to researcher's and subject's time constraint, transportation problems and others most of them could not participate in the study. Probably to overcome these problems, it is recommended to select elderly who lived in elderly care centre where a large number of people could be reached at one time. Next, the number of neurofeedback sessions in this study was considered as short (15 days) as compared to other studies. The effect of neurofeedback might be more robust in terms of absolute power changes and cognitive results if the numbers of sessions are increased. In terms of protocol, if separate protocol for each alpha, theta and beta2 is carried out for different groups, the changes in absolute power and its relationship with cognitive results will be clearer even though it is well known of alpha relation to cognitive performance in general.

### **1.7 Conclusion**

This study applied a non-pharmacological approach which was neurofeedback to enhance cognitive performance in elderly with mild cognitive impairment because cognitive

performance of elderly will decline with age and this make them more susceptible to be afflicted with age related cognitive impairment that will progress into dementia.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.0 Introduction**

This chapter portrayed a few vital aspects of neurofeedback, EEG and its relation to elderly with cognitive problems highlighted in literature. The first part of this chapter documented neurofeedback history and its application in various settings. The second part depicted the brain waves pattern of elderly afflicted with mild cognitive impairment (MCI) while the next part gave an overview of our current aging status. The last part highlighted on the cognition aspects that are related to aging and MCI.

#### **2.1 Neurofeedback Training**

##### **2.1.1 The History and Mechanism of Neurofeedback**

Electroencephalogram (EEG) biofeedback, then, now widely known as neurofeedback was discovered as early as 1960s. At that time, it was proven that brain patterns could be reconditioned and retrained. However, due to lack of convincing evidence and numbers of flawed studies, it was sidelined by science in 1980s. It was back on track after a series of researches by Sterman and Lubar (Hammond, 2007). In his early work where his group experimented with cats, they applied the SMR operant conditioning on the cats and found the cats were resistant to seizure after an exposure to established convulsive doses of hydrazine. Consequently, the same neurofeedback protocol was tried on human with epilepsy and it was shown to reduce seizure rates and EEG abnormalities.

In Asia Pacific region, a centre in Singapore namely Spectrum Learning had offered neurofeedback since in 1995 and it was the first centre in Asia (Spectrum Learning - Asia's First Neurofeedback Center, 2018). The Asia's First Neurofeedback Conference was held

in 2015 in Singapore by the Asia Pacific Neuro-biofeedback Association (APNA) which targeted clinicians, researchers and also community from Asia Pacific region such as Malaysia, Indonesia, Philippines and others. APNA was formed to promote the professional and clinical use of neurofeedback and biofeedback in the Asia Pacific region by targeting the involvement of clinicians and researchers. The community would be benefitted by getting information on neurofeedback and biofeedback intervention (Asia Pacific Neurobiofeedback Association (APNA), 2018).

Neurofeedback training is an operant conditioning self-regulation technique through which individual learns to change their brainwave activity. It is done by placing one or more electrode/s on scalp to allow for measurement of real time electrical activity of the brain. Then, the high-tech electronic equipment provides an instantaneous feedback in the form of auditory or visual about the brain activity. With continuous neurofeedback, coaching, and practice, optimum brainwave patterns can usually be retrained in most people.

Underlying mechanism of neurofeedback is based on a few models and theories such as the Operant (Instrumental) Learning, Awareness Theory and Global Workspace Theory (Sitaram et al., 2017). The Operant Learning theory, as applied to neurofeedback, states; when correct or desired brain responses are reinforced by contingent feedback and/or reward, the control of brain activity proceeds. The theory considers three main elements in its description of the procedure, discriminative stimuli, responses and reinforcers. A large extant literature of operant learning in humans and animals has elucidated the neurophysiological correlates of operant learning and highlighted the selective involvement of prefrontal and striatal synapses. Awareness Theory is almost similar as the Operant Learning theory. It proposes that the feedback signal provides information about a

physiological response (that is, brain activity) to which the subject becomes aware of, and this leads to voluntary control over the response. The model considers three elements, awareness of reinforcers (feedback and reward), the reinforcer response contingency and the response itself.

### **2.1.2 Neurofeedback in Various Settings**

Neurofeedback training is widely utilized in variety of settings in order to improve cognition, academic performance, attention and etc either in normal people (Vernon et al., 2003) or in people with certain abnormalities such as Attention Deficits & Hyperactive Disorder (ADHD) (Bakhshayesh et al., 2011). It is common in neurofeedback field to use combination of a few brain rhythms in its training in both normal and abnormal subjects due to the fact that each rhythm has its own function as been described briefly in the Introduction section.

In a study aiming to improve working memory in young normal healthy subjects (Vernon et al., 2003), three distinct combination of brain rhythms were applied to three different group. One non-training group and two experimental groups were formed and each group was trained with either (i) rewarding SMR (12-15Hz), inhibiting theta (4-7 Hz) & beta (18 – 22Hz) and (ii) rewarding theta, inhibiting delta (0-4 Hz) & alpha (8-12 Hz). The electrode placement was Cz and training was done in twice a week with total of 8 sessions. After the training, the SMR-group exhibited a significant and clear improvement in cued recall performance, using a semantic working memory task and showed reduction in errors for two-digit sustained attention task while no improvement seen in either groups for three digits task. In term of waves, SMR training disclosed a within-session increase in SMR and

reductions in theta and beta. This was not achieved with theta training and contrastingly alpha increased relative to theta.

In ADHD cases in which the objective of neurofeedback is to reduce inattention, impulsivity and hyperactivity, beta is usually combined with SMR or theta. In a randomized reinforcer-controlled design study, neurofeedback (NF) aimed at theta/beta ratio reduction and EMG biofeedback (BF) aimed for forehead muscle relaxation in 35 children with ADHD. The children were randomly assigned to either therapy group (NF) or control group (BF) and underwent thirty sessions of neurofeedback at CPz and PCz electrode placement. After the completing all sessions, neurofeedback effectively reduced theta/beta ratios in NF group and EMG levels in BF groups were reduced as well. NF group showed improvement in attention and reaction times in psychometric test. To further support the psychometric test result, parents of children in NF group reported compelling reductions in primary ADHD symptoms and an increased in attention as compared to BF group (Bakhshayesh et al., 2011).

### **2.1.3 Neurofeedback and Cognitive Performance in Normal Elderly**

Alpha rhythm is correlated with cognitive performance in general (Angelakis et al., 2004, 2007; Hanslmayr et al., 2005). In normal elderly where theta activity is not as excessive as in elderly with cognitive impairment, theta is considered as a vital component to be enhanced particularly at pre-frontal cortex where part of working memory system is located whereby an increase in working memory load is associated with a concurrent increase in theta power (Grunwald et al., 2001). Increase in beta2 or high beta rhythms is related to emotional intensity particularly anxiety or stress (Seo and Lee, 2010).

Alpha neurofeedback training in normal elderly had shown that older people could improve their cognitive performance in certain aspect of cognition such as working memory, processing speed executive function and etc. In an exploratory study, peak alpha frequency (PAF) and alpha amplitude were inhibited and enhanced; (i) PAF inhibited, alpha amplitude rewarded (ii) PAF rewarded, alpha amplitude inhibited with one mock feedback control. In (i), it was shown that the elderly subjects had improvements in memory while in (ii) there was a general improvement in speed of processing and executive function after 35-38 sessions which was considered as a good length of neurofeedback session (Angelakis et al., 2007).

Contrarily to Angelakis et al. (2007), another research combined alpha and theta were rewarded to further enhance the cognitive performance in healthy elderly (mean age of  $65.97 \pm 6.63$  years) particularly in working memory aspect in just 8 days with 30 minutes session per day (Reis et al., 2016). The intensive neurofeedback protocol successfully enhanced both alpha and theta power and yielded an improvement in NF group showed improvements in the Digit Span and Matrix Rotation performance after eight consecutive days of training, but only the latter presents statistically significant differences..The positive result suggested that an intensive and short NF protocol enabled elders to learn alpha and theta self-modulation and already presents moderate improvements in cognition and basal EEG.

When theta was up-trained alone at frontal midline without combining it with alpha or other rhythms in normal aging elderly, improvement in working memory function (i.e., recognition task performance) was observed in the older participants (Wang and Hsieh,

2013). The research focused mainly on frontal midline theta up training as previous studies suggested that this activity was related to several cognitive functions (e.g., working memory and attention) in which older adults might show impairments and, more recently, researchers have suggested that a higher resting frontal midline theta is significantly correlated with better cognitive performance (Finnigan and Robertson, 2011). The neurofeedback training at Fz for 12 sessions only (4 weeks) also reported that the frontal midline theta activity up training protocol benefitted the older participants in terms of orienting and conflict (executive function) scores in the Attention Network Task.

#### **2.1.4 Neurofeedback and Elderly with Cognitive Impairment**

Significant reduction alpha is responsible for slowing down processing speed and memory in particular (Klimesch, 1999) and it was often witnessed in cognitively impaired elderly. Contradictory to alpha, elderly with greater cognitive impairment present a greater amount of theta activity than is normal in aging individuals (Penttilä et al., 1985; Prichep et al., 1994) particularly at parieto-occipital area. Hence, in most neurofeedback protocols, alpha was up trained while theta would be suppressed.

In mid 90s, a “brain brightening” protocol was coined by Budzynski whereby they aimed to increase alpha rhythms while suppressing excessive slow rhythms which were theta and delta in a case-study to demonstrate the effect of neurofeedback and audio-visual simulation on a man who experienced age-related cognitive decline (ARCD). The purpose of this protocol was to restore the cognitive function of the man. The man was a 76 years old with history of multiple interventions on heart problems and made a self-reported cognitive decline. He received 30 sessions of neurofeedback at Cz (based on 10-20 electrode placement) over a five months period. Analysis of the brain activity in pre and

post neurofeedback revealed a reduction in lower frequency band (1-3, 3-5, 5-7 Hz) and increase in alpha rhythms. Microcog results showed he had improvement in all except in spatial processing and reaction time (Budzynski et al., 2009).

Due to fact that theta was proved to be excessive in MCI elderly, Beccera et al. (2012) aimed to reduce the theta absolute power on individualized selected electrode and observed neurofeedback effectiveness in terms of changes in theta absolute power in EEG and improvement in WAIS–revised and NEUROPSI test. The study disclosed the improvement in verbal comprehension index & verbal IQ of WAIS–revised and NEUROPSI test after 30 training sessions of neurofeedback in experimental group than in control group. Reduction in theta absolute power (AP) in the midline and left frontal leads could have induced the improvement in attention that was reflected in the total score of the NEUROPSI test.

The neurofeedback training in elderly with Alzheimer’s disease (AD) used individualized protocol to investigate the positive effect of neurofeedback on the declination of cognitive function (Luijmes et al., 2016). The patients were still on cholinesterase inhibitors because as neurofeedback is still not acknowledged as a treatment for AD, it is unethical to terminate them from consuming it. The study aimed to decrease the dominating slow waves; delta and theta activity which were unique to AD while increasing fast waves; alpha & beta. Ten AD patients underwent twice-weekly training with a total of 30 sessions at individualized training point according to QEEG results. Since this study was a pilot study, it only reported the effect of neurofeedback in Cambridge Cognitive Examination (CAMCOG) score only and not taking into account the behavioral & QEEG changes. Reliable Change Index was done for individual analysis and a Mixed Linear Model

analysis (using the procedure *lme* in the R statistical Software) for group analysis. The outcome on individual analysis showed there was no change (no decrement / increment) in CAMCOG score on various subscales. Group analysis disclosed an increment in mean of Memory Learning after the training while other subscales remain the same.

Despite of widely applied neurofeedback training in research setting, the training for elderly are less and it is even less for elderly with particular condition such as mild cognitive impairment. Thus, in the present study, alpha training will be employed to see the effect of training in cognitive performance in elderly with mild cognitive impairment in terms of working memory, processing speed concurrently with its EEG features before and after the training.

## **2.2 Electroencephalogram (EEG)**

### **2.2.1 Electroencephalogram (EEG) as Neuroimaging Tool**

Electroencephalogram (EEG) records the electrical activity of the brain in terms of five frequency bands: delta (below 4Hz), theta (4-8Hz), alpha (8-12 Hz), beta (13 – 28 Hz) and gamma (beyond 30 Hz). Alpha can be further divided into lower alpha (8-9Hz) and upper alpha (10 – 12 Hz) and it is the same for beta; beta1 at 13 – 16 Hz, beta2 at 16 – 20 Hz and beta3 at 20 -28 Hz.

With the increase knowledge in technology, a few upgrades in conventional EEG are introduced, for example a high-resolution EEG technique that enhances the spatial resolution of conventional EEG from 6-9 cm to 2-3 cm by the use of spatial enhancement method such as Laplacian transformation with a regularized 3D spline function. Even though other emerging modalities such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) have high spatial resolution for anatomical

details, they are still lacking in providing good temporal resolution when measuring functional brain activation which occurs in seconds to minutes time(Lizio et al., 2011).

EEG is one of the neuroimaging tools often coupled with neurofeedback training (NFT) to measure the differences in pre and post NFT (Angelakis et al., 2004; Lecomte and Juhel, 2011). EEG guided neurofeedback training is preferred because EEG has advantages for its cost, high temporal resolution, efficiency , potentially portable and it can be a powerful tool that provides dynamic information about brain functions (Cruse et al., 2011; Goldfine et al., 2011; Tzovara et al., 2012). However, in certain condition, post NF EEG changes could not be seen even there is clinical improvement happened. As an example, Angelakis and colleagues (2007) witnessed improvement in cognitive performance and observed an increase in peak alpha frequency (PAF) at frontal sites but not at posterior sites even though the subjects were trained at Pz.

### **2.2.2 Brain Patterns of Mild Cognitive Impaired Elderly**

Theta is traditionally to be related with drowsiness and proved to be associated with the greater cognitive impairments in patients with either mild cognitive impairment or dementia (Babiloni et al., 2007). Meanwhile, alpha rhythm is correlated with cognitive performance in general (Angelakis et al., 2004, 2007; Hanslmayr et al., 2005). Reduction in alpha power and increase in theta power in elderly beyond the age of 50 or 60 may be related to neurological disorder and not to age per se (Klimesch, 1999).

In Alzheimer's disease subjects, there is a raise in lower EEG frequency bands; delta and theta power while reduction in alpha and beta power in parieto-occipital region of Alzheimer's disease (AD) subjects as compared with normal age-matched subjects (Coben et al., 1983, 1985; Gianotti et al., 2007; Jeong, 2004; Mattia et al., 2003). In MCI subjects,

a heightening in power for theta and delta rhythms in temporal and occipital regions are observed as well as a reduction in power of beta rhythms in the same region (Jelic et al., 2000) and reduction of parietal and occipital alpha power (Babiloni et al., 2010).

Among, theta, delta and beta rhythms which are reported to be either excessive or suppress in MCI and AD subjects, a highlight on alpha and theta rhythm are given because individuals with greater cognitive impairment present a greater amount of theta activity than is normal in aging individuals (Penttilä et al., 1985; Prichep et al., 1994) while significant reduction alpha frequency is responsible for slowing down processing speed and memory in particular (Klimesch, 1999). This makes alpha & theta rhythm as an excellent predictor of cognitive impairment.

## **2.3 Elderly and Cognitive Problems**

### **2.3.1 Overview of Elderly and Aging**

Aging has a great impact on human physically and cognitively. Declination in cognitive performance is known to be associated with increasing in age (Salthouse, 2006). Currently, elderly of the age of 60 and above make up of 7.7% of the whole population in Malaysia and this number is expected to multiply up to 14.7% by 2030 (World Population Prospects, 2010). Given this fact, Malaysia is now moving towards becoming an aging country. With the escalating number of elderly in the Malaysia specifically and generally worldwide, age-related disease which inflicting with cognitive function in adult such as mild cognitive impairment (MCI) or dementias will multiply (Mafauzy, 2000) because old age is one of the contributing factors to its development (Baker et al., 2008; Rosdinom et al., 2011).

### **2.3.2 Cognitive Problem: Mild Cognitive Impairment and Alzheimer 's Disease**

Mild cognitive impairment (MCI) refers to a transitional stage between normal aging and Alzheimer's disease in which mild cognitive loss is detectable through neuropsychological test but it is not capable enough to affect the individual's ability to carry out everyday activities (Ganguli et al., 2004; Kelley and Petersen, 2007; Petersen et al., 2001).

MCI has been regarded as a clinical entity on its own and can be further segregated into two major subgroups: amnesic & Non-amnesic with further subdivisions within each either it is single or multiple domain type. Amnesic MCI is defined as subjects with impairment in the memory domain, with or without impairment in non-memory domains. Non-amnesic refers to subjects with impairment in one or more non-memory domains (Petersen, 2004). Commonly, MCI is referred to as aMCI as it involves memory problems with preserved general cognitive function (Petersen et al., 1999) and is prone to develop into dementia (Petersen, 2004).

Studies have shown that old age is one of the contributing factors to development of MCI as well as Alzheimer's disease and other dementias (Baker et al., 2008; Rosdinom et al., 2011). Other than age factor, memory impairment may be due to underlying depression, neuroticism, anxiety, fatigue, stress, chronic pain, sleep disorder, substance abuse, adverse effects of medications or serious medical conditions (Ellison, 2008).

A study was conducted among 346 elderly of the age of 60-87 in various clinics of UKM Medical Centre using MMSE as its instrumentation revealed the association of education level in development of MCI. It was shown that low level education tended to be related with higher prevalence of cognitive impairment (Chenderes et al., 2009; Razali et al., 2012).

Assessment of MCI in clinical setting are accomplished by taking clinical history and psychological assessment such as MMSE (Petersen, 2004; Petersen et al., 1999; Razali et al., 2012) while the etiology of the symptoms are elucidated based on clinical evaluation and neuroimaging studies using MRI and FDG-PET (Zhang et al., 2011). National Institute on Aging-Alzheimer's Association (NIA-AA) workgroup proposed criteria particularly for MCI due to AD in which they incorporate and provide a guideline for the use of AD biomarkers in predicting the progression of MCI to AD (Albert et al., 2011) even though, they recommended that diagnosis of MCI due to AD could be made based on the core clinical criteria (Albert et al., 2011; Petersen, 2004). The biomarkers could be used in research settings to help in the identification of MCI subtypes i.e. MCI due to AD and MCI that is unlikely due to AD. Two biomarkers suggested by NIA-AA are 1) biomarkers of amyloid beta ( $A\beta$ ) deposition and 2) biomarkers of neuronal injury and both can be found by analyzing the cerebrospinal fluid. There are variability across laboratories for these markers, thus standardization will be needed before they are considered for incorporation into routine care.

## **2.4 Cognition: Working Memory and Processing Speed**

### **2.4.1 Cognition**

Cognitive functions include attention, memory, language, perception, decision making, and problem solving. As we age, many aspects of information processing become less efficient, including speed of processing, working memory capacity, inhibitory function, and long-term memory. Contrarily, other aspects of cognitive function such as implicit memory and knowledge storage, are protected and relatively resistant to cognitive aging (Park et al., 2002). Researchers had reported evidence on cognitive decline in a few aspects of

cognitive function which related to aging such as in working memory (Park et al., 2002; Wingfield et al., 1988) and processing speed (Salthouse, 1991, 1996).

#### **2.4.2 Working Memory**

Working memory (WM) is widely thought to be one of the most vital mental components, critical for cognitive abilities such as planning, problem solving, and reasoning (Baddeley, 1986). Specifically, WM promotes active short-term maintenance of information for later access and manipulation (Baddeley et al., 2015). The form of the information held in WM is both auditory, as maintained by the phonological loop (e.g., to promote language comprehension), and visual, as maintained by the visuospatial sketchpad (e.g., to promote visuospatial reasoning) (Baddeley, 1986). Recent finding suggested that early impairment in visual episodic memory, executive function, semantic language/memory, attention and including working memory are strong predictors of progression from MCI to AD (Saunders and Summers, 2011). In terms of brain rhythms, theta and alpha were often discussed together in memory and cognitive performance topic particularly in working memory system (Klimesch, 1999).

#### **2.4.3 Processing Speed**

Working memory and processing speed (PS) are often linked together because slower processing is causatively linked to cognitive decline in old age and moderating the relationship between age and WM (Fry and Hale, 1996; Kail and Salthouse, 1994; Nettelbeck and Burns, 2010). Furthermore, it has been depicted that slower information processing due to aging can cause slower rehearsal and impoverishment of information, resulting in a poorer memory performance (Salthouse, 1991, 1996) and this is particularly

true for elderly with subjective memory complaints in which has shown to have slower speed of information processing (Mol et al., 2006).

## **2.5 Conclusion**

To sum up, this study applied alpha neurofeedback protocol by enhancing alpha while inhibiting theta and beta2 to mild cognitive impairment (MCI) elderly to enhance their cognitive performance due to two main reasons. The first reason was because a change in brain activity; a decrease in high frequency bands; particularly alpha (Luckhaus et al., 2008) while increase in low frequency bands; notably theta (Jelic et al., 2000) and the latter one was due to decline in a few cognition aspects specifically in working memory and processing speed (Saunders & Summers, 2011) in MCI elderly.

## **CHAPTER 3**

### **METHODOLOGY**

#### **3.0 Introduction**

This research aimed to explore, describe and analyzing QEEG brainwaves pattern in terms of absolute power & topography of the brain on elderly with probable MCI after receiving NFT. This chapter focused on methodological aspects as research design, participants recruitment method, instrumentation used, data collection and analysis procedure.

#### **3.1 Research Design**

This study employed convenience sampling method to recruit participants. It used quasi experimental method with two groups formed; experimental which received NFT and control which did not received any form of treatment/training. They were not randomly assorted as it was not a criterion of quasi experimental study and depending on subjects' willingness too.

#### **3.2 Subjects**

Initially 35 elderly lived around Kuching were recruited in the screening phase. 20 out of 35 passed the screening criteria which were (i) age 50 – 70 years old, (ii) obtained MMSE score 20 – 26 (iii) obtained PHQ-9 and GAD-7 score less than 10 (iii) able to perform pre and post task, WAIS-IV (iv) completed elementary school. Unfortunately only 14 people agreed to voluntarily participate in the study while the others said it was quite difficult to participate due to time constraint. 9 people were put in experimental group while 5 in control group. Before commencing the NFT, another 2 dropped out from experimental group with medical reasoning and due to time issue. Later after 2 sessions of NFT another 2 dropped out because of the same time issues problem. Finally, only 10 people managed

to participate until the end of the study, with only 5 people in experimental and the same 5 people on control group.

### **3.3 Ethics**

This study abided all five main ethical principles including minimizing the risk of harm, obtaining informed consent, protect the confidentiality of subjects, avoiding deceptive practices and providing the right to withdraw (Lærd Dissertation, 2018). The procedures were not involved any invasive procedure and harmless to the subjects. All subjects were informed well on the each procedure involved and the outcome of procedure. They then signed the consent form after agreed to participate in this study and were informed on their rights in term of confidentiality and their right to withdraw from the study.

### **3.4Phase of Study**

This study was divided into four phases to ensure that all subjects from experimental and control groups underwent the same flow of data collection procedure in the same length of time.

#### **3.4.1 Phase 1: Screening and Pre WAIS-IV**

Recruitment was done from early July till mid September 2016 by explaining the procedure thoroughly. Screening started from September 2016 till November 2016. It took almost 7 months to find suitable subjects for this study. MMSE, PHQ-9 and GAD-7 in Malay version were used in the screening phase. The sociodemographic data which consist of education year and other important details were obtained. WAIS-IV's working memory & processing speed components were administered along when the subjects passed the screening criteria. Then, the date for first QEEG was chosen according to subjects' availabilities.

### **3.4.2 Phase 2: First QEEG**

All 14 subjects (before drop out) underwent first QEEG. During the QEEG, subjects were seated comfortably. Then, brain activities in eyes open for and eyes close condition were recorded for 3 minutes each. Data analysis of QEEG recording was explained thoroughly in Section 3.7.

### **3.4.3 Phase 3: Neurofeedback Training**

Neurofeedback training (NFT) was commenced in average of 2 months with total of 15 sessions per subject in experimental group. Each training session lasted for 30 minutes. They were trained to increase alpha power while suppressing the theta and high beta.

### **3.4.4 Phase 4: Second QEEG & Post WAIS-IV**

The remaining 10 subjects underwent second QEEG. During the QEEG, subjects were seated comfortably. Then, brain activities in eyes open for and eyes close condition were recorded for 3 minutes each. Data analysis of QEEG recording was explained thoroughly in Section 3.7.

## **3.5 Instrumentation**

### **3.5.1 QEEG Machine and Software**

QEEG is one of the neuroimaging tools which measure the brain electrical activity in absolute power (microvolt,  $\mu V^2$ ), frequency produced by the brain and other aspects too. The electrodes were positioned according to 10-20 International System. The brain activity was recorded using Mitsar EEG 201 amplifier, with sampling rate of 250 Hz, low pass filter of 0.3 Hz, high pass filter of 50 Hz and notch filter setting at 45-55 Hz. After obtaining the electrical activity from the scalp it was amplified then digitized. The computation of spectral analysis was performed by Fast Fourier Transform algorithms.

This study used WinEEG software developed by Mitsar. The software enables user to obtained the recording and doing further analysis such as Independent Component Analysis (ICA) artifacts removal, spectral analysis which comprised of absolute power value in all locations, topography, coherence, asymmetry and etc. A detail on the analysis done in this research was described in Section 3.7.1.

### **3.5.2 NFT Software and Electrode Placement**

The NFT machine used in this study was from Spectrum Learning. It came with its own software incorporated together which known as BrainTrain. The machine had 2 channels but this study only use one channel. Each channel had two actives and ground electrode nodes. This study employed bipolar training where both active electrodes were attached on the scalp while the ground attached at the ear.

The training electrode was placed according to 10-20 system at T3, T4, C3, C4, P3 and P4. During the training, the electrodes were placed according to bipolar training setting in which ground electrode was attached to the earlobe while two active electrodes were either at T3/T4, C3/C4 and P3/P4. For the first 3 sessions of training, the active electrodes were placed at T3 and T4. The next 3 sessions, they were fixed at C3 and C4 and the remaining 9 sessions, they were fixed at P3 and P4.

