EEG SIGNAL ANALYSIS BEFORE AND AFTER PERFORMING SALAT ON GAMMA BAND

FARID SHIMAN

RESEARCH REPORT SUBMITTED IN PARTIAL FULFILLMENT FOR THE DEGREE OF MASTER OF ENGINEERING (BIOMEDICAL)

FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA
KUALA LUMPUR

2012

ABSTRAK

Meditasi kerohanian dan upacara penyembahan dilihat sebagai perkara yang diperlukan untuk keadaan rehat, gaya hidup yang sihat, dan sebagai terapi perubatan alternatif untuk keseimbangan minda dan tubuh.

Dalam kajian ini, penyelidikan telah dilakukan terhadap semua kesan neuropsikofisiologik sebelum dan selepas upacara sembahyang dalam Islam (solat) menggunakan alat elektroensefalogram (EEG). Data EEG dalam kajian ini direkodkan untuk sepuluh lelaki yang sihat sebelum dan selepas melakukan solat. Untuk menganalisis data dari isyarat EEG dalam kajian ini, perisian AcqKnowledge 4.0 (BIOPAC Systems Inc, Goleta, CA) dan Matlab digunakan untuk menentukan dan menganalisis data ketumpatan spektra kuasa (PSD) (dalam μv^2) dan untuk kumpulan sinar Gamma (30-60 Hz). Keputusan dari kajian ini menunjukkan kuasa sinar gamma dari bacaan EEG mempunyai peningkatan yang signifikan untuk keadaan selepas solat jika dibandingkan dengan keadaan sebelumnya. Analisis statistik (paired t-test) menunjukkan ada peningkatan yang signifikan pada kuasa gamma di bahagian frontal dan occipital otak.

Tambahan lagi, meditasi dalam salat dalam bentuk Perhatian Fokus (FA) dan Meditasi Transcendetional (TM) telah pertama kali diperkenalkan sebagai proses kognitif dan corak EEG dalam kajian ini. Kajian ini telah menunjukkan ada perubahan fisiologi semasa meditasi yang mencadangkan ada tempoh hypometabolik sedar yang mempunyai kualiti dalam menurunkan aktiviti saraf simpatetik dan meningkatkan aktiviti parasimpatetik.

ABSTRACT

Religious meditations and prayers were seen as the conditions necessary for promoting relaxation, healthy living, and acting as alternative medical therapies for balancing human mind and body. In this study, the investigation of all the neuropsychophysiological effects of pre- and post-baseline of an Islamic prayer (*Salat*) on the electroencephalogram (EEG) was carried out. The EEG data in this study were recorded for ten healthy males for pre- and post-baseline in the performance of the *Salat*. In order to analyze the data from the EEG signals of this study, AcqKnowledge 4.0 software (BIOPAC Systems Inc, Goleta, CA) and Matlab were used to compute and analyze the power spectral density (PSD) data (in μv^2) for the Gamma (30-60 Hz) band. The results show that the gamma EEG power has significant increase in post-baseline compared to the pre-baseline. The statistical analysis (paired t-test) indicated that there was significant increase of gamma power in the frontal and occipital channels.Additionally, meditation in *Salat* in the forms of Focus Attention (FA) and Transcendetional Meditation(TM) were introduced for the first time as cognitive processes and EEG pattern in this study. This study further revealed that there are physiological changes during meditation which in turn suggested that there is wakeful hypometabolic state which has the qualities of decreasing the sympathetic nervous activity but increasing parasympathetic activity.

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Prof. Fatimah Ibrahim, for her precious guidance, support, patience, and tolerance throughout the period of this project.

I would like to thank Dr. Ng. Siew Cheok for his comments and support.

I would like to thank Mohammad Javad Safari, Seyed Hossein Safavi, Maysam Oladazimi, and Fatemeh Molae.

Warmest gratitude to my parents for their love and patience.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

EEG	Electroencephalography
PSD	Power spectral density
SPSS	Statistical Package for the Social Sciences
FIR	Finite impulse response
IIR	Infinite impulse response
Hz	Hertz
FA	Focus attention
TM	Transcendental Meditation
OM	Open monitoring

1 CHAPTER I: INTRODUCTION

1.1 Overview

The signals from the electroencephalograph (EEG) are seen as the reflections of neural activities which are recorded in different ways by multiple electrode EEG devices from inside the brain, under the skull over the cortex, and in certain locations over the scalp (Sanei & Chambers, 2007). However, EEG was discovered to be an important clinical device in the field of clinical neurology for diagnosing and monitoring the nervous system based on the fact that it has the capability to reveal both the normal and abnormal electrical activity of the brain (Cooper *et al.*, 1980; Niedermeyer & Da Silva, 2005).

There are five major brain waves identified which can be distinguished by their frequency ranges. These brain waves include the delta (represented by δ) with the frequency range of between 0.5–4 Hz, theta (represented by θ) with the frequency range of between 4–8 Hz, alpha (represented by α) with the frequency range of between 8–13 Hz, beta (represented by β) with the frequency range of between 13–30 Hz ,and gamma (represented by ϒ) with the frequency range of between 30–128 Hz (Sanei *et al.*, 2007). Each gamma activity falls above traditional EEG frequency bands which was commonly considered to range between 30 and 80 Hz. Recently, researches conducted on EEG seemed to focus more on the increase of the activities in the gamma band for experimental subjects under meditation because of its relationship with cognitive functioning (Engel *et al.*, 2001; Fell *et al.*, 2003).

Another study on meditation maintained that it is a body and mind activity which effects self-regulating practice as it concentrates on training attention for voluntarily controlling the mental processes (Davidson & Lutz, 2008). The Muslim prayer which is known as *Salat* in Arabic could be viewed as a form of meditation. This present research specifically investigates the neurophysiological effects of the *Salat* as a form of prayer meditation. This research further unveils the meditation categories in terms of psychological and neurophysiological effects