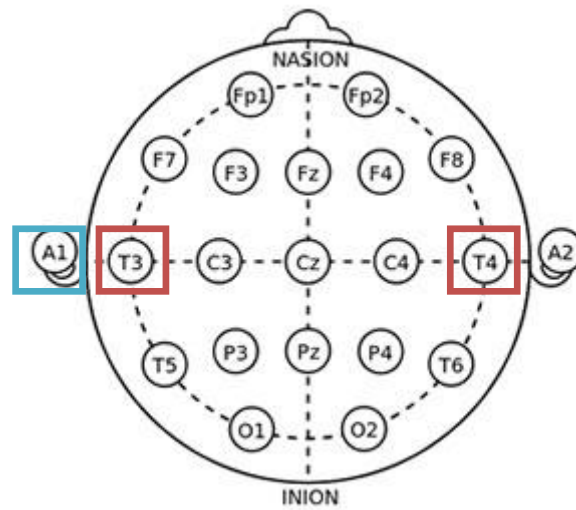


**Figure 3.1:** T3-T4 electrode placement

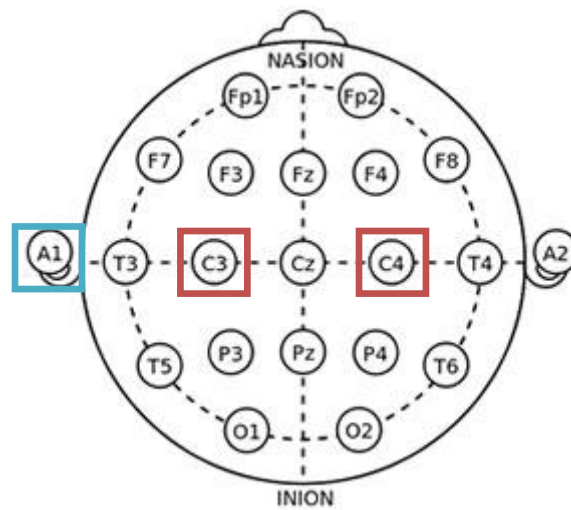


**Figure 3.2:** C3-C4 electrode placement

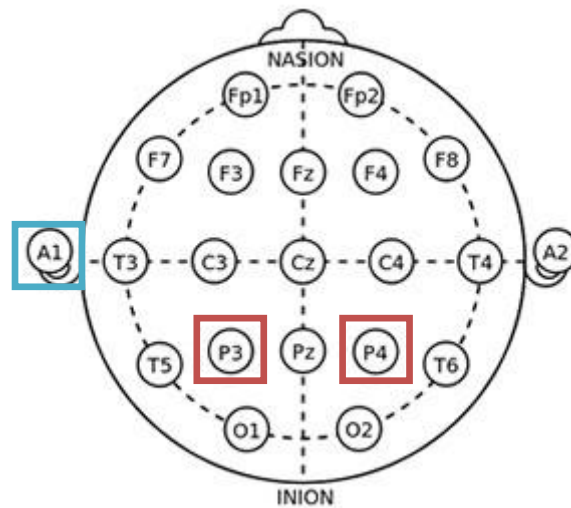


**Figure 3.3:** P3-P4 electrode placement

The placements of electrodes were chosen according to evidence in literature. Posterior area has the strongest alpha rhythms and known to be dominated by well-known alpha sources in parietal-occipital sulcus. Such sources most likely produce spectral peaks at  $\sim 11$  Hz over central posterior areas (e.g. Cz, Pz, P3 and P4)(Jensen et al., 2002). Beside, based on the work suggested by Thatcher et al. (1976), alpha activity was produced by two generators; one posterior (parieto-occipital) and one more central (centro-parietal), with reciprocal connections and even mutual competition for neuronal resources (van Boxtel et al., 2012). Thus, most study (Angelakis et al., 2007; Escolano et al., 2011; Jensen et al., 2002) which intended to improve the cognitive performance chose posterior site (eg: Pz, POz, P3 and P4) as electrode placement in NFT. T3 and T4 were recommended by Dr Othmer as one of the beginning site for NFT (Othmer and Othmer, 2012). Temporal lobes are associated with many functions such as reading (word recognition), memory, learning and a positive mood for left temporal while right temporal lobe is associated with music, anxiety, facial recognition, and sense of direction (Marzbani et al., 2016). Besides, with

respect to functional anatomy of memory, hippocampus in medial temporal lobe is associated with working memory system (Squire, 1992; Squire et al., 1993) and hippocampus is part of Papez cycle; a loop representing brain structures where theta rhythms are observed (Kropotov, 2009).

### 3.5.3 Mini Mental State Examination (MMSE)

The MMSE has the advantages of being brief, easy to administer and has a high inter-rater reliability. It is an 11-question measure that tests five areas of cognitive function: orientation, registration, attention and calculation, recall, and language (Folstein et al., 1975). The validated and Malay versions of the Mini Mental State Examination (MMSE) (Ibrahim et al., 2009) was used as one of its neuropsychological assessment to screen for normal elderly subjects within 20 until 26, as score 19 and below indicates dementia (Ibrahim et al., 2009; Razali et al., 2014). In Malaysia, there are three versions of validated MMSE which are MMSE-7, MMSE-3 and MMSE-S (Figure 5).

|   |  |                                                                         |
|---|--|-------------------------------------------------------------------------|
| 5 |  | <i>Perhatian dan Pengiraan (sila guna salah satu kaedah)</i>            |
|   |  | <i>M-MMSE-7: Sila tolak 7 dari 100 dan teruskan.</i>                    |
|   |  | <i>M-MMSE -3: Atau, tolak 3 dari 20 dan teruskan.</i>                   |
|   |  | <i>M-MMSE-S: Atau, ejakan perkataan 'DUNIA' dari belakang ke depan.</i> |

**Figure 3.4:** Question number 4 of validated Malay MMSE. (Source: Academy of Medicine of Malaysia - Clinical Practice Guidelines (CPGs), 2018)

### 3.5.4 WAIS– IV: Working Memory and Processing Speed

For the pre and post task assessment of cognitive performance, Digit Span & Arithmetic from Working Memory Index (WMI) and Symbol Search & Coding subtest from Processing Speed Index (PSI) were used. The scores before and after the NFT session will be compared to objectively measure the changes after the whole NFT sessions end.

### **3.5.5 GAD-7, PHQ-9 and Sociodemographic Questionnaire**

Patient Health Questionnaire (PHQ-9) is a self-administered depression module to identify patients with clinically meaningful symptoms of depression. This study accept score 1-14 (none – moderate depression). The internal reliability of PHQ-9 was good with Cronbach's alpha of 0.89 (Kroenke et al., 2001). Generalized Anxiety Disorder (GAD-7) is easy-to-use self-administered patient questionnaire is used as a screening tool and severity measure for generalized anxiety disorder (GAD). This study accepted people with score 0-10 (none – moderate anxiety) (Spitzer et al., 2006). This study used these questionnaires to exclude people with probable severe depression and anxiety. It was also suggested in literature to measure subject's state of mental health as depression & anxiety were part of co-founding factors in pre-MCI, MCI and AD (Mol et al., 2006; Reisberg et al., 2010). It was also documented that for each depressive symptom, risk of developing AD increased by an average of 19% in older adult (Wilson et al., 2002). The sociodemographic questionnaire collected data on age, gender, race, marital status, educational level and occupational status.

### 3.6 Data Collection Procedure

#### 3.6.1 QEEG Acquisition

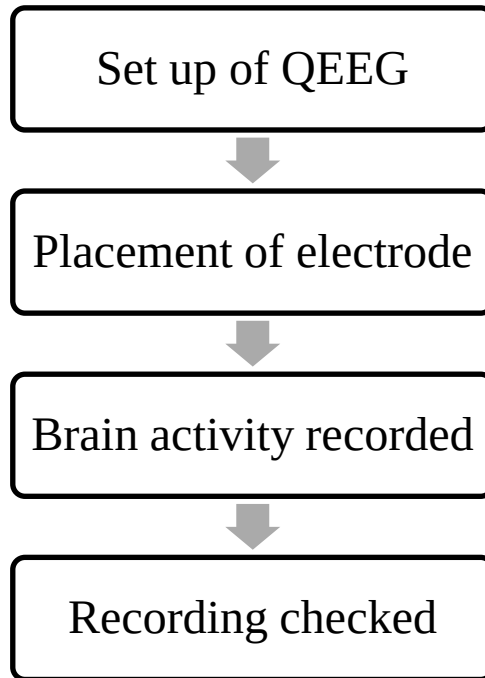


**Figure 3.5:** Steps for EEG acquisition

QEEG machine was set up by attaching it to its tripod. Electrodes then were carefully inserted at the amplifier body. After measuring the subject's scalp, an appropriate electrocap was put on and connected with the electrodes according to 10-20 system. Impedence was kept below 5 ohm. The WINEEG software was run to check the waves formed. When the waves formed looked normal, recording was started in eyes open condition for 3 minutes with subjects eyes remained focused on one black dot then followed by 3 minutes of eyes closed condition. At the end of every recording session, the recorded brain activity was checked to ensure that everything was well recorded.

### 3.6.2 Neurofeedback Training

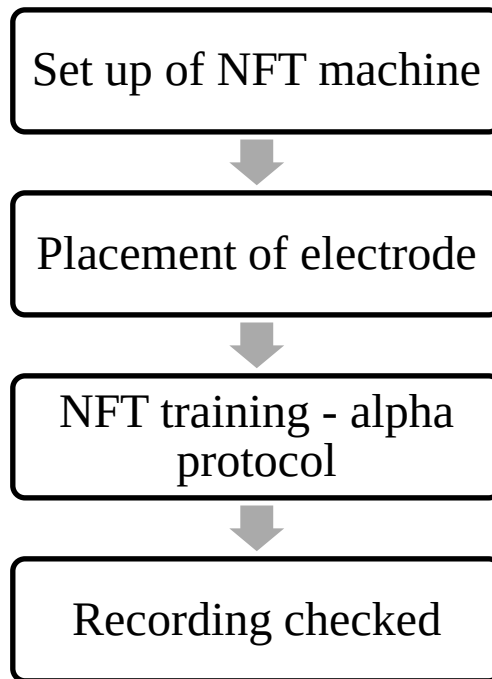


**Figure 3.6:** Steps during NFT

Training locations were identified by measuring the scalp using a tape. The two active electrodes were placed either at T3-T4 or C3-C4 or P3-P4 locations according to the subject's sessions which was explained earlier in section 3.5.2. Ground electrode was attached to earlobe before the subject put on the earphone. After the set up was checked, training started and ended 30 minutes later.

## 3.7 Data Analysis Procedure

### 3.7.1 QEEG Data Analysis

WinEEG software was used to process the raw data from QEEG recording. QEEG analysis steps in this study followed the guide written in Quantitative EEG, Event Related Potentials and Neurotherapy by Juri D.Kropotov (2010). Steps of QEEG analysis listed as follow.

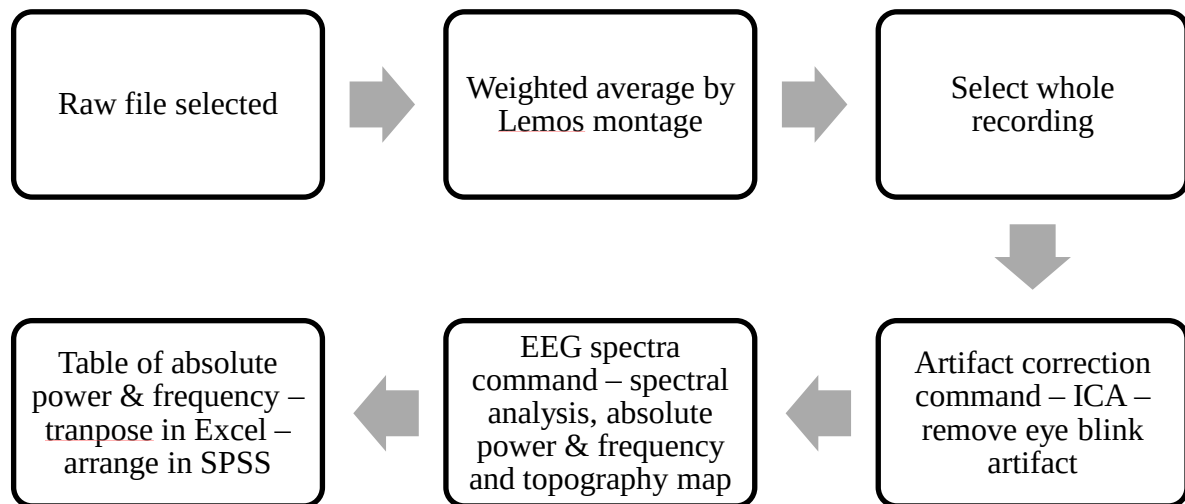


**Figure 3.7:** QEEG data analysis procedure

Raw file (e.g. D000712.eeg) of a particular subject was selected. Weighted average by Lemos montage was selected from Montage parameters windows. Visual inspection of vertical and horizontal eye movement was done. The whole record was selected by clicking the left button of the mouse at the beginning of the record and the right button at the end of the record. Clicking was done at the time bar located above the record.

From Analysis menu, Artifact correction command selected. By applying, Independent Component Analysis (ICA) eye blink related artifacts were removed from the raw EEG material. ICA is known as blind source separation which identifies a unique spatiotemporal signal generator such as eye blink. It is also widely used for source localization of brain rhythms. After the ICA Artifact correction was run, topographies presented on the right of the window with the first topography highlighted by red circle. This component was the strongest and usually corresponded to eye blink artifacts. After making sure that it was the case by visual inspection of the raw EEG presented on the left, the OK button was clicked to filter out this type of artifacts from the whole EEG record.

From Analysis menu, Mark Artifacts command was selected. After loading the parameters of artifact correction from database and pressing OK, the software marked the artifacts that fit the criteria. Next, EEG spectra command was clicked from Analysis menu. The parameters of EG spectra calculation loaded from the database. The software then was computed the spectra for Eyes Open/Eyes Close condition for each electrode separately and presented them in 19 graphs located in a way similar to electrode locations on scalp. Table of absolute value and frequency, topography map and asymmetry map were produced too. All results obtained from EEG spectra then was transferred to Word and rearrange in Excel before arranged in SPSS for further statistical analysis.

### 3.7.2 NFT Data Analysis

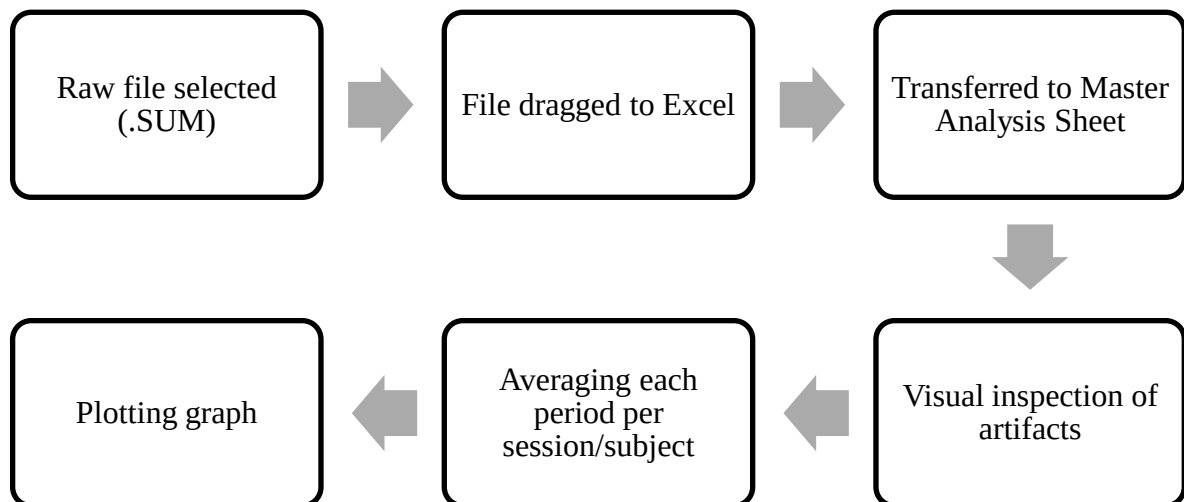


**Figure 3.8:** NFT data analysis procedure

Local disk (C:) opened then Spectrum Learning folder was selected. Microsoft Excel readily opened and subject.SUM file was dragged to the Excel sheet. The absolute power value ( $\mu V^2$ ) of alpha, theta and high beta then transferred to Master Analysis sheet to

obtain the average for each period per session (one session has 10 period which equal to 1 minute per period). Graph for 15 sessions of NFT was computed by SPSS.

### **3.7.3 Statistical Analysis Method**

Statistical analysis was only accounted for grouped analysis in section 4.4 Grouped QEEG Result & Analysis. It involved inter-subject analysis for experimental group and control group separately. This was done using Wilcoxon Signed Rank Test which was considered as the non-parametric pair to the paired sample t-test given that the number of subjects in this research was relatively small to use parametric test. In each group, Wilcoxon test was carried out to trace the differences in T3T4, C3C4 and P3P4 for alpha, theta and high beta before commencing the NFT and after it ended. Electrode grouping method (e.g: T3T4, C3C4 and P3P4) was chosen to make it easier to execute statistical analysis and it had been practiced in other research as well (Yuvaraj et al., 2014). Wilcoxon test was also executed for defining the difference in pre and post cognitive results in each group.

Meanwhile, intra-subject analysis was done to observe the differences in experimental and control group. Firstly, the difference in post and pre QEEG reading at respective locations were find by simply minus post to pre reading. Then, Mann Whitney test was carried out in SPSS. This step was also applied to grouped cognitive result section.

### **3.8 Conclusion**

After screening the subjects involved with Malay MMSE, GAD-7, and PHQ-9 to elderly aged 60-70 years old, the subjects who passed the tests were assigned to experimental and control group. The subjects performed WAIS-IV test before pre and post QEEG session to measure the changes in cognitive performance. QEEG data was analyzed using WINEEG

and NFT data was analyzed with Microsoft Excel. Lastly, both data were analyzed with non-parametric statistical tests.

## CHAPTER 4

### RESULTS

#### 4.0 Introduction

This chapter reported the result and analysis for several components in this study such as sociodemographic data, individual and grouped result for QEEG absolute power and cognitive results by means of graph, table and analysis using non-parametric testing which are Wilcoxon and Mann Whitney tests.

#### 4.1 Sociodemographic Data

**Table 4.1:** Sociodemographic data

| Variable        | Experimental     | Control           |
|-----------------|------------------|-------------------|
| Age             | 60.2 $\pm$ 2.4   | 63.3 $\pm$ 3.5    |
| Gender          | M = 3, F = 2     | M = 3, F = 2      |
| Education years | 8.6 $\pm$ 2.5    | 10 $\pm$ 7.04     |
| MMSE score*     | 23.20 $\pm$ 0.84 | 25.40 $\pm$ 0.894 |
| PHQ-9           | 3.40 $\pm$ 4.5   | 3.00 $\pm$ 3.6    |
| GAD-7           | 0.80 $\pm$ 1.3   | 2.40 $\pm$ 3.6    |

This final analysis involved 10 elderly subjects who voluntarily agreed to continue on participating with mean age of 60.2 years old ( $SD = 2.4$ ) for experimental group and 63.3 years old ( $SD = 3.5$ );  $Z = -1.485$ ,  $p = .151$ . There were no significant differences in education years (Exp:  $M = 8.6$  years,  $SD = 2.5$ ; Cont:  $M = 10$ ,  $SD = 7.04$ ,  $Z = -0.108$ ,  $p = .914$ ), Patient Health Questionnaire – 9 (PHQ-9) (Exp:  $M = 3.4$ ,  $SD = 4.5$ ; Cont:  $M = 3.0$ ,  $SD = 3.6$ ,  $Z = -0.212$ ,  $p = .841$ ) and Generalized Anxiety Disorder- 7 (GAD-7) questionnaire (Exp:  $M = .80$ ,  $SD = 1.3$ ; Cont:  $M = 2.4$ ,  $SD = 3.6$ ,  $Z = -0.417$ ,  $p = .690$ ).

Mini Mental State Examination (MMSE) score shown a statistical difference between experimental and control group ( $Z = -2.471$ ,  $p = .016$ ).

## 4.2 Individual QEEG Result and Analysis for Experimental Group

This section includes individual (i) absolute power analysis in pre and post NFT in three different sub- waves; alpha, theta and high beta training location T3T4, C3C4 and P3P4, (ii) topography & asymmetry of the whole brain. Statistical difference in pre and post absolute power was not reported in this section as it only covered the reporting of absolute power differences as it is just to show whether there was difference in pre and post NFT. The statistical differences will be reported in detail in Section 4.4 Grouped QEEG Result & Analysis. The individual QEEG result and analysis for control group was not stated here in detail because there was no changes in their QEEG patterns as they did not receive any kind of treatment.

### 4.2.1 Subject A

#### 4.2.1.1 Subject A: QEEG Absolute Power

**Table 4.2:** Subject A absolute power

| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Alpha ( $\mu V^2$ ) | 1.72     | 2.06      | 1.93     | 2.62      | 2.68     | 3.61      |
| Theta ( $\mu V^2$ ) | .93      | .98       | .49      | .77       | 1.01     | .81       |
| Beta2 ( $\mu V^2$ ) | 3.94     | .72       | .61      | .94       | .66      | .68       |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Alpha ( $\mu V^2$ ) | 1.55     | 1.69      | .86      | 1.53      | 1.21     | 1.55      |
| Theta ( $\mu V^2$ ) | 1.11     | .97       | .66      | .88       | 1.58     | .66       |

**Table 4.2:** Subject A absolute power (continued)

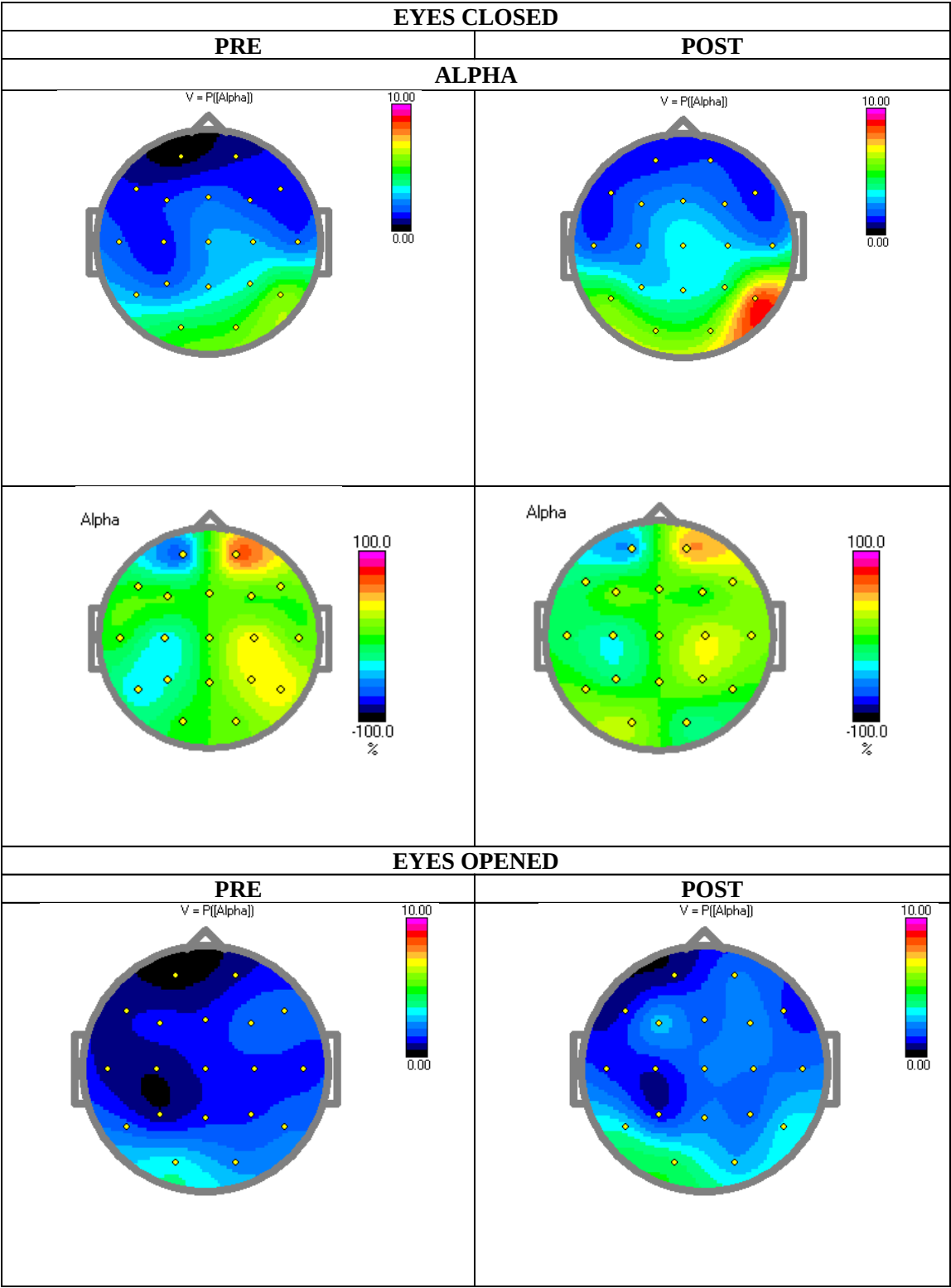
|                     |      |      |     |     |     |     |
|---------------------|------|------|-----|-----|-----|-----|
| Beta2 ( $\mu V^2$ ) | 9.64 | 2.47 | .88 | .86 | .94 | .80 |
|---------------------|------|------|-----|-----|-----|-----|

#### 4.2.1.1.1 Alpha

|                     |          |           |          |           |          |           |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Alpha ( $\mu V^2$ ) | 1.72     | 2.06      | 1.93     | 2.62      | 2.68     | 3.61      |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Alpha ( $\mu V^2$ ) | 1.55     | 1.69      | .86      | 1.53      | 1.21     | 1.55      |

**Eyes closed.** All locations in post NFT had increments in alpha absolute value with least difference of  $0.34 \mu V^2$  at T3T4 and maximum difference of  $0.93 \mu V^2$  at P3P4. The differences in pre and post NFT was clear in topography and asymmetry map with a reduced in unbalanced right and left alpha power.

**Eyes opened.** All locations had higher post NFT absolute power values with maximum difference of  $0.67 \mu V^2$  and minimum difference of  $0.14 \mu V^2$ . The differences in pre and post NFT was clear in topography and asymmetry map with a good symmetry was achieved.



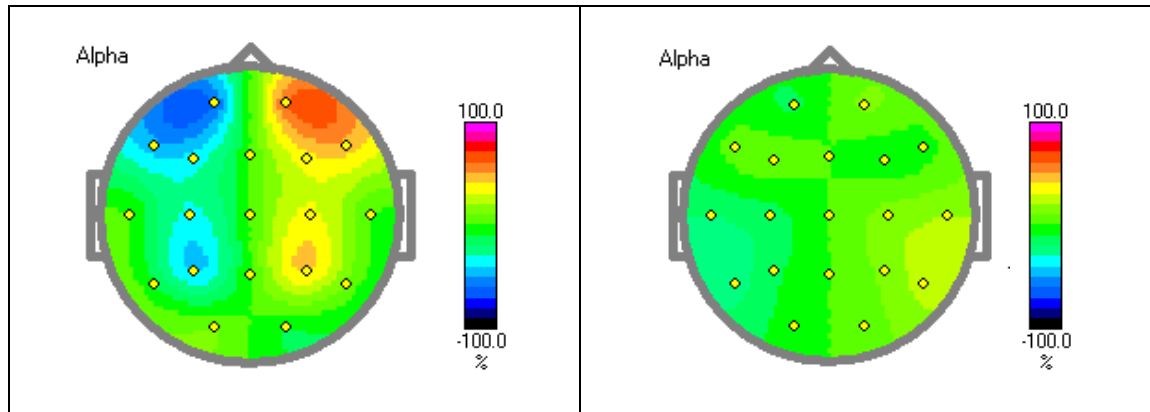


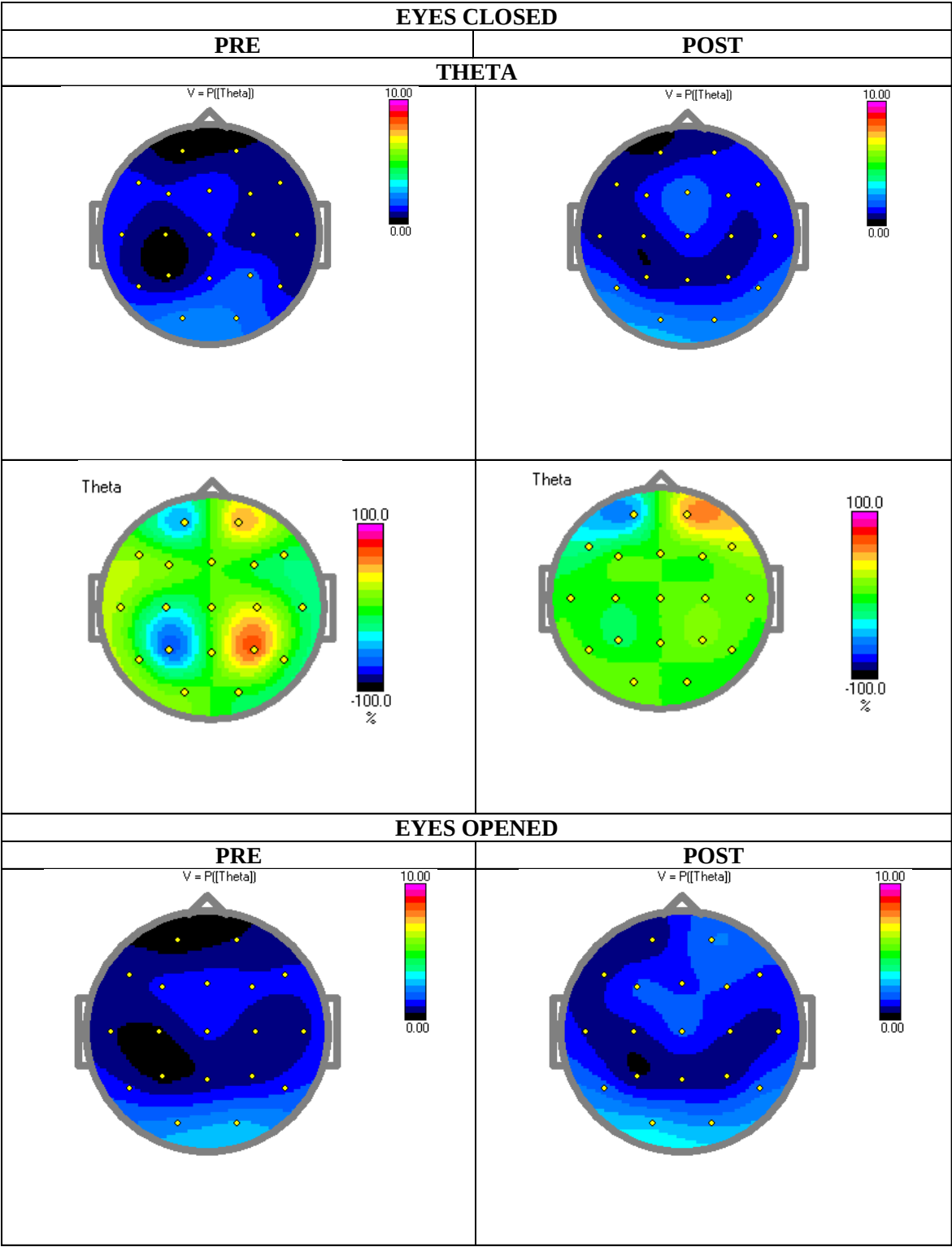
**Figure 4.1:** Subject A – alpha topography

#### 4.2.1.1.2 Theta

|                     |          |           |          |           |          |           |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Theta ( $\mu V^2$ ) | .93      | .98       | .49      | .77       | 1.01     | .81       |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Theta ( $\mu V^2$ ) | 1.11     | .97       | .66      | .88       | 1.58     | .66       |

**Eyes closed.** The only location that had decrease in theta power was P3P4 with pre and post difference  $-0.2 \mu V^2$ . T3T4 pre reading was  $0.93 \mu V^2$  and it not much different from the post NFT;  $0.98 \mu V^2$ . For C3C4, the absolute power increase from  $0.44 \mu V^2$  to  $0.77 \mu V^2$ . The differences in pre and post NFT was clear in topography and asymmetry map with a balanced in left and right theta.

**Eyes opened.** Two locations; T3T4 & P3P4 were successfully reduced in post NFT absolute power with difference of post and pre of  $-0.14 \mu V^2$  and  $-0.92 \mu V^2$ . In eyes opened condition, the difference in both topography and asymmetry map in pre and post NFT were not as clear as in eyes closed condition.



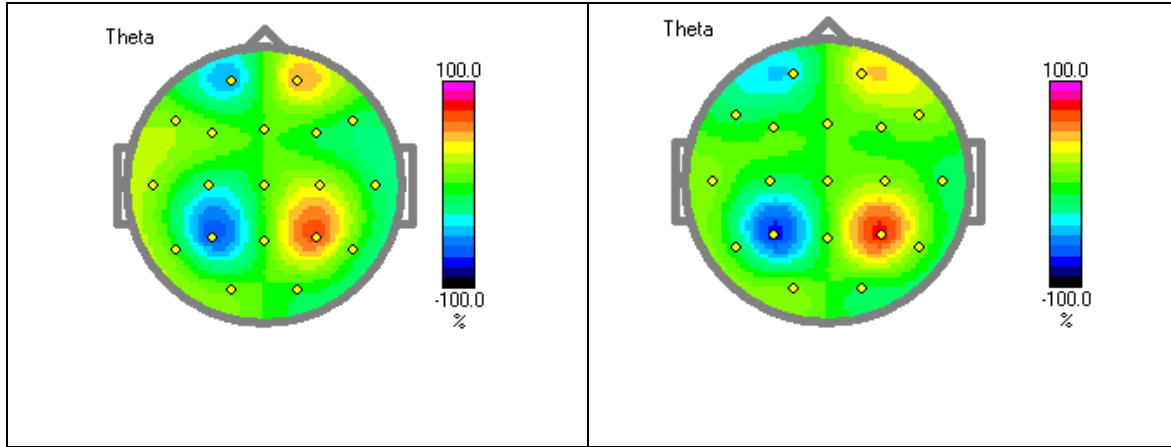


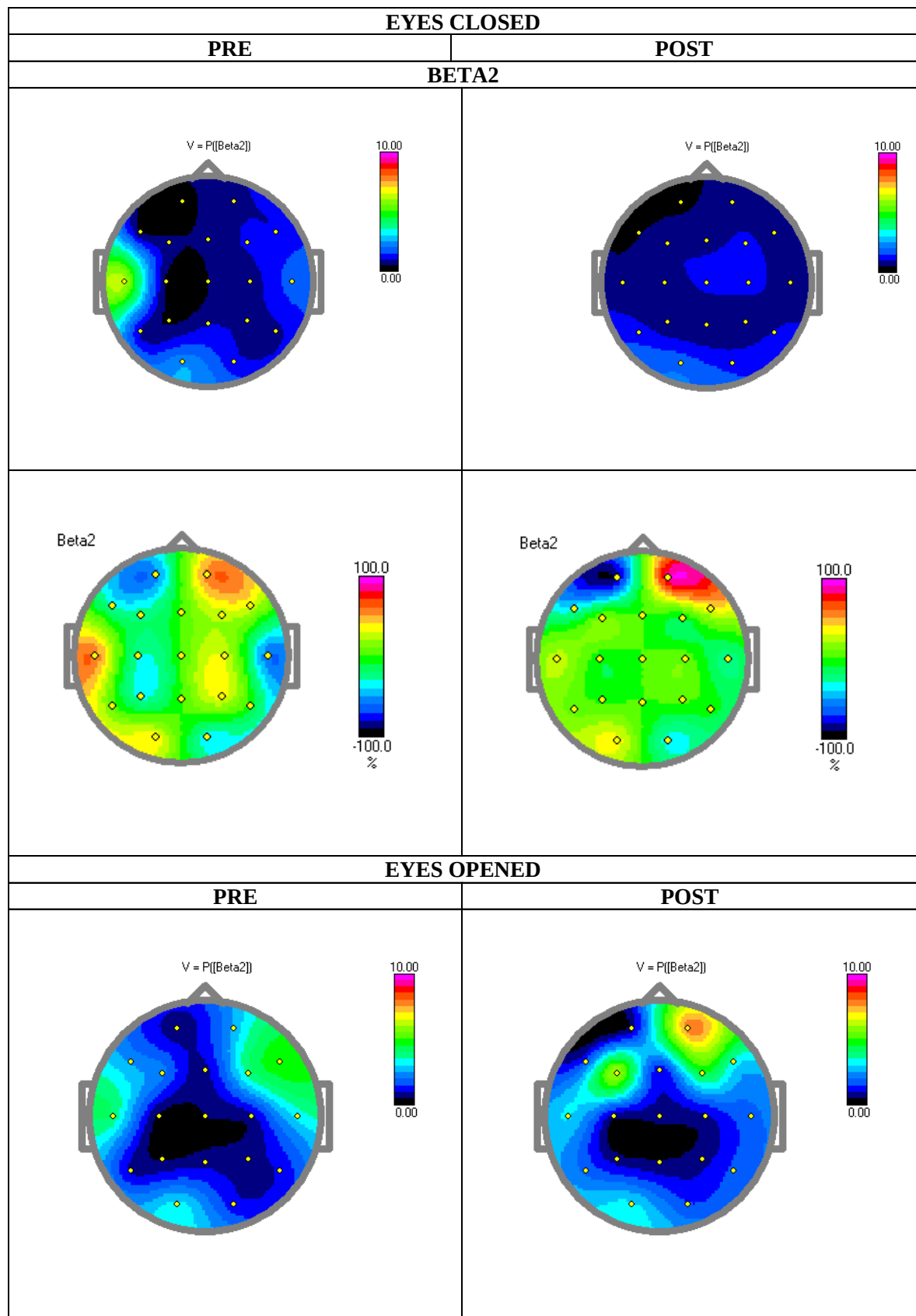
**Figure 4.2:** Subject A – theta topography

#### 4.2.1.1.3 Beta2

| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Beta2 ( $\mu V^2$ ) | 3.94     | .72       | .61      | .94       | .66      | .68       |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Beta2 ( $\mu V^2$ ) | 9.64     | 2.47      | .88      | .86       | .94      | .80       |

**Eyes closed.** T3T4 beta2power was dramatically reduced from  $3.94 \mu V^2$  to  $0.72 \mu V^2$  while in two other location C3C4 and P3P4 increments were observed with  $0.33 \mu V^2$  and  $0.02 \mu V^2$  respectively. While at the training areas the beta symmetry was almost achieved, it was opposite to non-training frontal areas.

**Eyes opened.** At T3T4, beta2 absolute power was greatly reduced from  $9.64 \mu V^2$  to  $2.47 \mu V^2$  and the C3C4 and P3P4 had reduction of  $0.02 \mu V^2$  and  $0.14 \mu V^2$  after the NFT. The asymmetry map of eyes opened resembled the eyes closed asymmetry map.



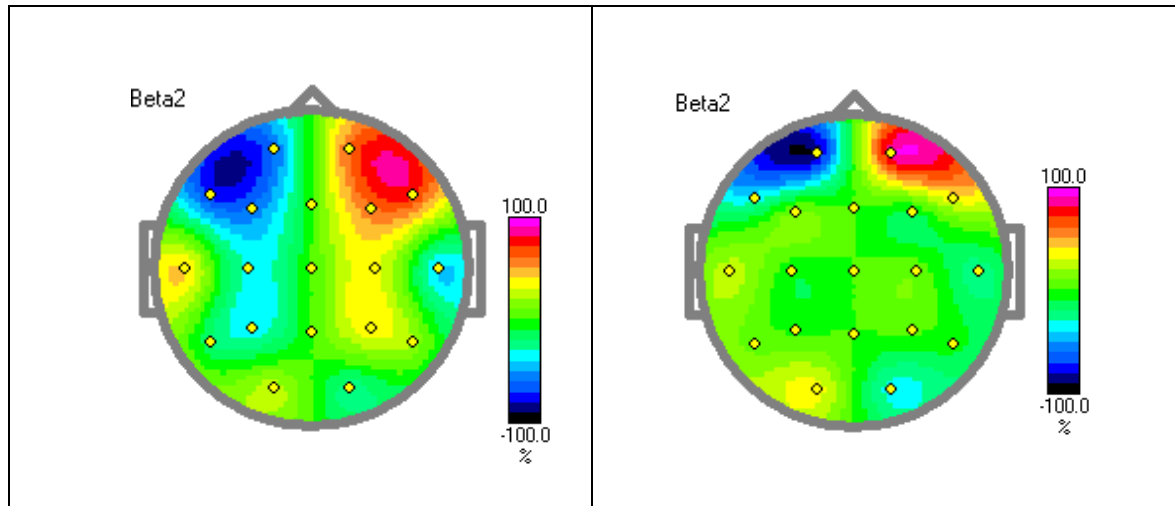


**Figure 4.3:** Subject A – beta2 topography

## 4.2.2 Subject B

### 4.2.2.1 Subject B: QEEG Absolute Power

**Table 4.3:** Subject B absolute power

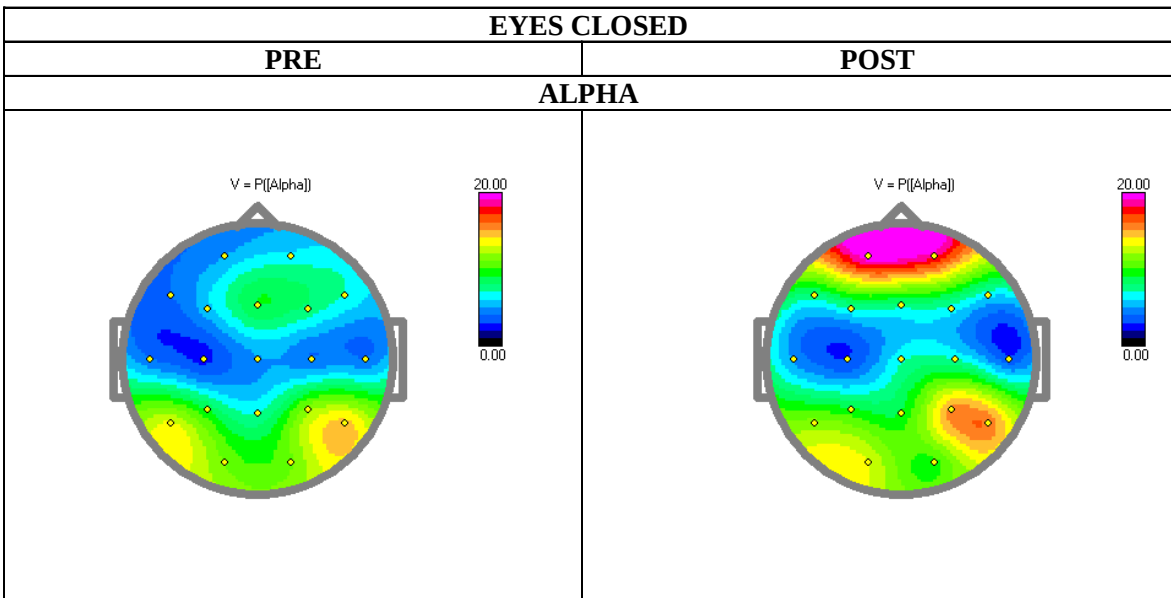
| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Alpha ( $\mu V^2$ ) | 4.08     | 4.12      | 3.41     | 5.00      | 10.47    | 12.35     |
| Theta ( $\mu V^2$ ) | .68      | .82       | .46      | .70       | .65      | 1.14      |
| Beta2 ( $\mu V^2$ ) | 2.49     | .70       | .58      | .64       | .61      | .81       |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Alpha ( $\mu V^2$ ) | 3.30     | 2.78      | 1.82     | 2.46      | 2.06     | 2.67      |
| Theta ( $\mu V^2$ ) | .68      | 1.11      | .37      | .64       | .38      | 1.05      |
| Beta2 ( $\mu V^2$ ) | 12.98    | 1.60      | 1.40     | .68       | .70      | .64       |

#### 4.2.2.1.1 Alpha

|                     |          |           |          |           |          |           |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Alpha ( $\mu V^2$ ) | 4.08     | 4.12      | 3.41     | 5.00      | 10.47    | 12.35     |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Alpha ( $\mu V^2$ ) | 3.30     | 2.78      | 1.82     | 2.46      | 2.06     | 2.67      |

**Eyes closed.** P3P4 showed the highest pre and post alpha;  $10.47\mu V^2$  and  $12.35\mu V^2$  respectively and also highest increment in alpha which is 1.88. T3T4 had slight increased in alpha from  $4.08\mu V^2$  to  $4.12\mu V^2$  while C3C4 from  $3.41\mu V^2$  to  $5.00\mu V^2$ . In pre NFT, asymmetry was seen from frontal to temporal regions. After NFT, mild asymmetry was observed at only T3T4. The effect of NFT was clear in topography map as been described in absolute power above.

**Eyes opened.** T3T4 had decreased in post absolute power and the other two locations exhibited increase in post absolute power as had been seen in eyes closed condition.



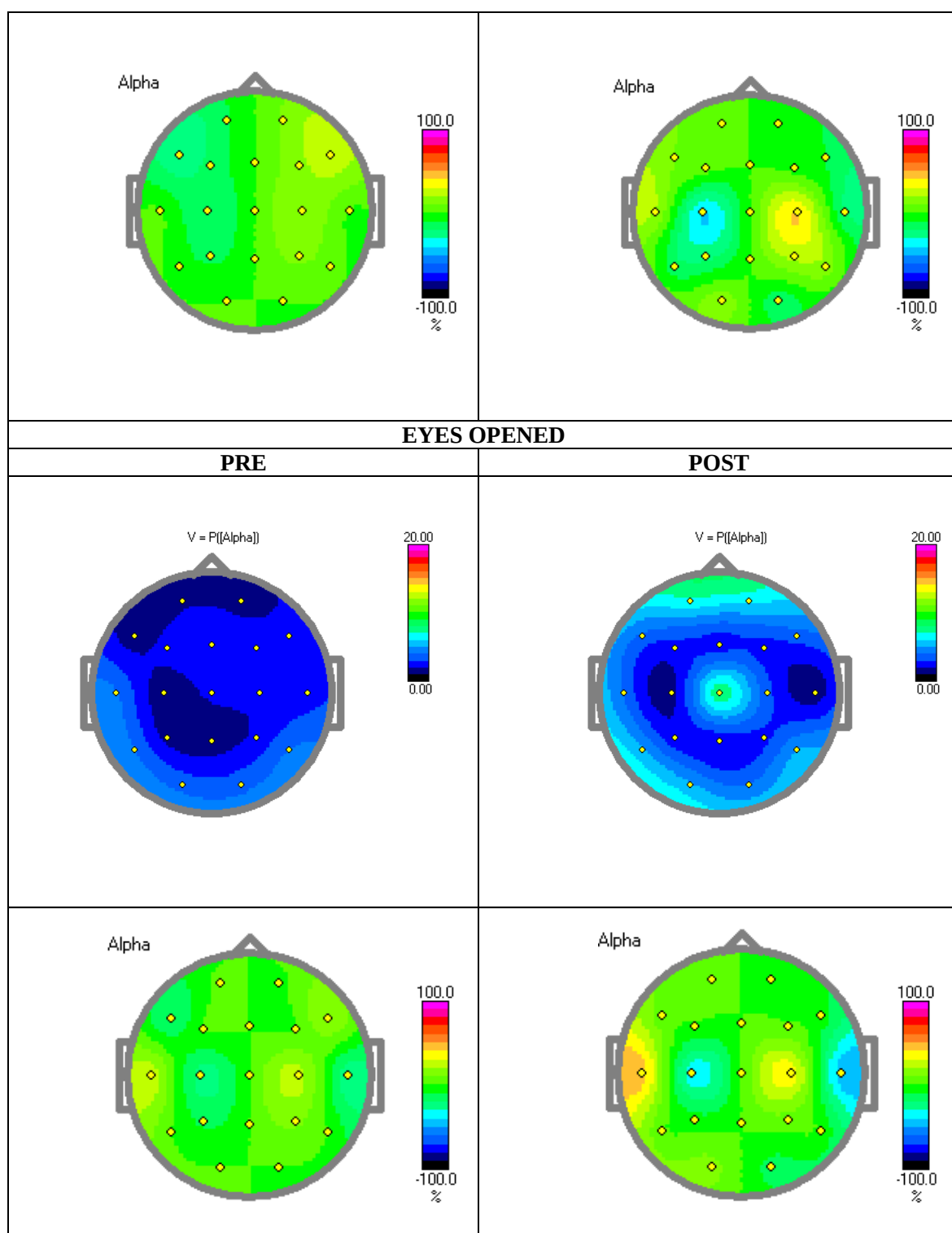


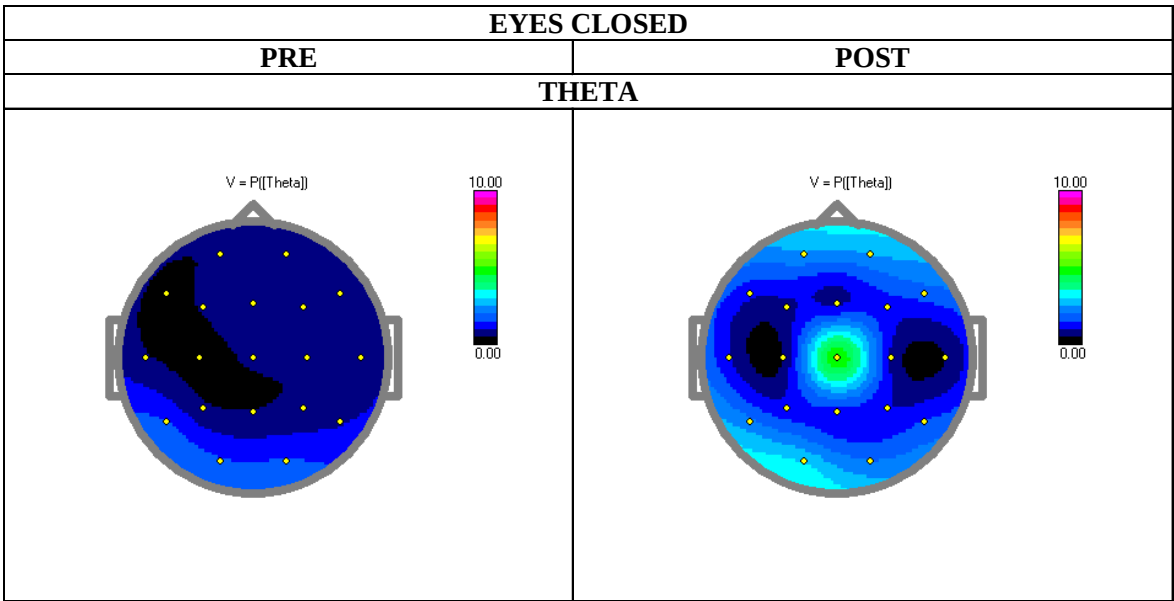
**Figure 4.4:** Subject B – alpha topography

4.2.2.1.2 Theta

|                     |          |           |          |           |          |           |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Theta ( $\mu V^2$ ) | .68      | .82       | .46      | .70       | .65      | 1.14      |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Theta ( $\mu V^2$ ) | .68      | 1.11      | .37      | .64       | .38      | 1.05      |

**Eyes closed.** Despite the suppression of theta during NFT, all locations still had addition in theta absolute power with the lowest increment in T3T4,  $0.14 \mu V^2$  and the highest at P3P4,  $0.49 \mu V^2$ . There was a subtle difference in asymmetry map in pre and post NFT.

**Eyes opened.** The results of eyes opened condition duplicated the eyes closed condition with all locations had increased in post NFT reading. Overall, the symmetry of theta was almost achieved.



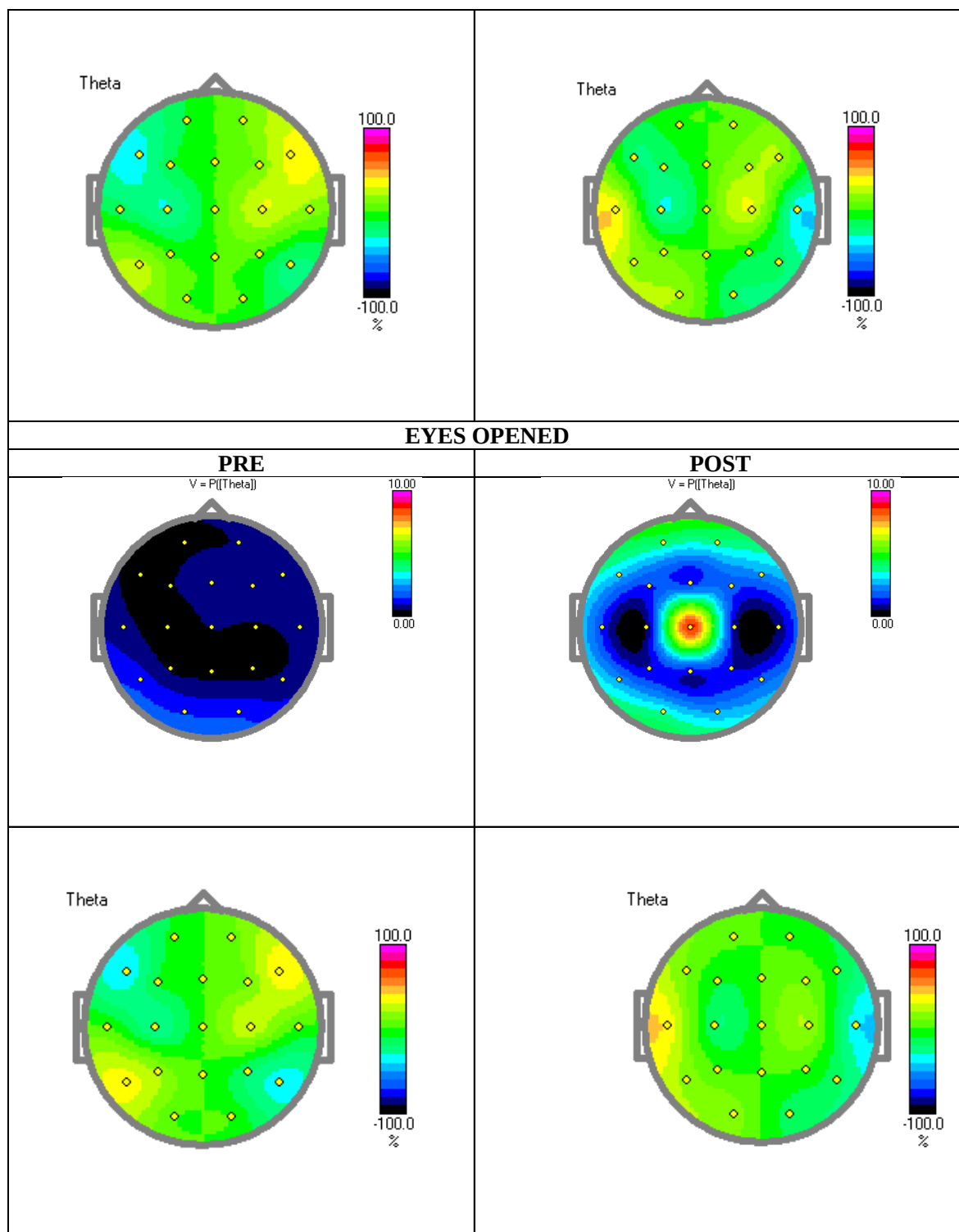


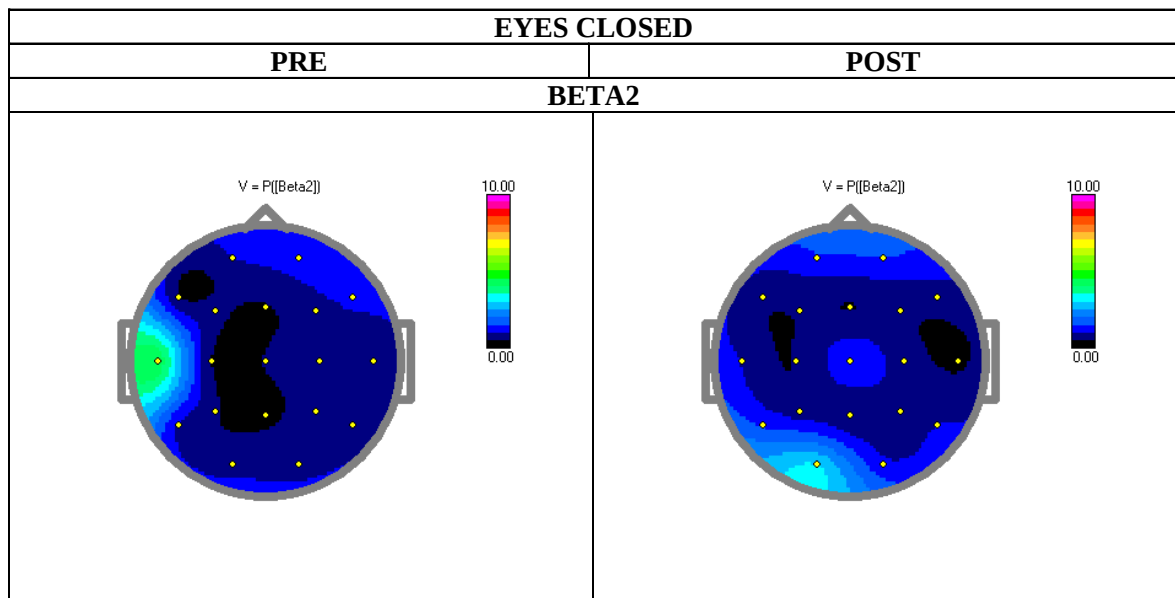
**Figure 4.5:** Subject B – theta topography

#### 4.2.2.1.3 Beta2

|                     |          |           |          |           |          |           |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Beta2 ( $\mu V^2$ ) | 2.49     | .70       | .58      | .64       | .61      | .81       |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Beta2 ( $\mu V^2$ ) | 12.98    | 1.60      | 1.40     | .68       | .70      | .64       |

**Eyes closed.** At T3T4, beta2 power was greatly reduced from 2.49 to 0.70. The other two locations showed raise of beta2 power with 0.06 and 0.20. The reduction & increment of beta2 power were clear in topography map. In asymmetry map, it was observed that the imbalance beta2 power at T3T4 was reduced as been described earlier.

**Eyes opened.** As had been observed at T3T4 of eyes closed condition, beta2 power of eyes opened condition imitated the result with a huge reduction in post NFT reading from 12.98 to 1.60. The reduction of absolute power was clearly seen on topography map particularly at T3 but symmetry at T3 and T4 were not observed.



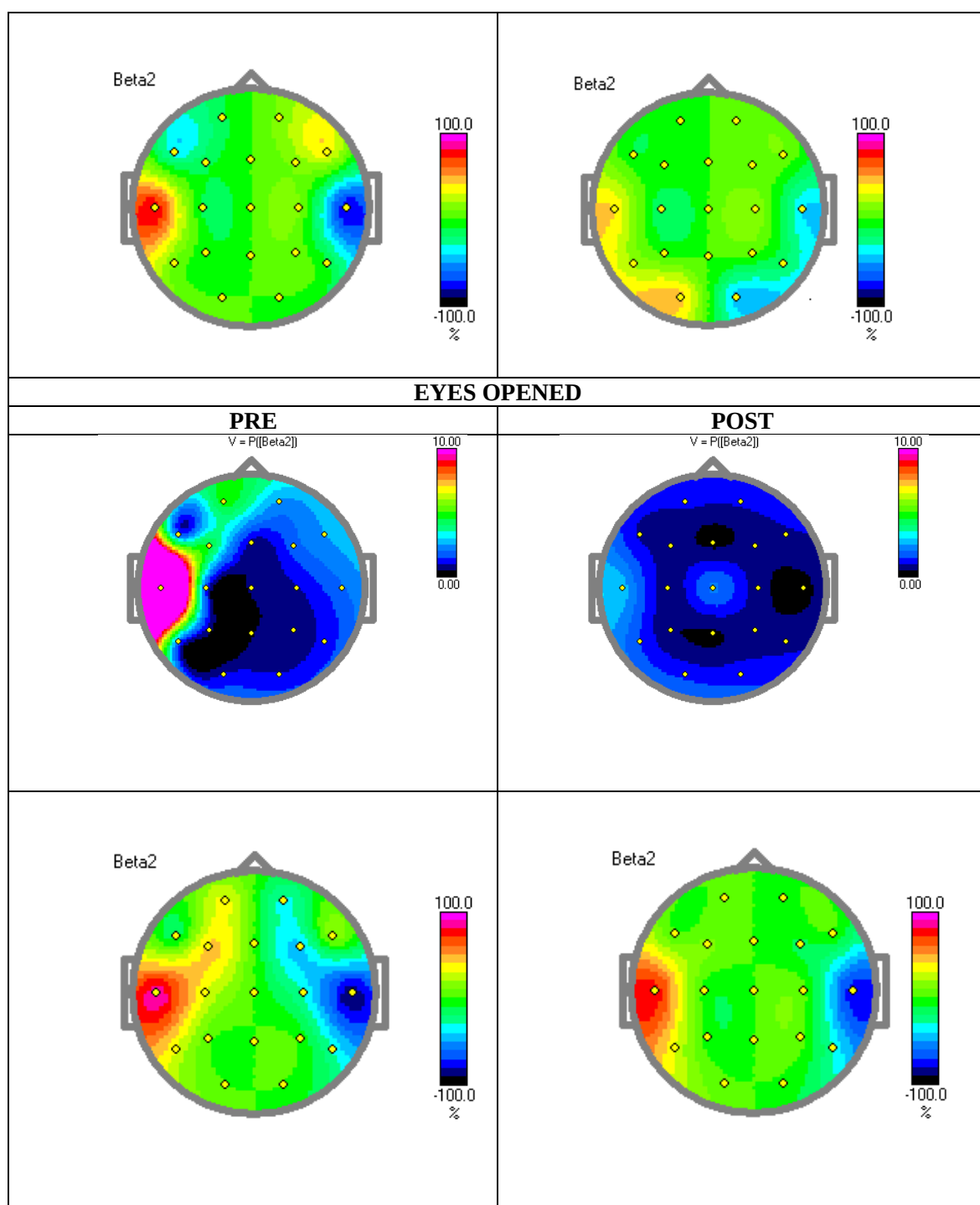


**Figure 4.6:** Subject B – beta2 topography

### 4.2.3 Subject C

#### 4.2.3.1 Subject C: QEEG Absolute Power

**Table 4.4:** Subject C absolute power

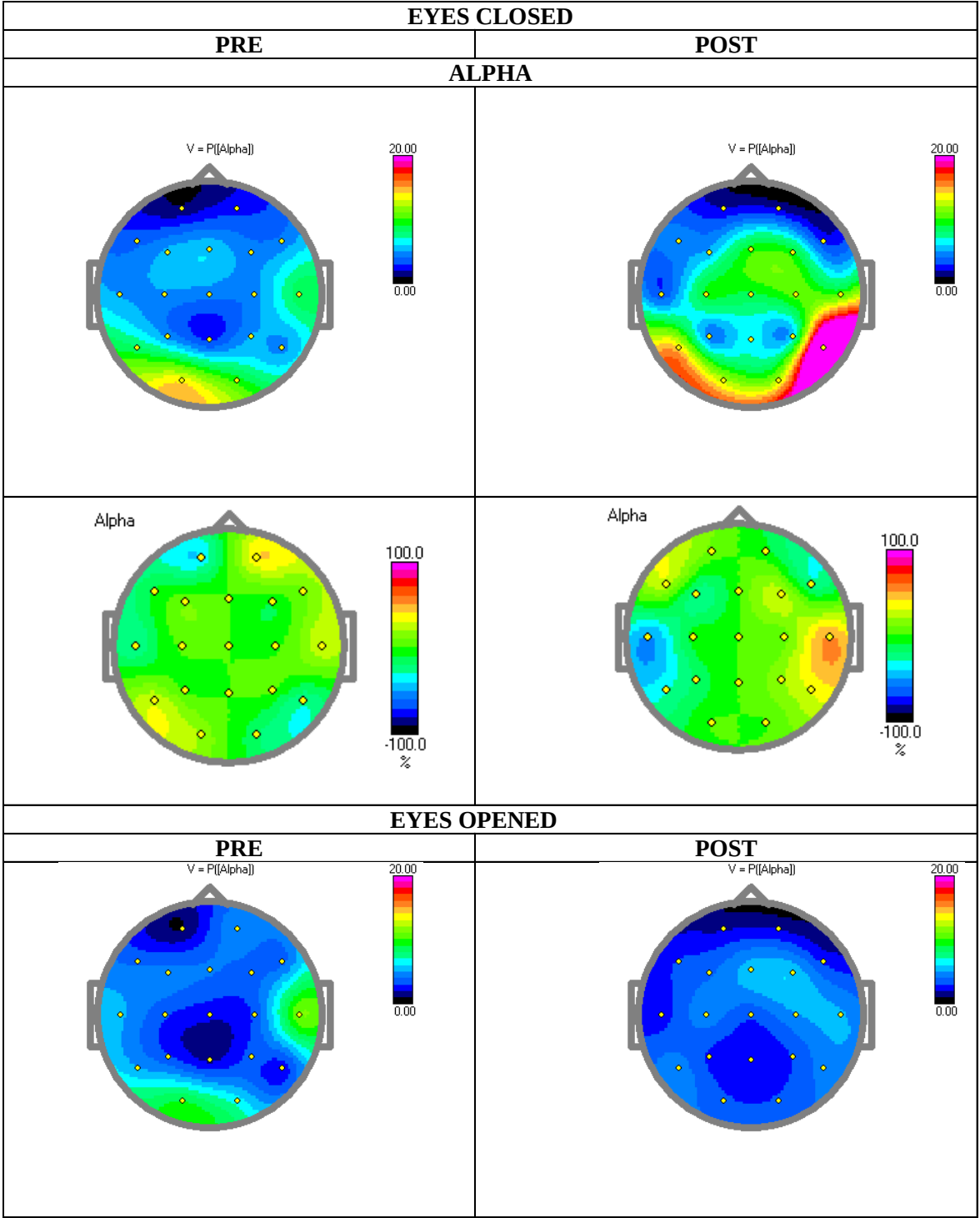
| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Alpha ( $\mu V^2$ ) | 6.76     | 6.78      | 4.72     | 9.78      | 5.01     | 5.64      |
| Theta ( $\mu V^2$ ) | 1.72     | 1.69      | 1.26     | 1.52      | 1.03     | .80       |
| Beta2 ( $\mu V^2$ ) | 9.86     | 9.14      | 7.56     | 6.48      | 3.16     | 2.52      |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Alpha ( $\mu V^2$ ) | 8.04     | 3.79      | 3.28     | 4.74      | 3.30     | 2.98      |
| Theta ( $\mu V^2$ ) | 1.63     | 1.50      | 1.23     | 1.41      | 1.03     | .79       |
| Beta2 ( $\mu V^2$ ) | 14.11    | 8.65      | 7.72     | 5.86      | 3.51     | 2.07      |

##### 4.2.3.1.1 Alpha

| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Alpha ( $\mu V^2$ ) | 6.76     | 6.78      | 4.72     | 9.78      | 5.01     | 5.64      |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Alpha ( $\mu V^2$ ) | 8.04     | 3.79      | 3.28     | 4.74      | 3.30     | 2.98      |

**Eyes closed.** All locations in post NFT showed increments in alpha absolute value with least difference of  $0.02 \mu V^2$  at T3T4 and maximum difference of  $5.06 \mu V^2$  at C3C4. At P3P4, a moderate increment was observed;  $0.63 \mu V^2$ . From the topography, the difference between pre and post absolute power was clear.

**Eyes opened.** As opposed to eyes closed result, only at C3C4 an increase in alpha absolute power was observed and it was reflected by the topography of the brain. Alpha symmetry was almost the same for left and right sides.



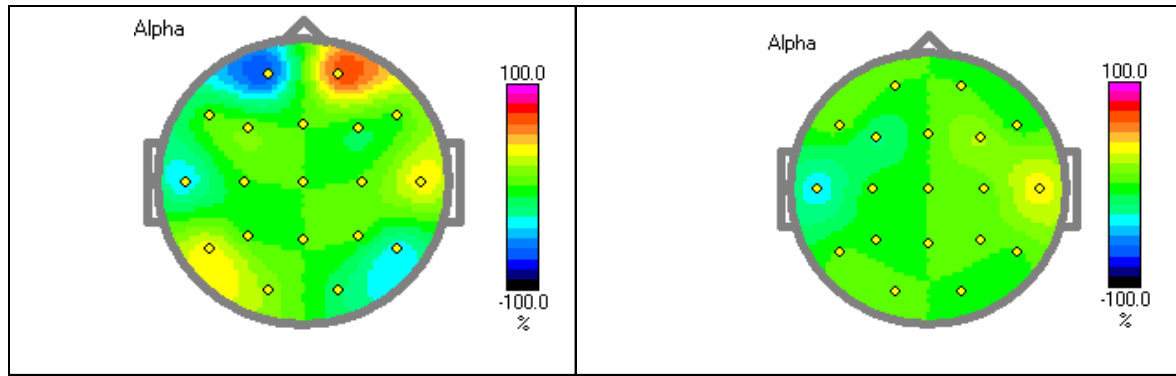


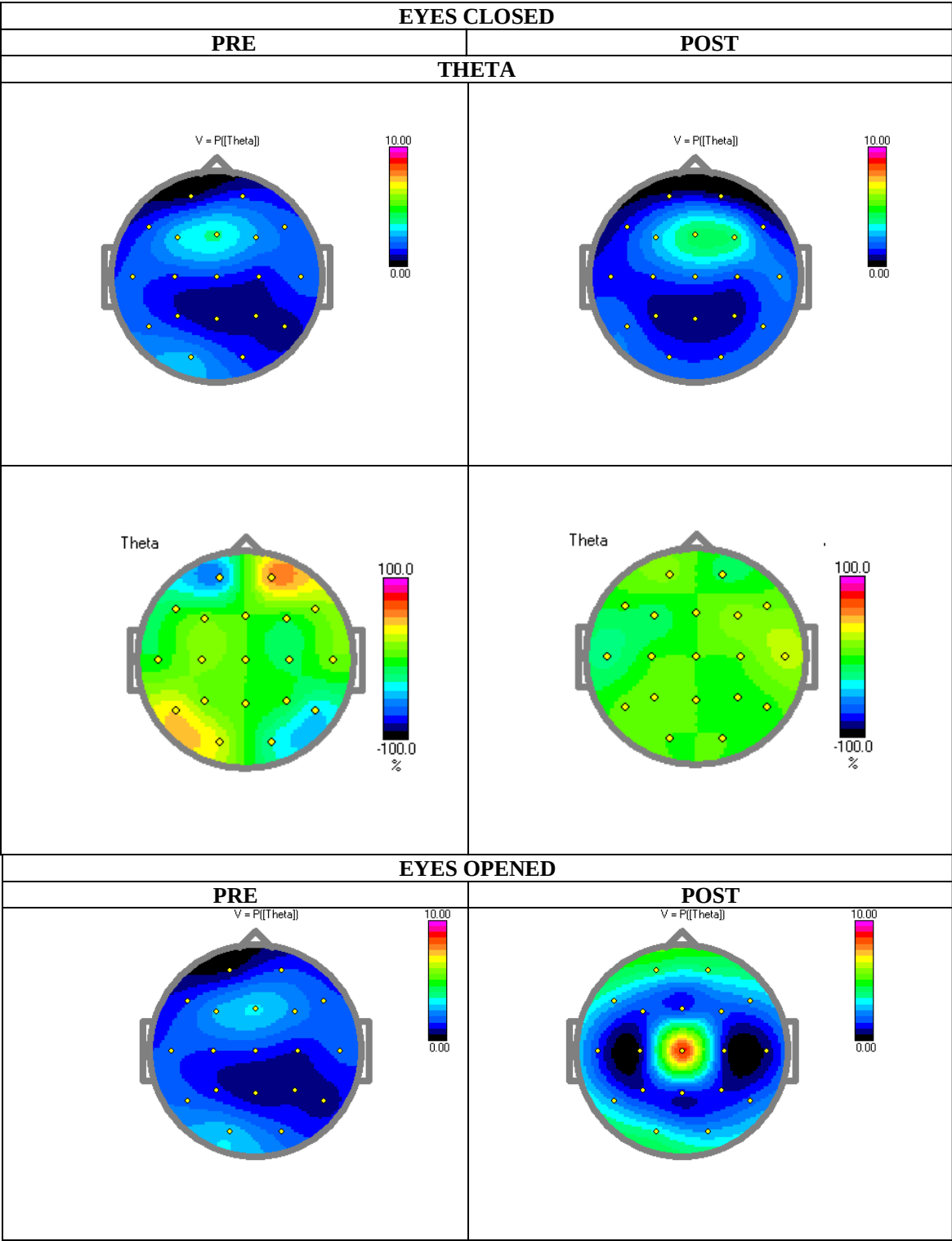
**Figure 4.7:** Subject C – alpha topography

#### 4.1.3.1.2 Theta

| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Theta ( $\mu V^2$ ) | 1.72     | 1.69      | 1.26     | 1.52      | 1.03     | .80       |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Theta ( $\mu V^2$ ) | 1.63     | 1.50      | 1.23     | 1.41      | 1.03     | .79       |

**Eyes closed.** The only location that showed decrease in theta power was P3P4 with pre and post difference  $-0.23\mu V^2$ . T3T4 pre reading was  $1.26\mu V^2$  and the post NFT is  $1.52\mu V^2$ . The difference in topography was subtle but through asymmetry map, symmetry of theta was almost achieved.

**Eyes opened.** Theta absolute power was decreased at T3T4 and P3P4. Increment of theta was seen at C3C4 with difference of  $0.38\mu V^2$ .



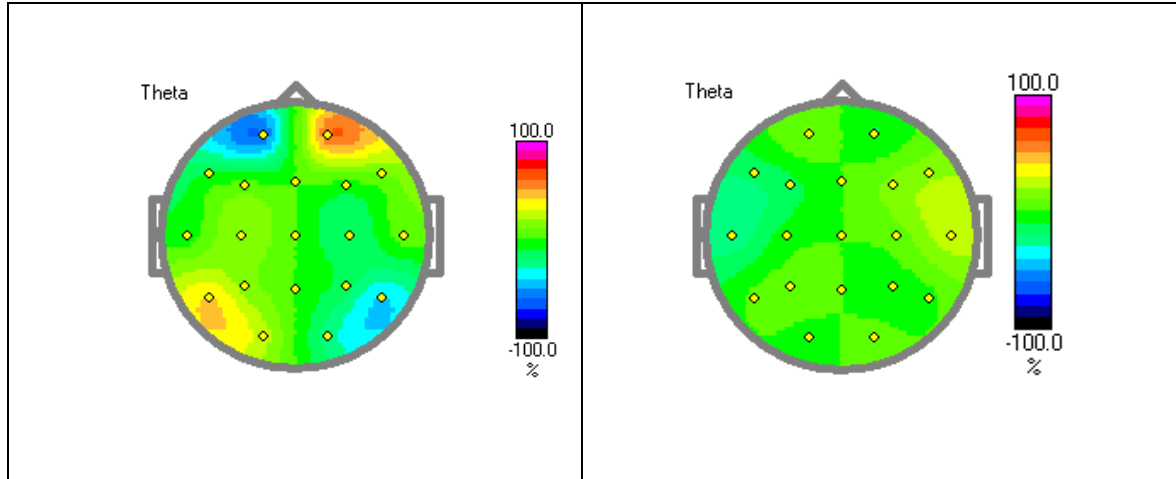


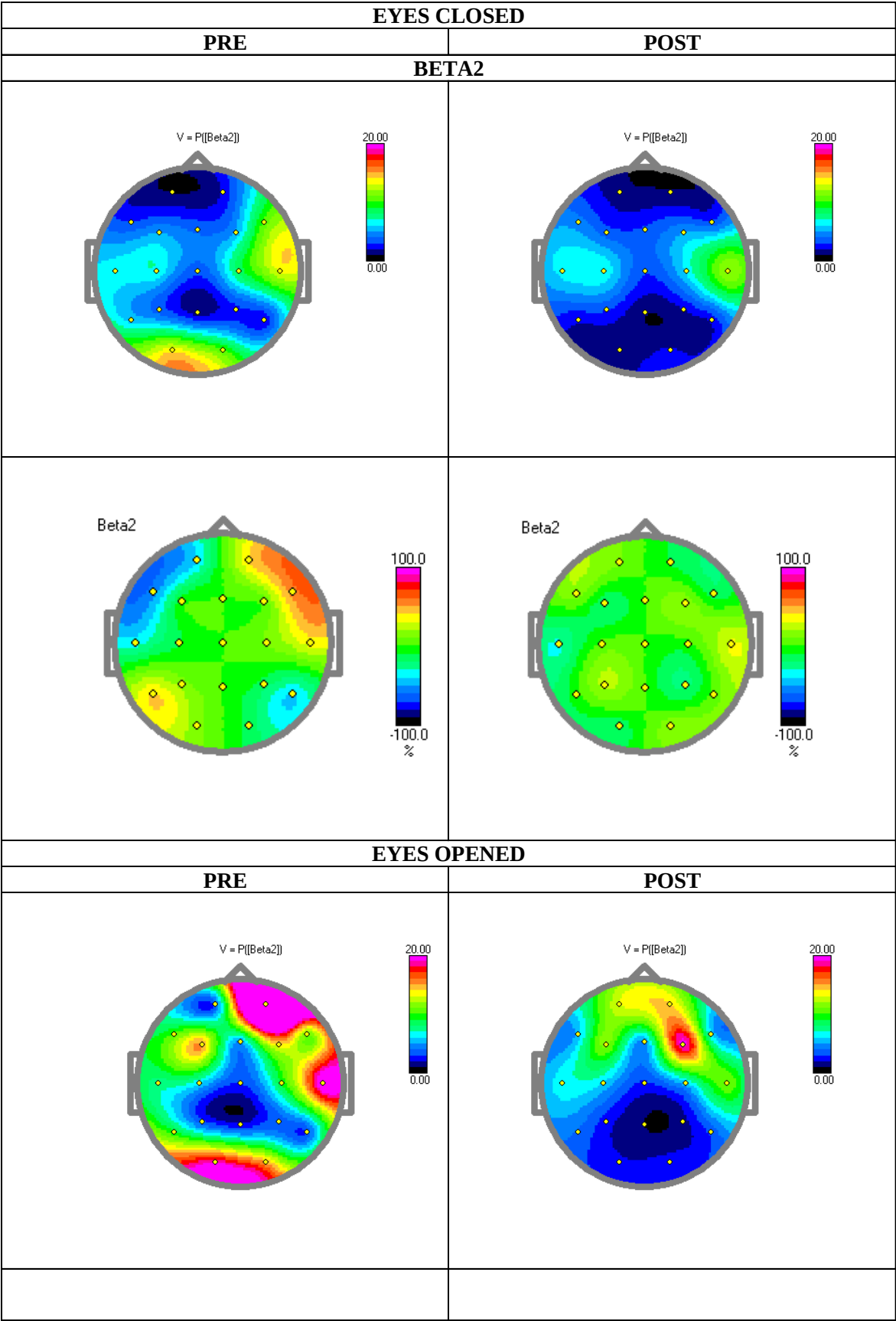
**Figure 4.8:** Subject C – theta topography

#### 4.1.3.1.3 Beta2

|                     |          |           |          |           |          |           |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Beta2 ( $\mu V^2$ ) | 9.86     | 9.14      | 7.56     | 6.48      | 3.16     | 2.52      |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Beta2 ( $\mu V^2$ ) | 14.11    | 8.65      | 7.72     | 5.86      | 3.51     | 2.07      |

**Eyes closed.** Suppression of beta2 was successful in all three locations. At T3T4, absolute power decline from  $9.86\mu V^2$  to  $9.14\mu V^2$  with difference of  $-0.72\mu V^2$ . C3C4 displayed a great difference between pre and post which was  $-1.08\mu V^2$  while at P3P4 the difference was  $-0.64\mu V^2$ . From the topography, the suppression of beta2 was observed at parieto-occipital areas or the training sites. The effect of this gave the changes in asymmetry map with reduced asymmetry in the whole brain.

**Eyes opened.** The result of eyes opened condition resembled the eyes closed condition with the greatest difference observed at T3T4 from  $14.11\mu V^2$  to  $8.65\mu V^2$ . Whole brain symmetry was observed after NFT.



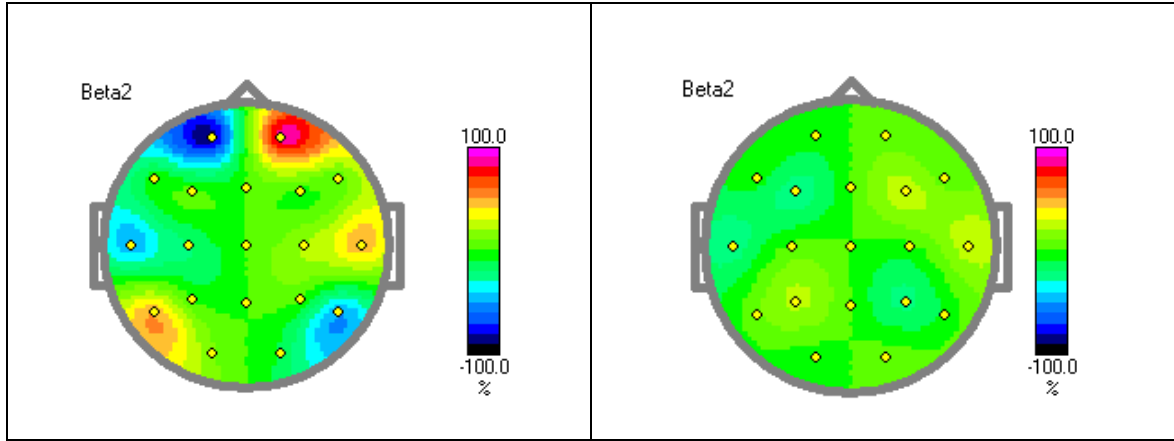


**Figure 4.9:** Subject C – beta2 topography

#### 4.2.4 Subject D

##### 4.2.4.1 Subject D: QEEG Absolute Power

**Table 4.5:** Subject D absolute power

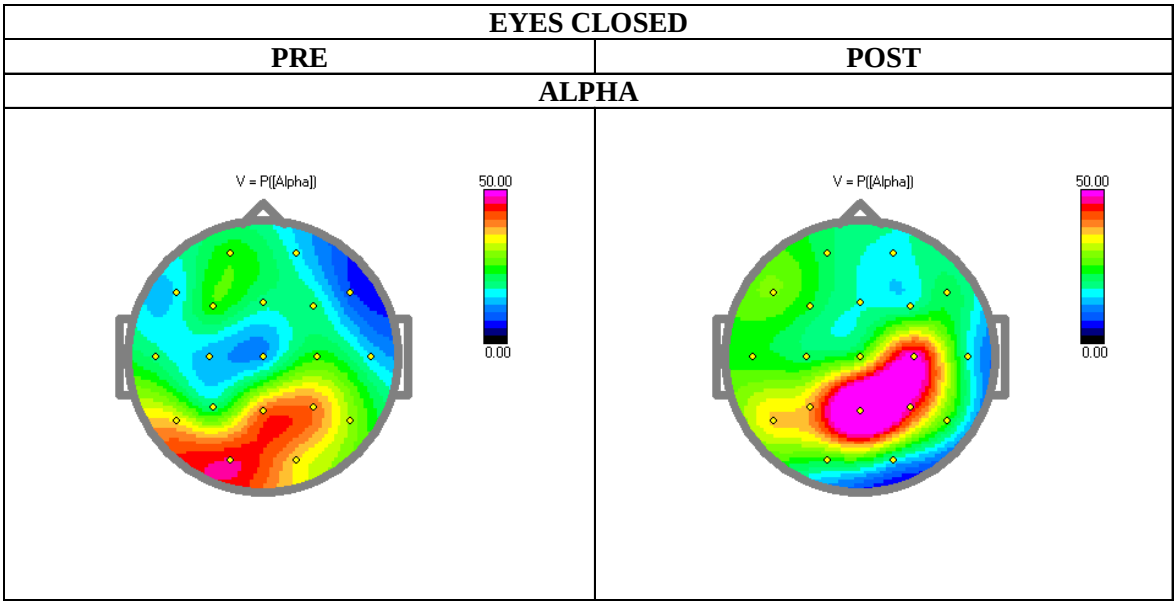
| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Alpha ( $\mu V^2$ ) | 17.10    | 19.87     | 18.72    | 34.94     | 30.04    | 41.32     |
| Theta ( $\mu V^2$ ) | 5.48     | 8.52      | 2.94     | 6.12      | 4.02     | 7.68      |
| Beta2 ( $\mu V^2$ ) | 4.56     | 2.69      | 1.67     | 1.84      | 1.37     | 1.32      |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Alpha ( $\mu V^2$ ) | 10.22    | 17.94     | 11.57    | 25.54     | 13.61    | 27.29     |
| Theta ( $\mu V^2$ ) | 2.74     | 9.05      | 1.46     | 4.18      | 1.91     | 5.11      |
| Beta2 ( $\mu V^2$ ) | 7.94     | 9.42      | 2.07     | 1.72      | 1.41     | 1.38      |

#### 4.2.4.1.1 Alpha

|                     |          |           |          |           |          |           |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Alpha ( $\mu V^2$ ) | 17.10    | 19.87     | 18.72    | 34.94     | 30.04    | 41.32     |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Alpha ( $\mu V^2$ ) | 10.22    | 17.94     | 11.57    | 25.54     | 13.61    | 27.29     |

**Eyes closed.** All locations in post NFT showed increments in alpha absolute value. T3T4 displayed the lowest increment with  $2.77\mu V^2$  while the highest was at C3C4 with difference of  $16.22\mu V^2$  and lastly P3P4 with  $10.92\mu V^2$ . The increase of alpha was clear in topography map especially at P3P4.

**Eyes opened.** As been observed in eyes closed condition, all location in eyes opened condition also exhibited increase in post absolute power. The change of alpha was apparent in the topography map.



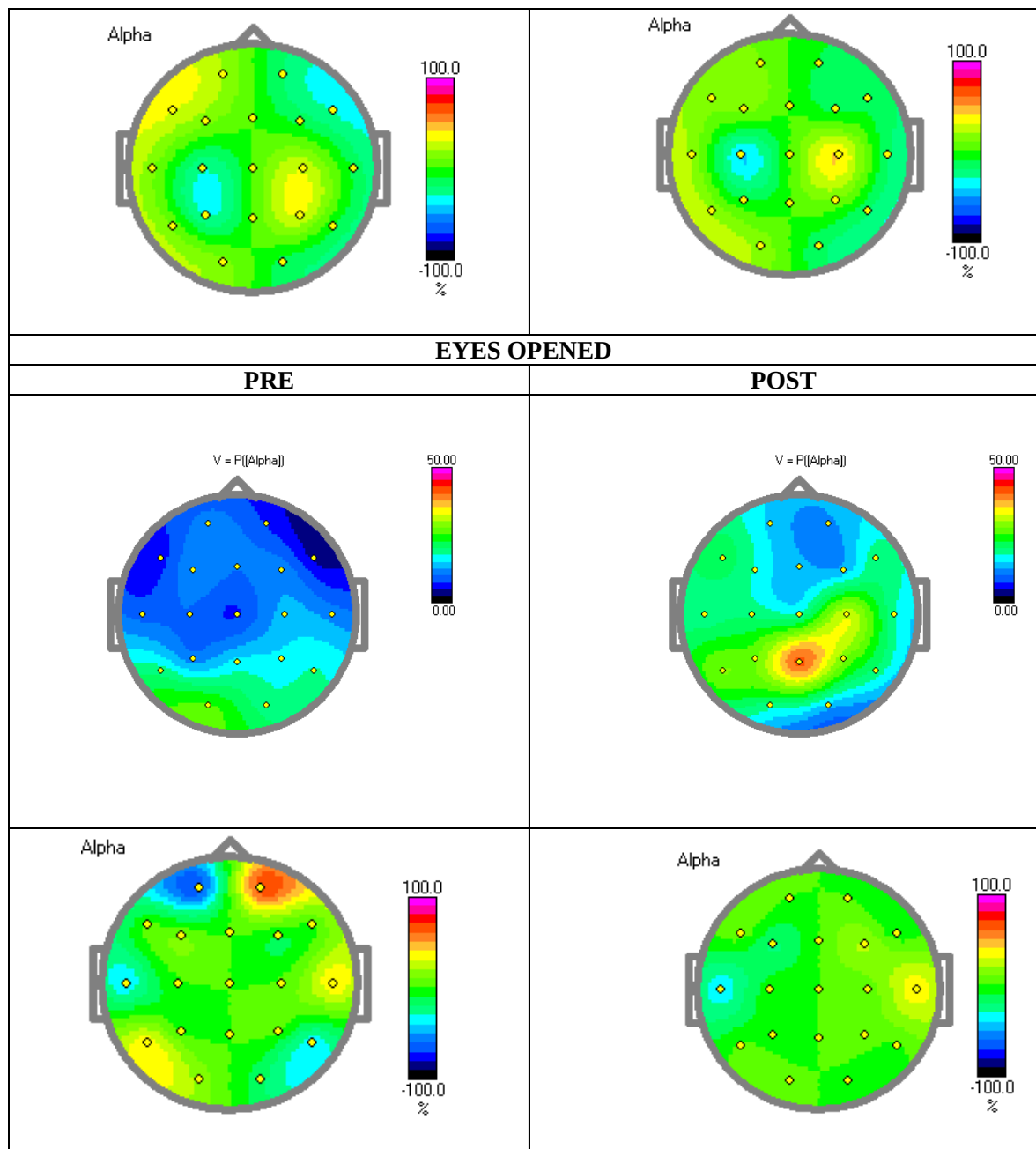


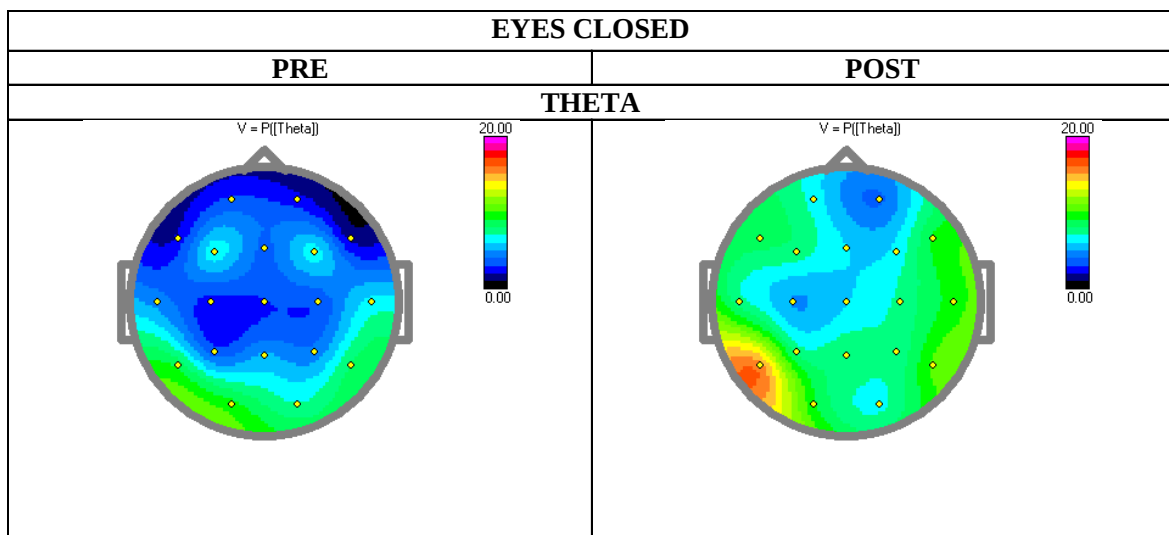
**Figure 4.10:** Subject D – alpha topography

#### 4.2.4.1.2 Theta

|                     |          |           |          |           |          |           |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Theta ( $\mu V^2$ ) | 5.48     | 8.52      | 2.94     | 6.12      | 4.02     | 7.68      |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Theta ( $\mu V^2$ ) | 2.74     | 9.05      | 1.46     | 4.18      | 1.91     | 5.11      |

**Eyes closed.** As been seen in almost all subjects, suppression of theta was failed as all locations displayed increase in theta absolute power. At T3T4, pre reading was  $5.48\mu V^2$  and post reading was  $8.52\mu V^2$ . Post reading for C3C4 was  $3.18\mu V^2$  higher than pre reading. The highest difference was seen at P3P4 with value of  $3.66\mu V^2$ . Topography map showed overall increase of theta in all locations not only the training sites and not much difference observed in asymmetry map.

**Eyes opened.** Eyes opened condition duplicated the result of eyes closed with all locations had increased in theta. The highest difference was observed at T3T4 with the value of  $6.31\mu V^2$ .



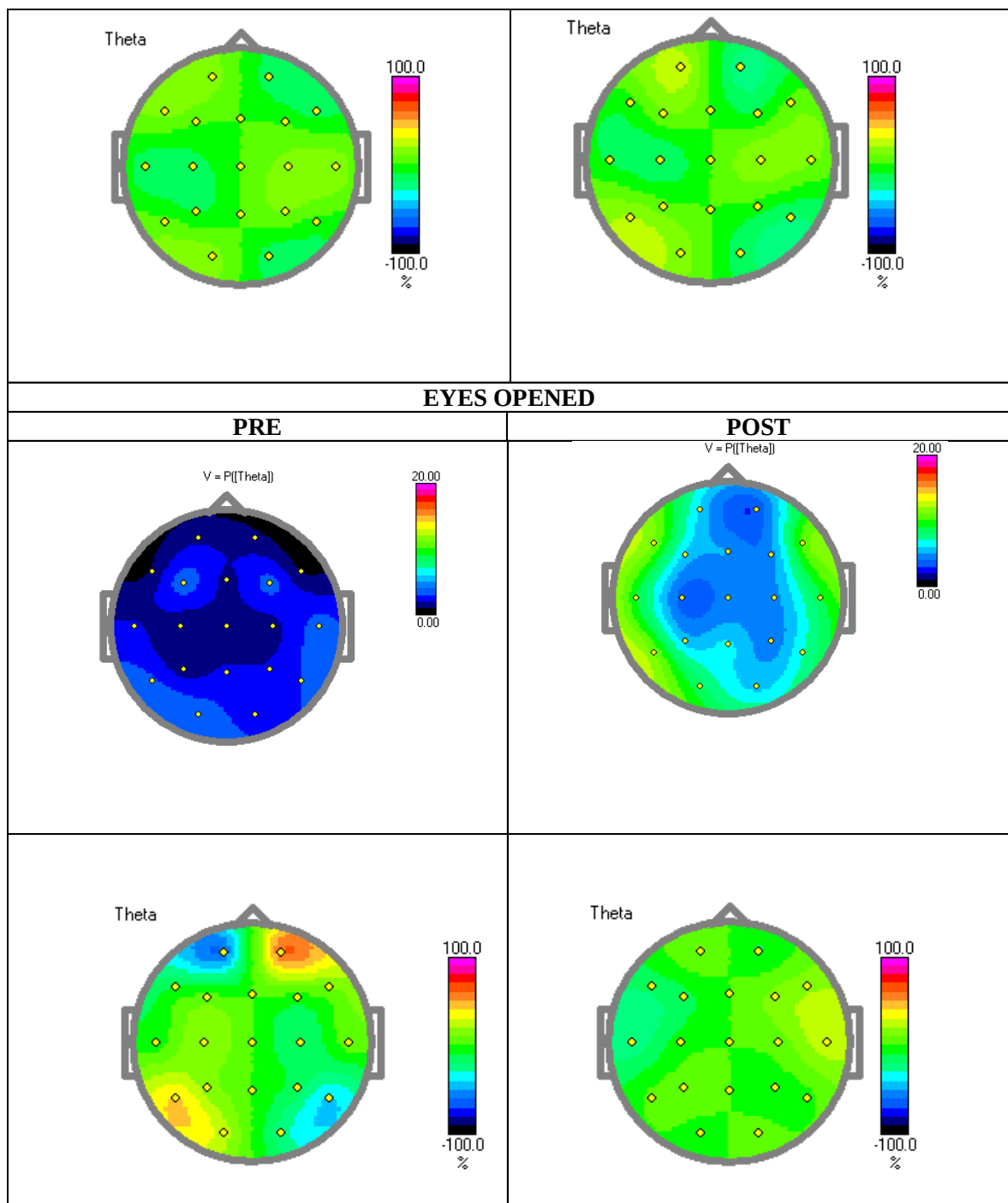


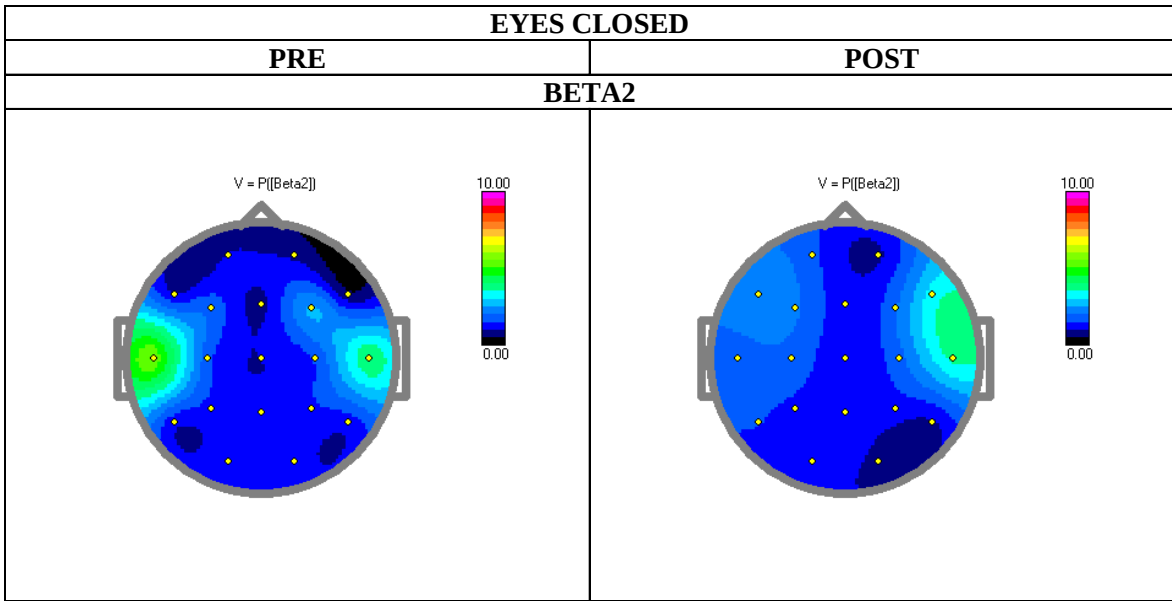
**Figure 4.11:** Subject D – theta topography

4.2.4.1.3 Beta2

|                     |          |           |          |           |          |           |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
|                     | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Beta2 ( $\mu V^2$ ) | 4.56     | 2.69      | 1.67     | 1.84      | 1.37     | 1.32      |
|                     | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Beta2 ( $\mu V^2$ ) | 7.94     | 9.42      | 2.07     | 1.72      | 1.41     | 1.38      |

**Eyes closed.** At two locations, T3T4 and P3P4, beta2 power decreased by  $1.87\mu V^2$  and  $0.05\mu V^2$  respectively. Only C3C4 power was increased from  $1.67\mu V^2$  to  $1.84\mu V^2$ . The increase of beta2 absolute power was apparent in pre and post topography.

**Eyes opened.** At T3T4, the absolute power value increased instead of decreasing. At C3C4 the power decreased from  $2.07 \mu V^2$  to  $1.72 \mu V^2$  while at P3P4 it decreased in value from  $1.41 \mu V^2$  to  $1.38 \mu V^2$ . A good symmetry of brain was observable.



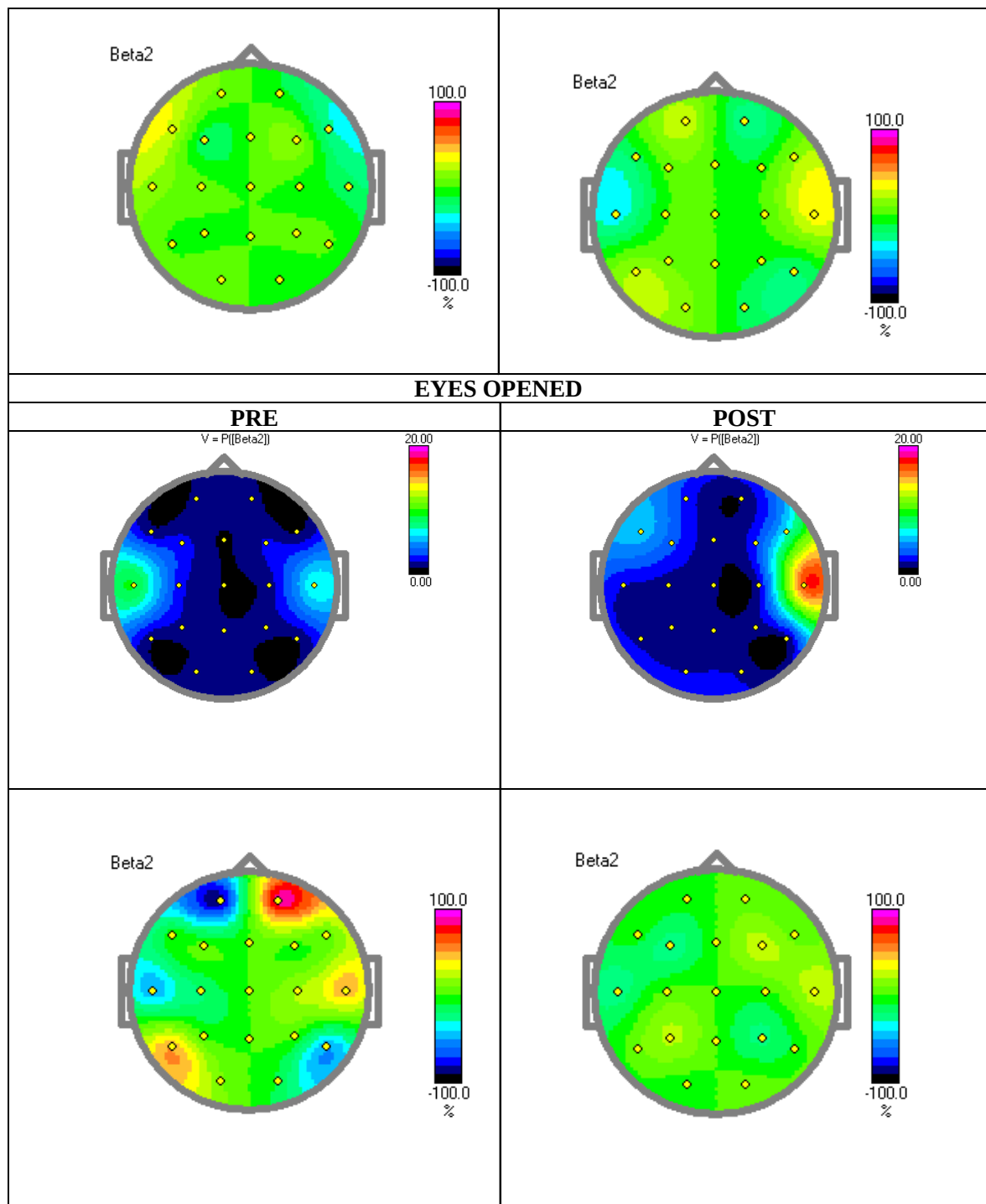


**Figure 4.12:** Subject D – beta2 topography

## 4.2.5 Subject E

### 4.2.5.1 Subject E: QEEG Absolute Power

**Table 4.6:** Subject E absolute power

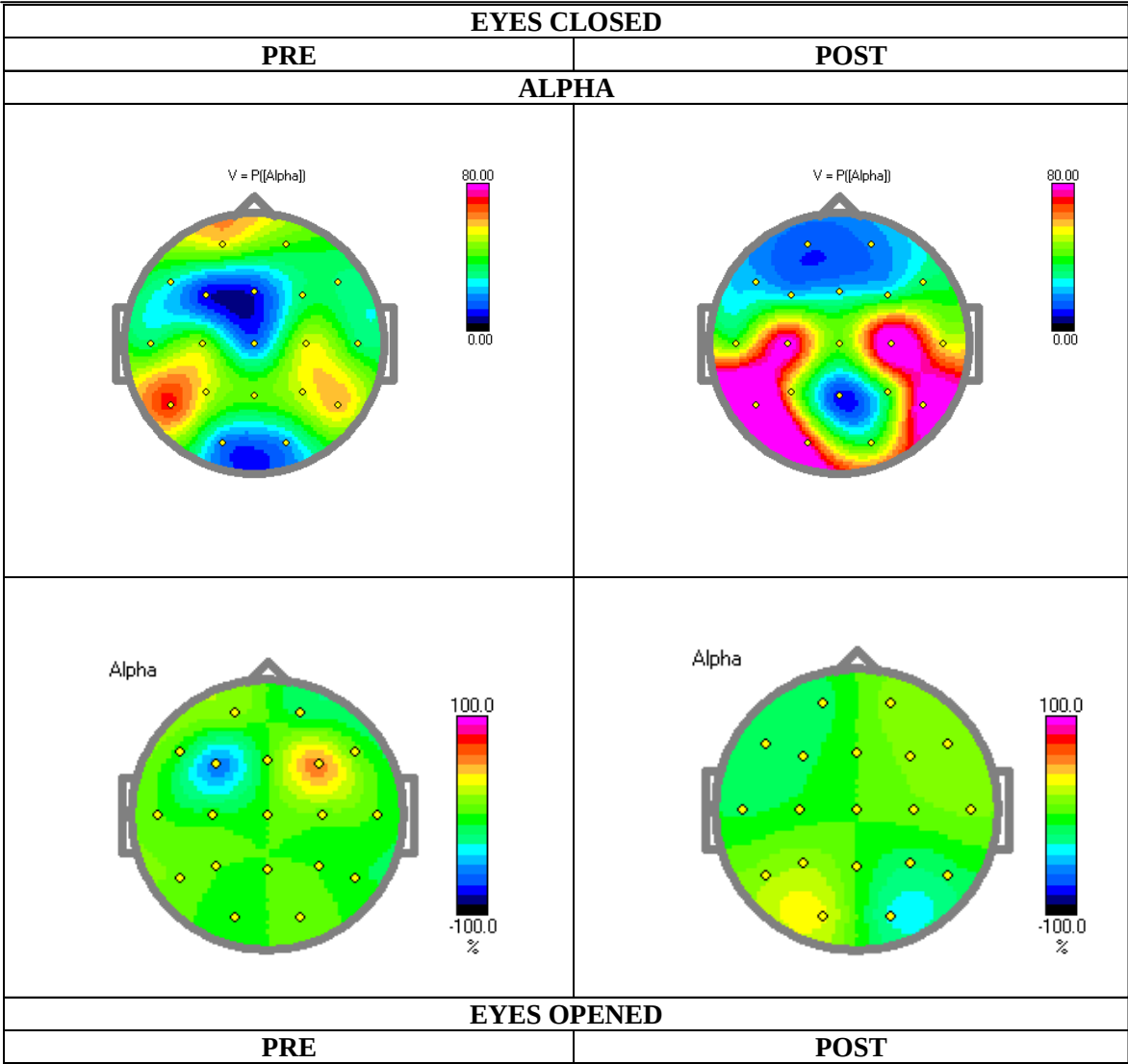
| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Alpha ( $\mu V^2$ ) | 32.86    | 47.45     | 48.97    | 85.75     | 52.23    | 47.35     |
| Theta ( $\mu V^2$ ) | 4.84     | 8.10      | 4.44     | 8.30      | 4.63     | 5.80      |
| Beta2 ( $\mu V^2$ ) | 3.22     | 2.95      | 3.54     | 4.05      | 3.44     | 1.90      |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Alpha ( $\mu V^2$ ) | 22.23    | 35.55     | 37.85    | 61.53     | 29.47    | 29.09     |
| Theta ( $\mu V^2$ ) | 3.14     | 5.76      | 3.26     | 5.16      | 2.71     | 3.65      |
| Beta2 ( $\mu V^2$ ) | 3.25     | 4.73      | 3.07     | 3.89      | 2.37     | 2.65      |

#### 4.2.5.1.1 Alpha

| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Alpha ( $\mu V^2$ ) | 32.86    | 47.45     | 48.97    | 85.75     | 52.23    | 47.35     |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Alpha ( $\mu V^2$ ) | 22.23    | 35.55     | 37.85    | 61.53     | 29.47    | 29.09     |

**Eyes closed.** All locations in post NFT showed increments in alpha absolute value except for P3P4 which had reduction by  $4.88 \mu V^2$  from the pre reading,  $52.23 \mu V^2$ . T3T4 displayed the lowest increment with  $14.59 \mu V^2$  and at P3P4 the difference was  $36.78 \mu V^2$ . The topography showed clear differences in pre and post QEEG with a better symmetry formed in post QEEG.

**Eyes opened.** At T3T4 and C3C4 had increased in absolute power with difference of 13.32 and 23.68 respectively. At P3P4, a slight decreased in absolute power was seen. The difference in topography map was apparent in pre and post while a good symmetry was achieved.



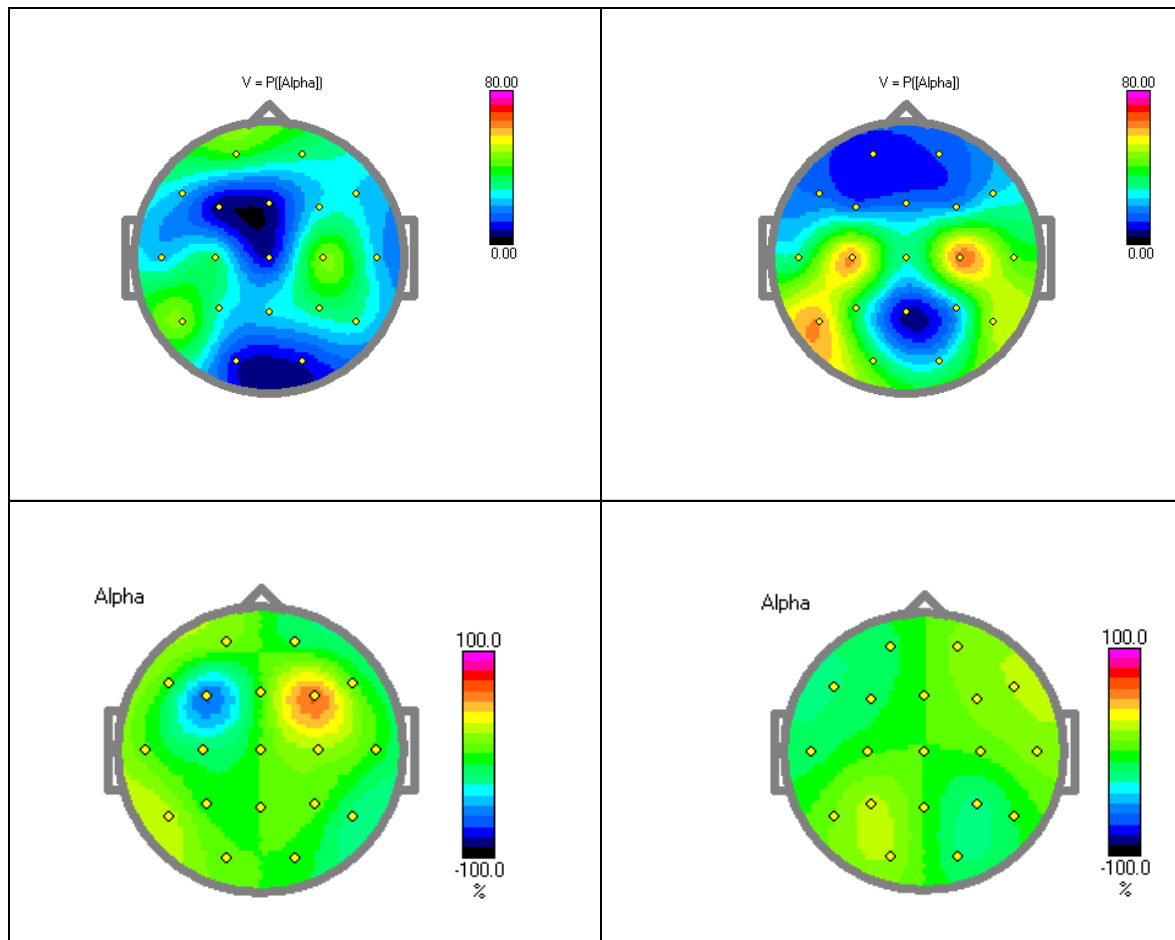


**Figure 4.13:** Subject E – alpha topography

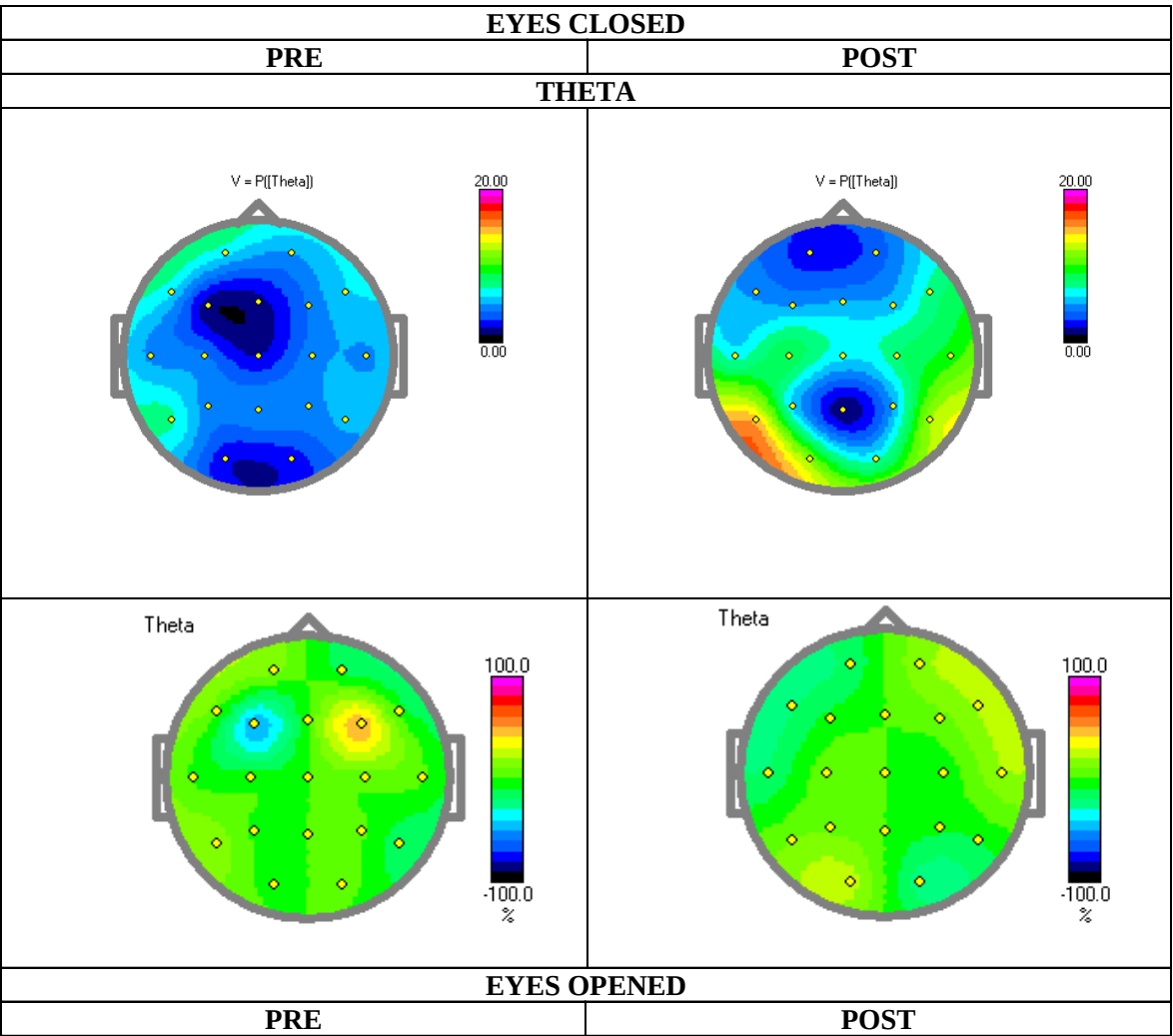
#### 4.2.5.1.2 Theta

|                     |          |           |          |           |          |           |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Theta ( $\mu V^2$ ) | 4.84     | 8.10      | 4.44     | 8.30      | 4.63     | 5.80      |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Theta ( $\mu V^2$ ) | 3.14     | 5.76      | 3.26     | 5.16      | 2.71     | 3.65      |

**Eyes closed.** As has been seen in almost all subjects, suppression of theta was failed as all locations displayed increase in theta absolute power. At T3T4 & C3C4, the theta values

were almost doubled and at P3P4 increment was  $1.17 \mu V^2$ . The topography map reflected the increase in theta instead of the effort to suppress it. Symmetry of theta was almost achieved.

**Eyes opened.** All locations had increased in theta after NFT. The least increment of absolute power was at P3P4 with  $0.94 \mu V^2$ . Symmetry of theta was almost as similar as in eyes closed condition.



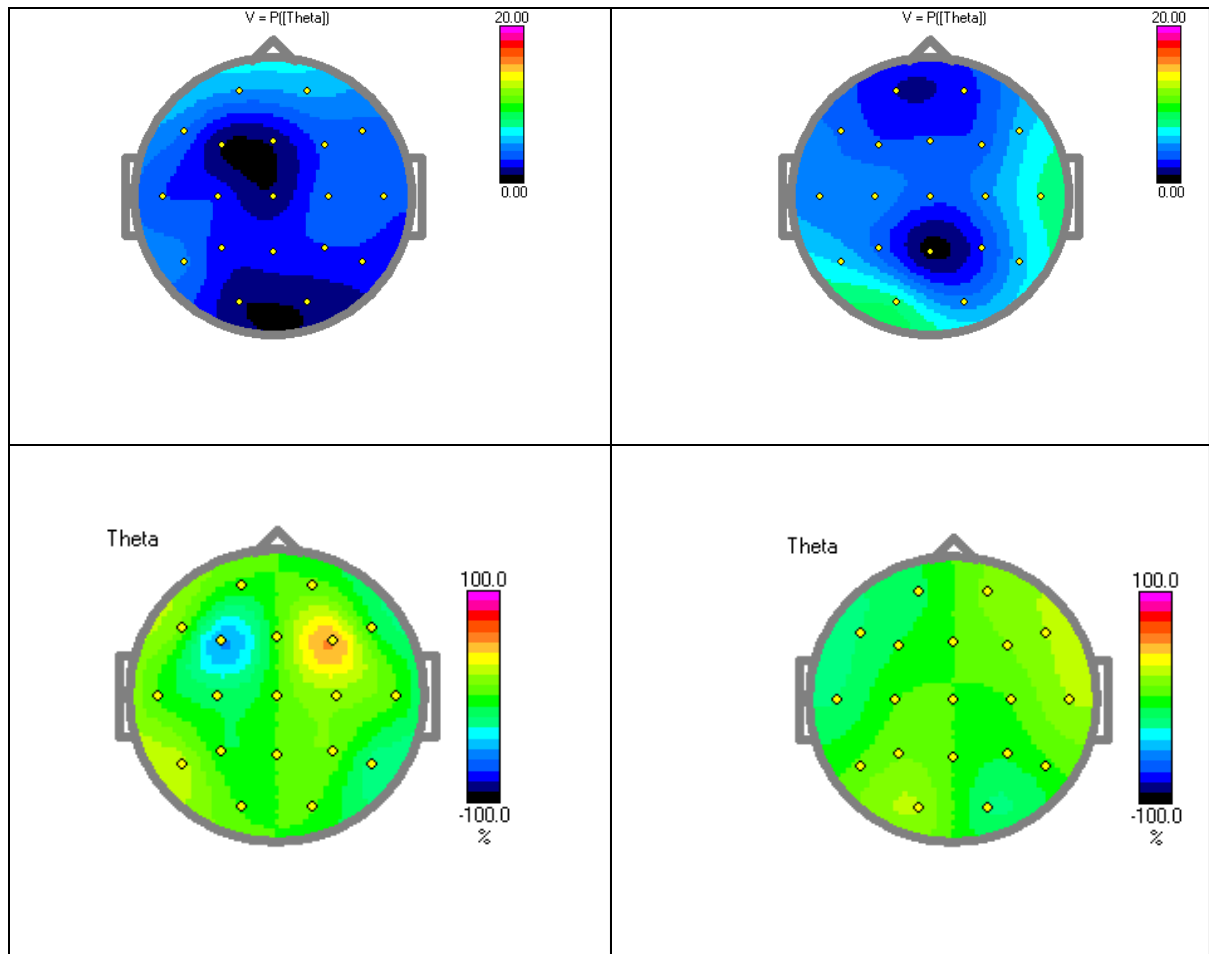


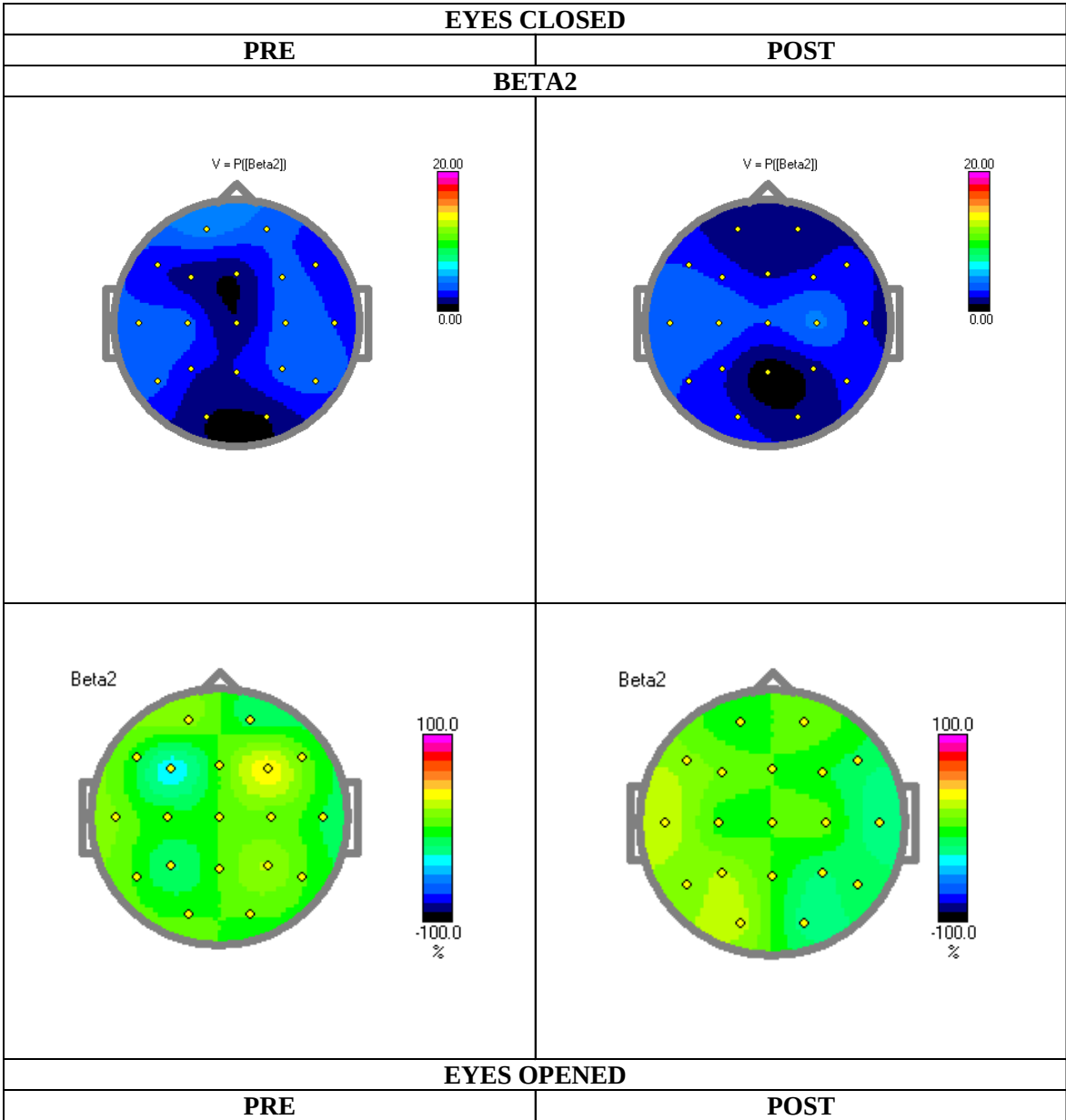
**Figure 4.14:** Subject E – theta topography

#### 4.2.5.1.3 Beta2

|                     |          |           |          |           |          |           |
|---------------------|----------|-----------|----------|-----------|----------|-----------|
| Eyes closed         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Beta2 ( $\mu V^2$ ) | 3.22     | 2.95      | 3.54     | 4.05      | 3.44     | 1.90      |
| Eyes opened         | T3T4 pre | T3T4 post | C3C4 pre | C3C4 post | P3P4 pre | P3P4 post |
| Beta2 ( $\mu V^2$ ) | 3.25     | 4.73      | 3.07     | 3.89      | 2.37     | 2.65      |

**Eyes closed.** At two locations, T3T4 and P3P4, beta2 power decreased by  $0.27\mu V^2$  and  $1.54\mu V^2$  respectively. Only C3C4 power was increased from  $3.54\mu V^2$  to  $4.05\mu V^2$ . There was subtle difference in pre and post beta2 topography as depicted in the table below.

**Eyes opened.** Instead of decreasing, all locations had increased in power with the highest increase was observed at T3T4 with difference of  $1.48 \mu V^2$ . The symmetry of both left and right sides were apparent.



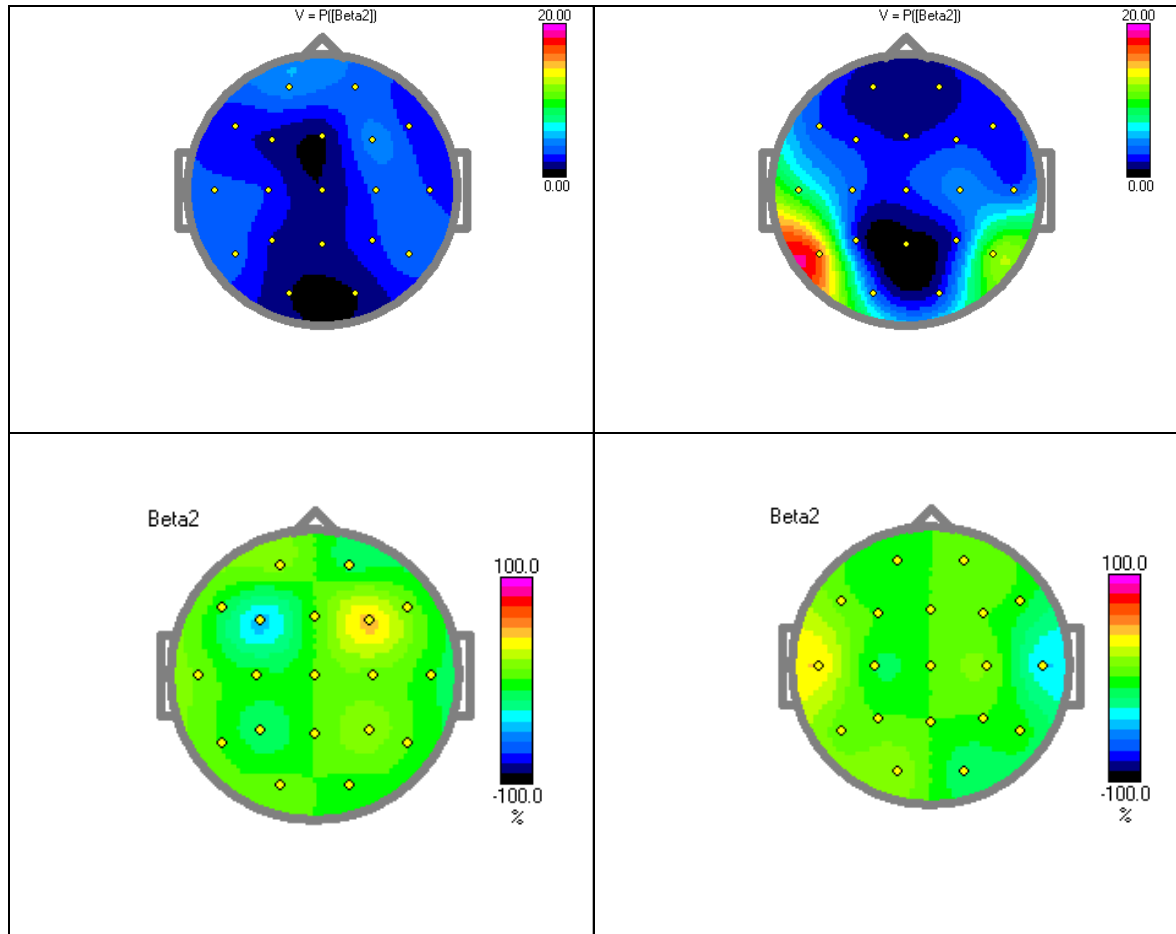


**Figure 4.15:** Subject E – beta2 topography

### 4.3 Individual Cognitive Result and Analysis

This section highlighted on individuals' pre and post score in Working memory component: Digit Span & Arithmetic and Processing Speed component: Symbol Search & Coding. Both experimental and control groups were included to see the better picture of differences for those who underwent NFT and ones who did not.

**Table 4.7:** Individual cognitive results

| Subjects | DS Pre | DS Post | AR Pre | AR Post | SS Pre | SS Post | CD Pre | CD Post |
|----------|--------|---------|--------|---------|--------|---------|--------|---------|
| E1       | 20     | 21      | 7      | 10      | 22     | 25      | 44     | 50      |
| E2       | 18     | 19      | 13     | 11      | 25     | 29      | 45     | 62      |
| E3       | 19     | 21      | 6      | 9       | 14     | 19      | 39     | 38      |
| E4       | 15     | 16      | 7      | 9       | 19     | 21      | 33     | 39      |
| E5       | 18     | 19      | 6      | 10      | 25     | 26      | 59     | 55      |
| C1       | 19     | 17      | 22     | 10      | 19     | 20      | 42     | 42      |
| C2       | 23     | 17      | 11     | 12      | 22     | 19      | 41     | 32      |
| C3       | 23     | 21      | 9      | 9       | 20     | 32      | 43     | 45      |
| C4       | 22     | 24      | 9      | 8       | 21     | 28      | 45     | 52      |
| C5       | 25     | 19      | 7      | 7       | 17     | 28      | 25     | 36      |

**Subject E1.** This person had shown increase in all components. The lowest increment was observed in Digit Span and the highest was Coding. The increment for DS, AR, SS and CD were 1, 3, 3 and 6 mark/s respectively.

**Subject E2.** Out of four components, the only component that demonstrated a decrease in score was AR. The other components the least had 1 mark difference in DS and maximum of 17 marks in CD while 4 mark in SS.

**Subject E3.** Out of four components, the only component that shown decrease in score was CD with 1 mark lowered than the pre score. DS displayed an increase in 2 marks, AR was 3 marks and SS gave the highest increase with 5 marks higher than the pre score.

**Subject E4.** The subjects scored higher in post NFT in all components with the lowest increment observed in DS; 1 mark and the highest increment in CD; 6 marks. Each AR and SS had the same increment which was 2 marks.

**Subject E5.** Unlike the others who had higher score in CD post, the subject scored had reduction by 4 marks. The other components had either 1 mark increment; DS and SS while the highest increment was 4 marks for AR.

**Summary For Experimental Group.** All subjects had improvement in 2 components which were DS and SS. Only 1 subject (E2) had decreased in AR score by 2 marks while 2 out of 5 subjects (E3 & E5) had lower CD post with 1 and 4 marks lower respectively

**Subject C1.** All components showed lower in post score for DS (2 marks), AR (12 marks) and SS (2 marks) while CD had no change in score.

**Subject C2.** Reduction of score could be observed in DS (6 marks), SS (3 marks) and CD (9 marks) and AR had 1 mark increment from 11 to 12 marks.

**Subject C3.** Reduction of score could be observed in DS (2 marks) only. AR remained unchanged while unexpectedly SS and CD had increase in score by 12 and 2 marks respectively.

**Subject C4.** This subject also had unexpected higher post score compared to pre score in 3 out of 4 components. The increment were DS (2 marks), SS (7 marks) and CD (7 marks).

**Subject C5.** Decrease in score was observed in DS and AR while SS and CD had increment in score by 11 marks.

**Summary For Control Group.** All subjects had lower score in post AR score. Only 1 subject had shown an increase in DS score while others had decreased in their score. 2 out of 5 subjects had decrease in SS and CD while the other 3 had increase in their post score.

**Conclusion.** A pattern of increase and decrease of score was regular in experimental group with all of them shown increment in DS and SS while for AR only one had lower score in post AR and CD only 2 had lower score in post CD. In control group, the pattern of

changes was not regular with 1 subject had higher post DS score, 3 out of 5 had SS and CD scores higher than the pre score and even some did not had changes in score at all.

#### 4.4 Grouped QEEG Result and Analysis

##### 4.4.1 Intra-Group Absolute Power Analysis and Result

Due to the small sample size in this study ( $N = 10$ ), the appropriate statistical measure selected for analysis was non parametric test; Wilcoxon signed-rank test. Thus, absolute power (AP) is presented as median (mdn) instead of mean. In this section only, both eyes opened and eyes closed conditions are analyzed to provide an overview of differences in both conditions. Table 8 shows the median AP in pre and post QEEG for both experimental (NFT) and control group in eyes opened condition. Note that difference in median does not have to be equal to the difference in the medians (e.g.,  $1.625 - 1.500 \neq 0.435$ ) unlike the mean.

**Table 4.8:** Intra-group absolute power ( $\mu V^2$ ) in eyes opened

| Location          | Experimental |        |        | Control |        |        |
|-------------------|--------------|--------|--------|---------|--------|--------|
|                   | T3T4         | C3C4   | P3P4   | T3T4    | C3C4   | P3P4   |
| Theta Pre         | 1.625        | 1.235  | 1.575  | 0.963   | 0.800  | 0.868  |
| Theta Post        | 1.500        | 1.410  | 1.045  | 1.330   | 1.420  | 1.300  |
| Difference in mdn | 0.435        | 0.275* | 0.230  | 0.460   | 0.255  | 0.206  |
| Z                 | -1.214       | -2.023 | -0.405 | -0.674  | -0.674 | -1.214 |
| p                 | .225         | .043*  | .686   | .500    | .500   | .225   |
| Alpha Pre         | 8.040        | 3.275  | 3.300  | 2.074   | 2.060  | 1.748  |
| Alpha Post        | 3.790        | 4.740  | 2.980  | 2.315   | 2.613  | 1.610  |
| Difference in mdn | 0.144        | 1.465* | 0.342  | 0.434   | 0.810  | 0.380  |
| Z                 | -0.674       | -2.023 | -0.674 | -0.405  | -1.483 | -1.753 |
| p                 | .500         | .043*  | .500   | .686    | .138   | .080   |
| Hbeta Pre         | 9.640        | 2.070  | 1.410  | 2.158   | 1.552  | 0.893  |
| Hbeta Post        | 5.725        | 1.720  | 1.375  | 2.320   | 3.151  | 0.900  |
| Difference in mdn | -5.460       | -0.350 | -0.060 | 0.698   | 1.599  | 0.067  |
| Z                 | -1.214       | -0.944 | -0.944 | -1.753  | -1.753 | -0.405 |
| p                 | .225         | .345   | .345   | .080    | .080   | .686   |

Of the 10 participants recruited to the study, 5 participants in experimental underwent neurofeedback training while the control group did not receive any training. In **eyes opened condition**, the absolute power of those in experimental group elicited a significant increase in theta C3C4, alpha C3C4 and high beta P3P4. Even though theta was suppressed during NFT, theta at C3C4 depicted increase in median post AP ( $0.275 \mu V^2$ ) in all 5 participants rather than a decrease in AP ( $z = -2.023, p = .043$ ). At C3C4, there was a statistically significant median increase in alpha AP ( $1.465 \mu V^2$ ) in all 5 experimental participants,  $z = -2.023, p < .050$ . High beta was successfully suppressed ( $-0.060 \mu V^2$ ) after NFT at P3P4 ( $z = -2.023, p = .043$ ). In control group, pre and post QEEG shows no distinguishable differences in all rhythms and all locations.

**Table 4.9:** Intra-group absolute power ( $\mu V^2$ ) in eyes closed

| Location          | Experimental |        |        | Control |        |        |
|-------------------|--------------|--------|--------|---------|--------|--------|
|                   | T3T4         | C3C4   | P3P4   | T3T4    | C3C4   | P3P4   |
| Theta Pre         | 1.720        | 1.255  | 1.025  | 0.939   | 0.696  | 0.674  |
| Theta Post        | 1.685        | 1.515  | 1.135  | 1.256   | 2.055  | 1.210  |
| Difference in mdn | 0.140        | 0.287  | 0.485  | 0.461   | 0.093  | 0.585  |
| Z                 | -1.753       | -2.023 | -1.214 | -0.944  | -1.214 | -2.023 |
| p                 | .080         | .043 * | .225   | .345    | .225   | .043 * |
| Alpha Pre         | 6.755        | 4.720  | 10.470 | 2.231   | 2.970  | 7.615  |
| Alpha Post        | 6.775        | 9.775  | 12.350 | 2.444   | 2.335  | 2.752  |
| Difference in mdn | 0.339        | 5.055  | 1.880  | 0.463   | -1.070 | -2.15  |
| Z                 | -2.023       | -2.023 | -2.023 | -0.944  | -1.214 | -2.023 |
| p                 | .043 *       | .043 * | .043 * | .345    | .225   | .043*  |
| Hbeta Pre         | 3.940        | 1.665  | 1.365  | 1.720   | 0.910  | 0.975  |
| Hbeta Post        | 2.690        | 1.835  | 1.320  | 2.315   | 1.363  | 0.637  |
| Difference in mdn | -1.790       | 0.170  | -0.045 | -0.010  | 0.172  | -0.050 |
| Z                 | -2.023       | -0.674 | -0.944 | -0.135  | -0.944 | -0.944 |
| p                 | .043 *       | .500   | .345   | .893    | .345   | .345   |

**Eyes closed condition** revealed more substantial results in all rhythms particularly alpha which are significant in all locations of training. All 5 experimental participants show increment in median by  $0.287 \mu V^2$  at the end of the training ( $z = -2.023, p = .043$ ) for theta

even though theta was suppressed during the training. Training up alpha in T3T4, C3C4 and P3P4 locations caused escalation of alpha AP by  $0.339 \mu V^2$ ,  $5.055 \mu V^2$  and  $1.88 \mu V^2$  respectively,  $z = -2.023$ ,  $p = .043$  while training down high beta was only successful in one location, T3T4(  $z = -2.023$ ,  $p = .043$ ,  $d = -1.790 \mu V^2$ ). Control participants shows increment in theta at P3P4 by  $0.585 \mu V^2$  in post QEEG and decrease in alpha at P3P4 by  $2.15 \mu V^2$ ,  $z = -2.023$ ,  $p = .043$ .

#### 4.4.2 Inter-Group Absolute Power Analysis and Result

**Table 4.10:** Inter-group alpha absolute power – eyes closed

| Location        | E T3T4 | C T3T4 | E C3C4 | C C3C4 | E P3P4 | C P3P4 |
|-----------------|--------|--------|--------|--------|--------|--------|
| Alpha Mean Rank | 6.00   | 5.00   | 7.60   | 3.40   | 8.00   | 3.00   |
| <i>U</i>        | 10.000 |        | 2.000  |        | 0.000  |        |
| <i>Z</i>        | -0.522 |        | -2.193 |        | -2.611 |        |
| <i>p</i>        | 0.602  |        | 0.028  |        | 0.009  |        |

**Table 4.11:** Inter-group alpha absolute power – eyes opened

| Location        | E T3T4 | C T3T4 | E C3C4 | C C3C4 | E P3P4 | C P3P4 |
|-----------------|--------|--------|--------|--------|--------|--------|
| Alpha Mean Rank | 5.40   | 5.60   | 6.40   | 4.60   | 5.00   | 6.00   |
| <i>U</i>        | 12.000 |        | 8.000  |        | 10.000 |        |
| <i>Z</i>        | -.104  |        | -.940  |        | -.522  |        |
| <i>p</i>        | .917   |        | .347   |        | .602   |        |

A Mann-Whitney U test was run to determine if there were differences in alpha absolute power in eyes closed condition between experimental and control group. Distributions of the absolute power for experimental and control group were not similar, as assessed by visual inspection.

**Eyes closed.** Alpha absolute power at T3T4 for experimental group (mean rank = 6.00  $\mu V^2$ ) were not statistically significantly higher than for control group (mean rank = 5.00  $\mu V^2$ ),  $U = 10.00$ ,  $z = -0.522$ ,  $p = .602$ . This was contrarily to C3C4 and P3P4 which

shown statistically significant results. Alpha absolute power at C3C4 for experimental group (mean rank = 7.60) was significantly higher than for control group (mean rank = 3.40),  $U = 2.00$ ,  $z = -2.193$ ,  $p = .028$ . This was also observed at P3P4 with experimental group (mean rank = 8.00) absolute power was greater control group (mean rank = 3.00),  $U = 0.00$ ,  $z = -2.611$ ,  $p = .009$ .

**Eyes opened.** In eyes opened condition, there were no statistical differences in all locations with only at C3C4 which had a higher alpha absolute power in experimental group (mean rank = 6.40 than control group (mean rank = 4.60),  $U = 8.00$ ,  $z = -0.940$ ,  $p = .347$ ).

**Table 4.12:** Inter-group theta absolute power – eyes closed

| Location        | E T3T4 | C T3T4 | E C3C4 | C C3C4 | E P3P4 | C P3P4 |
|-----------------|--------|--------|--------|--------|--------|--------|
| Theta Mean Rank | 5.60   | 5.40   | 6.80   | 4.20   | 5.20   | 5.80   |
| $U$             | 12.000 |        | 6.000  |        | 11.000 |        |
| $Z$             | -0.104 |        | -1.358 |        | -0.313 |        |
| $p$             | 0.917  |        | 0.175  |        | 0.754  |        |

**Table 4.13:** Inter-group theta absolute power – eyes opened

| Location        | E T3T4 | C T3T4 | E C3C4 | C C3C4 | E P3P4 | C P3P4 |
|-----------------|--------|--------|--------|--------|--------|--------|
| Theta Mean Rank | 5.80   | 5.20   | 6.20   | 4.80   | 5.40   | 5.60   |
| $U$             | 11.000 |        | 9.000  |        | 12.000 |        |
| $Z$             | -.313  |        | -.731  |        | -.104  |        |
| $p$             | .754   |        | .465   |        | .917   |        |

**Eyes closed.** For theta, the distributions of the theta absolute power for experimental and control group were also not similar, as assessed by visual inspection. Theta absolute power at T3T4 for experimental (mean rank = 5.60) and control group (mean rank = 5.40) were not statistically significantly different,  $U = 12.00$ ,  $z = -0.104$ ,  $p = .917$ . At C3C4, absolute power experimental group (mean rank = 6.80) was slightly higher than control (mean rank = 4.20) with no statistical significant difference,  $U = 6.00$ ,  $z = -1.358$ ,  $p = .175$ . Contrarily,

at P3P4, experimental group (mean rank = 5.20) has lower absolute power than control group (mean rank = 5.80) but showed no statistical difference,  $U = 11.00$ ,  $z = -0.313$ ,  $p = .754$ .

**Eyes opened.** Two locations had higher theta absolute power in experimental than in control group which were T3T4 ( $U = 11.00$ ,  $z = -0.313$ ,  $p = .754$ ) and C3C4 ( $U = 9.00$ ,  $z = -0.731$ ,  $p = .465$ ) despite the effort to decrease theta power. No statistical differences in all locations.

**Table4.14:** Inter-group beta2 absolute power – eyes closed

| Location        | E T3T4 | C T3T4 | E C3C4 | C C3C4 | E P3P4 | C P3P4 |
|-----------------|--------|--------|--------|--------|--------|--------|
| Beta2 Mean Rank | 3.40   | 7.60   | 5.20   | 5.80   | 5.60   | 5.40   |
| $U$             | 2.000  |        | 11.000 |        | 12.000 |        |
| $Z$             | -2.193 |        | -0.313 |        | -0.104 |        |
| $p$             | 0.028  |        | 0.754  |        | 0.917  |        |

**Table4.15:** Inter-group beta2 absolute power – eyes opened

| Location        | E T3T4 | C T3T4 | E C3C4 | C C3C4 | E P3P4 | C P3P4 |
|-----------------|--------|--------|--------|--------|--------|--------|
| Beta2 Mean Rank | 4.20   | 6.80   | 5.20   | 5.80   | 5.60   | 5.40   |
| $U$             | 6.000  |        | 3.000  |        | 7.000  |        |
| $Z$             | -1.358 |        | -1.984 |        | -1.149 |        |
| $p$             | .175   |        | .047*  |        | .251   |        |

**Eyes closed.** For beta2, the distributions of the absolute power for experimental and control group were also not similar, as assessed by visual inspection. Beta2 absolute power at T3T4 for experimental (mean rank = 3.40) and control group (mean rank = 7.60) were notably different,  $U = 2.00$ ,  $z = -2.193$ ,  $p = .028$ . At C3C4, absolute power experimental group (mean rank = 5.20) was slightly lower than control (mean rank = 5.80) with no statistical significant difference,  $U = 11.00$ ,  $z = -0.313$ ,  $p = .754$ . Contrarily, at P3P4, experimental group (mean rank = 5.60) has higher absolute power than control group (mean rank = 5.40) but showed no statistical difference,  $U = 12.00$ ,  $z = -0.104$ ,  $p = .917$ .

**Eyes opened.** There was a statistical difference between experimental (mean rank = 5.20) and control group (mean rank = 5.80) at C3C,  $U = 3.00$ ,  $z = -1.98$ ,  $p = .047$ ). No significant differences observed in the other two locations.

#### 4.4.3 Grouped Cognitive Result and Analysis

##### 4.4.3.1 Intra-Group: Digit Span

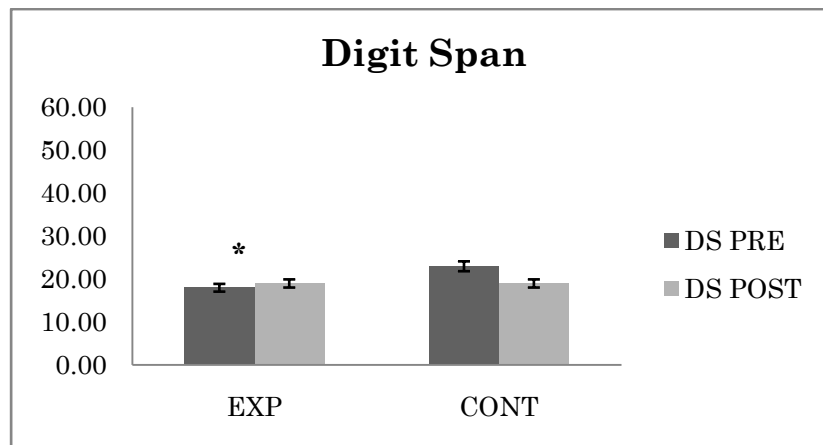


**Figure 4.16:** Intra-group pre-post digit span score

Wilcoxon signed ranked test determined the differences within each group in pre and post condition. Thus, score is presented as median (mdn) instead of mean. Note that difference in median does not have to be equal to the difference in the medians (e.g.,  $1.625 - 1.500 \neq 0.435$ ) unlike the mean.

In **experimental** group, NFT elicited an increase in the post Digit Span score in all 5 subjects. The test determined that there was a statistically significant median increase in Digit Span score (1.00),  $z = -2.121$ ,  $p = .034$ . **Control** group showed lower pre score (23.00) than post score (19.00) decreased (-2.00) in Digit Span score in 4 out of 5 but no significant difference was observed,  $z = -1.518$ ,  $p = .129$ .

#### 4.4.3.2 Intra-Group: Arithmetic

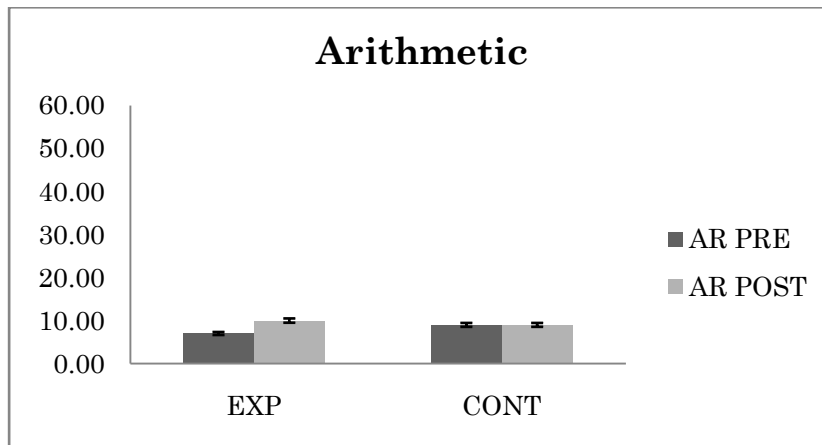


**Figure 4.17:** Intra-group pre-post arithmetic span score

A Wilcoxon signed-rank test determined there was no significant median increase (3.00) in **experimental** group in arithmetic score,  $z = -1.633$ ,  $p = .102$ . **Control** group showed unchanged pre and post score (9.00) with 2 of 5 had decreased in score, another 2 had the same score while 1 showed increase in score with no significant difference was observed,  $z = -0.816$ ,  $p = .414$ .

#### 4.4.3.3 Intra-Group: Symbol Search

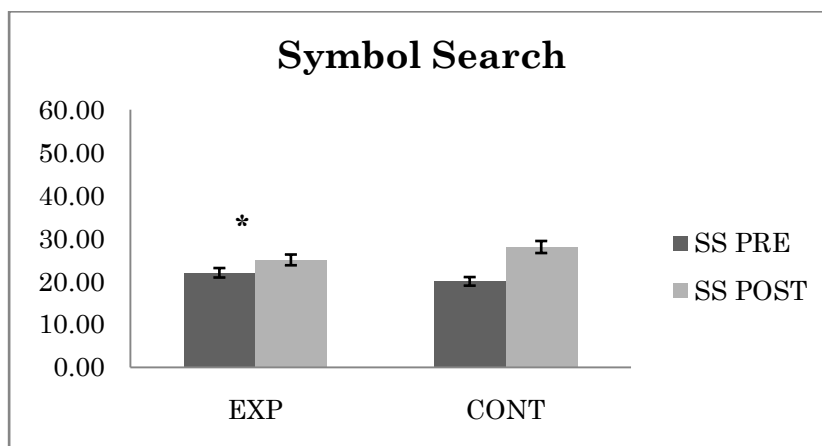


**Figure 4.18:** Intra-group pre-post symbol search score

A Wilcoxon signed-rank test determined there was a significant median increase by 3.00 in **experimental** group (pre = 22.00, post = 25.00) in symbol search score,  $z = -2.023$ ,  $p = .043$ . **Control** group showed no distinguish difference  $z = -1.483$ ,  $p = .138$ .

#### 4.4.3.4 Intra-Group: Coding

A Wilcoxon signed-rank test determined there were no significant median increase (6.00) in **experimental** group  $z = -1.219$ ,  $p = .223$  and in control group, no change in median observed,  $z = -0.730$ ,  $p = .465$ .

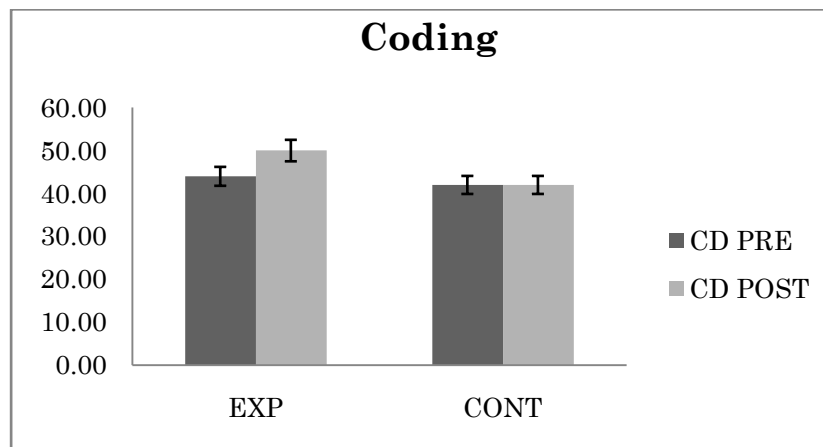


**Figure 4.19:** Intra-group pre-post coding score

#### 4.4.3.5 Inter-Group: Digit Span, Arithmetic, Symbol Search and Coding

**Table 4.16:** Inter-group cognitive results

| Test      | Digit span |      | Arithmetic |      | Symbol search |      | Coding |      |
|-----------|------------|------|------------|------|---------------|------|--------|------|
| Group     | Exp        | Cont | Exp        | Cont | Exp           | Cont | Exp    | Cont |
| Mean rank | 7.10       | 3.90 | 7.20       | 3.80 | 4.90          | 6.10 | 5.60   | 5.40 |
| <i>U</i>  | 4.500      |      | 4.000      |      | 9.500         |      | 12.000 |      |
| <i>Z</i>  | -1.741     |      | -1.786     |      | -0.629        |      | -0.105 |      |
| <i>p</i>  | 0.082      |      | 0.074      |      | 0.530         |      | 0.917  |      |

A Mann-Whitney U test was run to determine if there were differences in cognitive results between experimental and control group. Distributions of the score for experimental and

control group were not similar, as assessed by visual inspection. Digit Span score for experimental group (mean rank = 7.10) were not statistically significantly higher than control group (mean rank = 3.90),  $U = 4.50$ ,  $z = -1.741$ ,  $p = .082$ . The same result was observed in Arithmetic, Symbol Search and Coding score.

#### **4.5 Conclusion**

Alpha absolute power post NFT had shown increment for all locations and all subjects. At intra-group level, all locations had significant increase in alpha absolute power while at inter-group level analysis, statistically significant results were seen at C3C4 and P3P4 between experimental and control group. In terms of cognitive performance at individual level analysis, a pattern of increase and decrease of score was regular in experimental subjects and in control group; the pattern of changes was not regular. As expected, intra group analysis of experimental group showed significant result but only for Digit Span & Symbol Search and no significant difference between experimental & control group.

## **CHAPTER 5**

### **DISCUSSION**

#### **5.0 Introduction**

The main purpose of this study was to enhance the cognitive performance in elderly with alpha protocol neurofeedback by (i) applying alpha protocol, alpha was trained up while theta and high beta were suppressed, (ii) then, observing the changes in absolute power of alpha, theta & high beta and lastly (iii) evaluate the improvement in cognitive performance and discussed in extensive manner for alpha because of its strong relation and evidence with cognitive performance in NFT and EEG studies and discussed in brief for theta and beta2.

#### **5.1 Eyes Closed and Opened Condition EEG**

In this study, both resting eyes closed and opened condition were recorded and analyzed. From the result analysis in terms of absolute power, there were differences in either individual or group level result particularly for alpha. For alpha, although all locations were reported to increase in absolute power in eyes closed condition at individual level, this was not the case for eyes opened condition. At intra-group level, significant increased in alpha was observed at C3C4 only and no statistical difference was noted at inter-group level with alpha with lower alpha mean rank at T3T4 and P3P4. However it was clear that alpha activity increased due to neurofeedback and not because of the eyes condition because in control group no difference was exhibited in pre and post QEEG. Nevertheless, this study did not intend to study the differential effect in NFT training condition in eyes opened and eyes closed.

Focus on alpha rhythm was given because it is universally known the alpha activity and its relationship with eyes condition; alpha is dominant during eyes closed resting condition and is suppressed with visual stimulation in eyes opened condition and it is most pronounced in posterior regions. Eyes closed condition is also the best condition to assess alpha rhythms because it is dominant during this condition and this study used auditory cues instead of visual cues in the training (Barry et al., 2007).

Furthermore, this study focused on eyes closed EEG result in discussion section even though the NFT was done in eyes opened condition because in study of MCI or AD population, eyes closed or known as resting state EEG markers is a promising non-invasive screening for elderly with risk of developing AD (Baker et al., 2008; Vecchio et al., 2013). Resting state eyes closed could be easily and rapidly recorded in clinical environment specifically for elderly who is prone to fatigue and anxiety which usually related to task performance (Vecchio et al., 2013). In relation to cognitive status, power of resting state eyes closed EEG rhythms was repeatedly found to be correlated to subjects' cognitive status in MCI and AD subjects. It was found that lower alpha power reflected lower cognitive status in various cognitive tests to MCI and AD subjects such as Alzheimer's Disease Assessment Scale-Cognitive (ADAS-cog) (Luckhaus et al., 2008), Mini Mental State Examination (MMSE) (Babiloni et al., 2006) and Cambridge Cognition Examination (CAMCOG) (Claus et al., 2000).

## **5.2 Effect of Training Up Alpha in NFT to Alpha Absolute Power in EEG**

The absolute power measure in QEEG showed alpha activity increased whether in individual or grouped result in experimental group but not in control group which did not received any kind of intervention. In intra-group result, significant difference was observed

in all locations; T3T4, C3C4 and P3P4 in experimental group. In inter-group result, there was significant difference in between experimental and control group observed in central (C3C4) and parietal areas (P3P4) but not in T3T4. Among all three locations (T3T4, C43C4 and P3P4) either in inter or intra-group P3P4 has the highest alpha absolute power changes because it is known that posterior area has the strongest alpha rhythms and known to be dominated by well-known alpha sources in parietal-occipital sulcus. Such sources most likely produce spectral peaks at  $\sim 11$  Hz over central posterior areas (e.g. Cz, Pz, P3 and P4) (Jensen et al., 2002). Beside, alpha activity was produced by two generators; one posterior (parieto-occipital) and one more central (centro-parietal), with reciprocal connections and even mutual competition for neuronal resources. The selections of central posterior sites were based on this nature of fact. Hence by taking advantage of this condition at central posterior areas, it was easier to increase alpha rhythms. This explained the results particularly in inter-group result and also the reason P3P4 had the highest absolute power changes in intra-group result.

The present finding adds to the growing body of literature on the alpha trainability when alpha neurofeedback was applied even though the time course of training could be considered as short as only 15 sessions were done (Cho et al., 2008; van Boxtel et al., 2012). The change in alpha activity was thought to be permanent as reported by van Boxtel et al., (2012) who did the follow up after 3 months of NFT. This might explained the effect of alpha NFT to cognitive performance in the experimental group in the next section.

### **5.3 Effect of Suppressing Theta in NFT to Theta Absolute Power in EEG**

The suppression of theta yielded mix result at individual with majority of the subjects had increment in theta absolute power. At individual level of experimental group, only two

subjects had decreased in theta absolute power; subject A (P3P4) and C (T3T4, P3P4). In intra-grouped result, theta C3C4 had significant increased in absolute power instead of decreasing while in inter-grouped result, at P3P4, experimental group's theta was lower than control but the difference was insignificant. It could be concluded in this study the suppression of theta was unsuccessful.

In cognitive enhancement training, theta was usually inhibited (Penttilä et al., 1985) because its excessive theta activity was related to cognitive impairment. Contrarily to this study, most study yielded successful result when theta was inhibited not only in terms of absolute power or relative power but also in behavioral or cognitive changes (Becerra et al., 2012; Vernon, 2005).

The failure to suppress theta in this study corroborated with earlier alpha/theta training which failed to suppress theta activity in 4 out of 10 elderly in neurofeedback group (Lecomte and Juhel, 2011) . This result was not only observed in the elderly group but in a group of healthy young individuals who failed to decrease theta in an attempt to increase alpha & suppress theta (Hanslmayr et al., 2005). The mixed result after neurofeedback training is evidence that the adjustment of brain function is not as easy with neurofeedback (Stermann, 2000) neither in elderly nor in young people.

The other reason for this might be because more sessions are needed to suppress theta because of the complexity of this study which involves enhancement and suppression of alpha, theta and beta2 simultaneously. Success of theta activity changes were observed in a study when only theta suppression or enhancement was involved at posterior location, O1 and P3 (Beatty et al., 1974) even when 2 sessions of 1 hour training was done. Suppressed theta group showed less theta activity while enhanced-theta-group showed increased in

theta activity. When theta (enhancement) and alpha (suppression) training were combined in a 8 session neurofeedback, no change was reported in both theta and alpha activity due to that several different components (alpha and theta) and length of training schedule as the factors that affecting the end result of neurofeedback training(Boynton, 2001). From these two studies, it was clear that number of rhythms involved or the complexity of protocol in neurofeedback training affected the results of EEG particularly for theta.

#### **5.4 Effect of Suppressing Beta2 in NFT to Beta2 Absolute Power in EEG**

The suppression of beta2 yielded mix result at individual and grouped level. For high beta at individual level, 4 out of 5 subjects decrease high beta at T3T4 location. At intra and inter group level, high beta depicted significant lower high beta in post QEEG at T3T4 only. Beta frequency range was stated to be from 13 Hz to 30 Hz, with beta1 at 13 – 16 Hz, beta2 at 16 – 20 Hz and beta3 at 20 -28 Hz (Rangaswamy et al., 2004). From the analysis of frequency of all subjects' average range was 19 – 20 Hz and it fallen into beta2 range.

Suppression of beta2 were often paired with other brain rhythm components such as SMR (12 -15 Hz) and theta. It was seldom be a main component to be discussed extensively in most neurofeedback studies contributing to its lack of report regarding its effect when it was suppressed. However, the combinations of beta2 with others simultaneously during neurofeedback showed beta2 suppression was successful (Vernon et al., 2003) as had been seen in the current study too.

#### **5.5 Alpha and Cognitive Performance**

The present study aimed to observe the changes in cognitive performance in terms of working memory (Digit Span, Arithmetic) and processing speed (Symbol Search, Coding) by means of conducting Wechsler-IV (WAIS-IV) test before and after commencing

neurofeedback in experimental group while in control group it was conducting during first QEEG and the second QEEG. In attempt to improve cognitive performance in various domains, alpha rhythms has always been using as an indicator because alpha oscillation has been positively correlated with mental performance at all ages, both in healthy individuals and in individuals with neurological conditions (Klimesch, 1997).

#### **5.5.1 Unselective Alpha Band Training (8 – 12 Hz)**

Alpha neurofeedback whether as unselective alpha band (8 – 12 Hz) or selective alpha band training either upper, lower alpha, individual alpha had shown improvement in cognitive performance in various domains such as working memory, attention and etc. This study chose to apply unselective alpha band training because 9 – 12 Hz alpha activity was linked to the working memory task (Jensen et al., 2002) and in memory scanning task (Klimesch, 1999) even though most study used upper alpha to enhance the cognitive performance. Besides that, elderly with probable MCI or MCI, had shown to have decrement in both alpha lower and upper alpha; with more decrement in lower alpha as observed in standardized low-resolution brain electromagnetic tomography (sLORETA) (Babiloni et al., 2010). The average of alpha frequency range in this study was 8.7 Hz – 10 Hz which show overlapping between lower and upper alpha frequency, thus, separating lower and upper alpha power was not a choice.

This study employed general or unselective alpha band training and resulted in promising outcome in experimental group as compared to control group. Individual results for experimental group depicted increment in all subjects in Digit Span, Arithmetic, Symbol Search and whereas only 3 out of 5 showed increment in Coding score. Intra-grouped result showed significant increase in Digit Span and Symbol Search in experimental group

while inter-group result displayed nearly significant differences in between experimental and control group. To author's knowledge, there are only two studies applying neurofeedback in unselective alpha (8 – 12 Hz) to increase cognitive performance. The first study carried out neurofeedback on adult aged 20-29 years old with individual alpha band (8 -12 Hz) at Cz location for a total of 20 sessions (Nan et al., 2012). The results of this study coincide with Nan et al. (2012) where after the neurofeedback, there was an improvement in forward and backward of Digit Span score in NFT group and they were significantly larger than those of control group. Even though this study and the mentioned study had different target groups; elderly and young adult respectively, elderly and young adult could enhance their cognitive state after neurofeedback training (Lecomte and Juhel, 2011; Wang and Hsieh, 2013) even though the rate of learning might be different due to nature of cognitive differences. Angelakis et al. (2007) rewarded increase in alpha amplitude in one of its training conditions. As the result, increment in alpha amplitude (8 – 12 Hz) was reported to enhance memory in 3-back task performance (working memory measure) and visual memory (Angelakis et al., 2007). These studies provided evidences; improvement in working memory measure regardless the test used was possible after unselective alpha neurofeedback.

### **5.5.2 Upper Alpha Band (10 -12 Hz)**

It is worth to elaborate the success of neurofeedback in upper alpha band (10-12 Hz) to support finding of this study because it applied unselective alpha training (8 -12 Hz). For a short period of time of upper alpha training; 5 days on young adults resulted in increase of mean in working memory test; conceptual span test and the improvement in training group was suggested to be resulted from neurofeedback training (Escolano et al., 2011). To support current study as it was fore-mentioned that the rate of learning might be different

in young and elderly due to nature of cognitive differences, upper alpha power was rewarded and theta was suppressed in 10 elderly (65 to 80 years old) from experimental group in 4 sessions of neurofeedback. There were increase in alpha spectral power observed in 8 participants and decrease of the spectral power of the theta frequency bands was observed in 6 participants and there were mixed result observed in at individual level which measured using Reliable Change Index (RCI) and at grouped level, no significant difference in between experimental, control and 'waiting list group'. From this and current study it was indicated that even when there were changes in EEG, sometimes the changes in cognitive performance could not be detected through cognitive testing or batteries. In young adult, fewer sessions might cause changes in both EEG and cognitive performance while elderly required more sessions.

### **5.5.3 Processing Speed**

While evidence of working memory and alpha training was discussed extensively in Section 5.5.1 and Section 5.5.2, processing speed is not discuss here due to lack of neurofeedback study that measures processing speed in alpha training even though this study reported a significant increase in one of processing speed components which is symbol search and insignificant increase in coding. The increase in working memory measures might depict the increase in processing speed because both were causatively linked to cognitive decline in old age and processing speed was known to moderating the relationship between age and WM (Fry and Hale, 1996; Kail and Salthouse, 1994; Nettelbeck and Burns, 2010).

## **5.6 Theta and Cognitive Performance**

Even though in this study, theta suppression was considered as unsuccessful either at individual level and grouped level (intra and inter), the fact that two subjects with 1 and 2 locations showed decrement in theta absolute power is not fair to be neglected in terms of cognitive performance and theta. Nonetheless, the difference in individual cognitive results in subject A and C did not exhibit different pattern from others in experimental group who had stagnant or increase in theta absolute values although the differences between experimental and control group was clear in Digit Span and Symbol Search tests.

The current finding agrees with the previous studies (Beatty et al., 1974; Becerra et al., 2012) though they did not describe their results in terms of individual analysis; rather they were reported in grouped analysis. In grouped analysis of theta suppression group (at O1 and P3) as compared to theta-augment group, the first group performed significantly better in radar monitoring task than the latter group (Beatty et al., 1974). The same positive result from suppression of theta in elderly group also replicating the Beatty et al. (1974) in which reduction in theta in the midline and left frontal leads could have induced the improvement in attention that was reflected in the total score of the NEUROPSI test; a test battery in Spanish that measures attention and memory (Becerra et al., 2012).

## **5.7 Beta2 and Cognitive Performance**

As explained in Section 5.4, the effect of beta2 suppression was not often discussed extensively in terms of its activity and it was the same in the aspect of cognitive performance. However, beta2 suppression was always done in study related to cognitive enhancement (Egner and Gruzelić, 2001, 2004; Vernon et al., 2003) because excessive

beta on quantitative analysis could be related to symptoms of brain over arousal such as anxiety, hyperactivity and etc.

## **5.8 Conclusion**

The neurofeedback training successfully increase the absolute power of all subjects in all locations significantly at individual and grouped level either in intra and inter-group. Suppression of theta yielded mix result with most of the participants had increased the absolute power at individual level and at grouped level (intra and inter) significant increase was observed at C3C4 only while the two other locations had non-significant increase in absolute power. For beta2, majority of subjects (3/5) had decreased absolute power while at intra group level for experimental group; significant decrease was seen at T3T4 & P3P4 with slight increase in power at C3C4. At inter-group level, experimental group happened to have significant reduction in beta2 absolute power as compared to control group. It could be concluded that only alpha up training was successful.

In terms of cognitive results, in individual analysis, a pattern of increase and decrease of score was regular in experimental group with all of them shown increment in DS, AR and SS while for CD only 2 had lower score in post CD. In control group, the pattern of changes was not regular with 1 subject had higher post DS score, 3 out of 5 had SS and CD scores higher than the pre score and even some did not had changes in score at all. At intra-group level, for experimental group, significant increase in score was seen in Digit Span and Symbol Search only while the other two components had non-significant increment. For control group, no significant result observed at all components. In between group analysis (inter-group), no significant differences for all components observed at all. With regards to literature and the result of this study which coincides with literature, alpha and

cognitive results were discussed in detailed manner in discussion due to strong evidence of alpha relationship with cognitive functions. In conclusion, the changes recorded in QEEG particularly in alpha absolute power and in cognitive results were due to neurofeedback. The potential of NFT as reported in this study specifically for elderly may be used as a non-pharmacological approach along side with medications usage in elderly to combat cognitive impairment.

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## APPENDIX

### Subject A

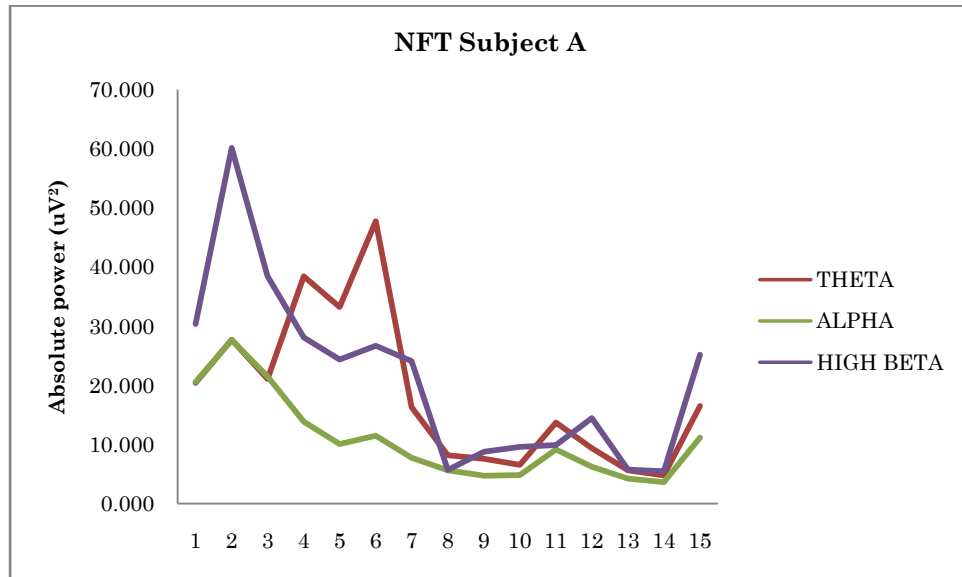


**Figure A1:** NFT graph subject A

### Subject B

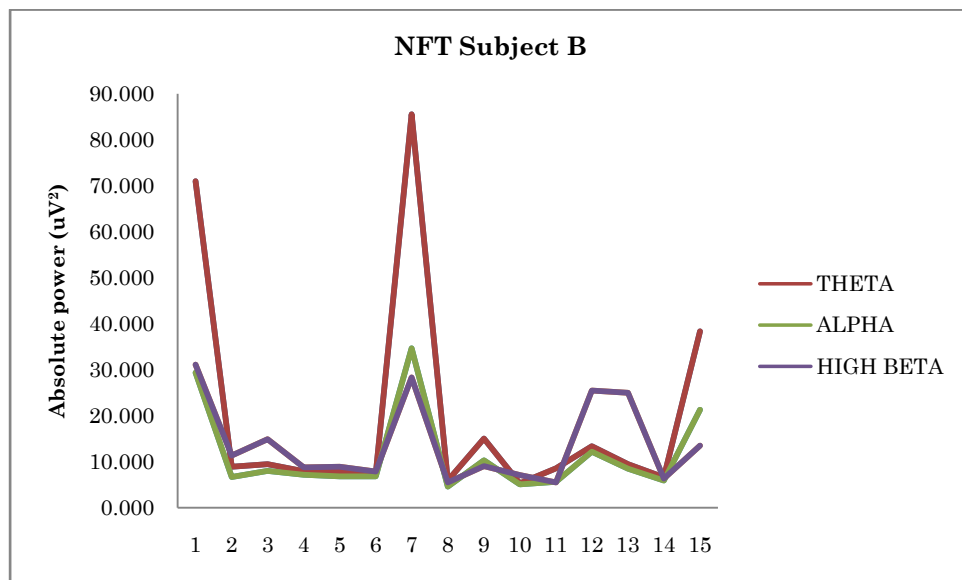


**Figure A2:** NFT graph subject B

**Subject C**

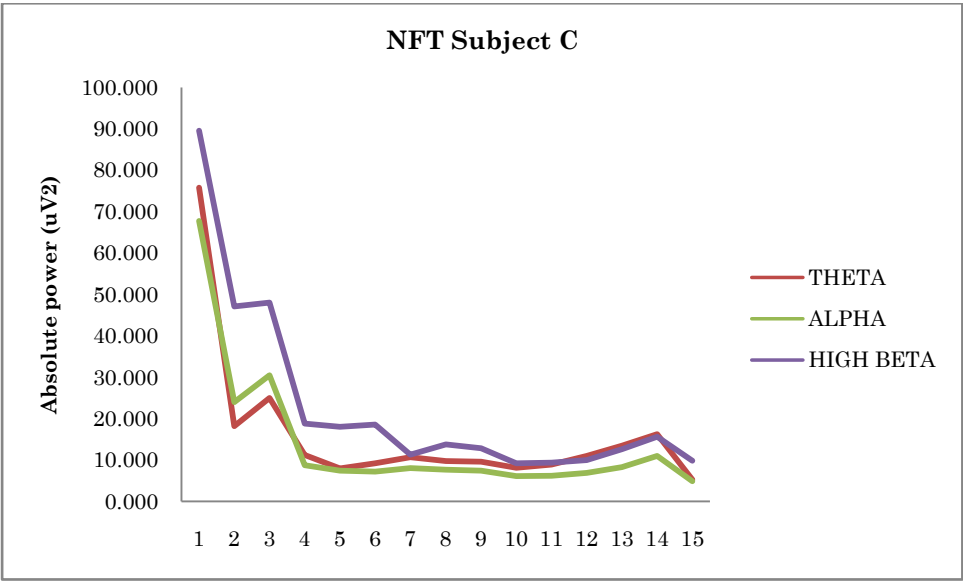


**Figure A3:** NFT graph subject C

**Subject D**

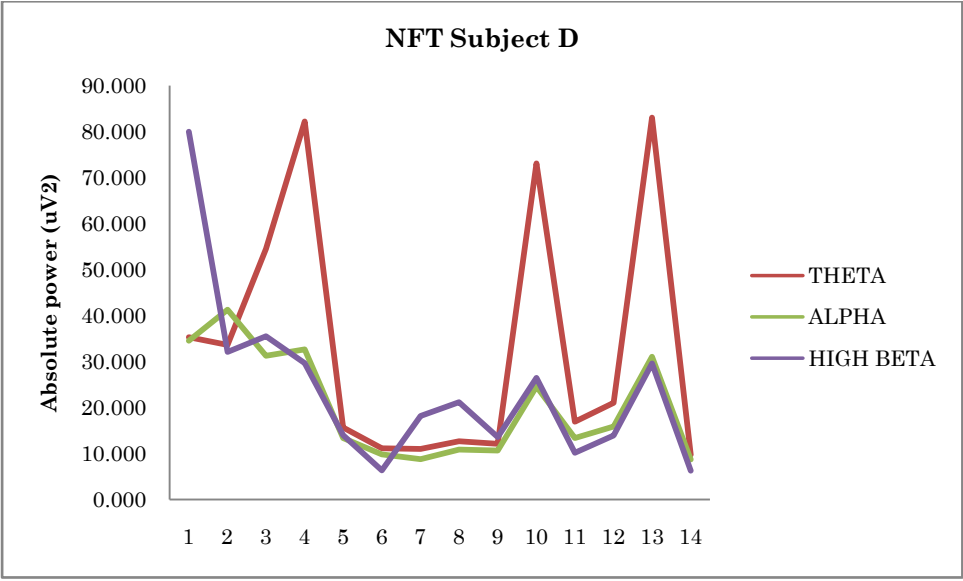


**Figure A4:** NFT graph subject D

**Subject E**

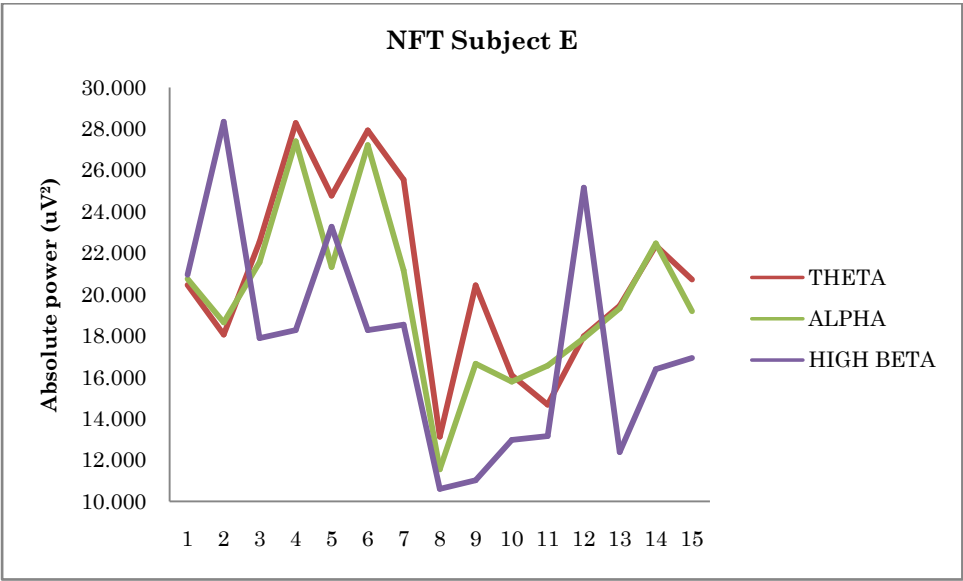


**Figure A5:** NFT graph subject E

**Grouped NFT graph**

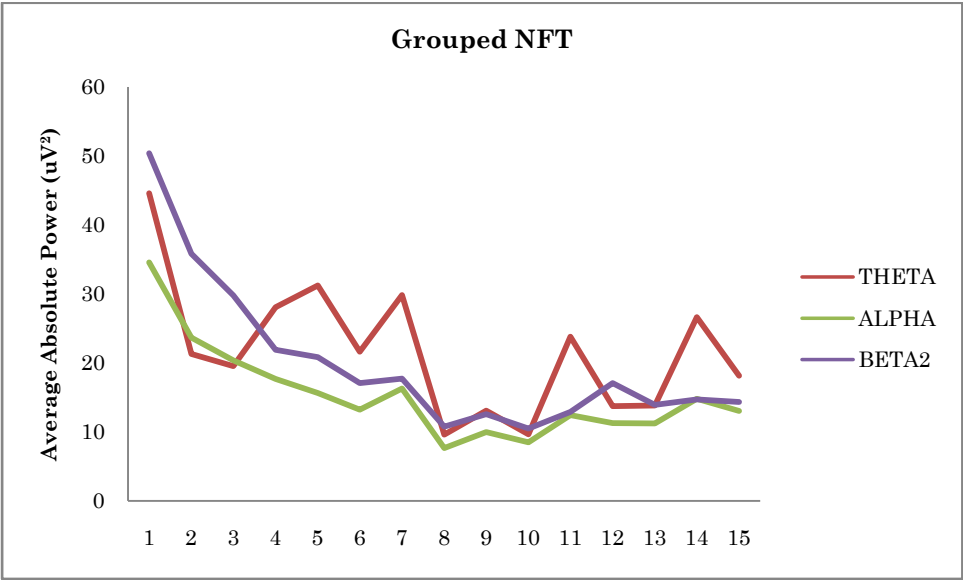


**Figure A6:** Grouped NFT graph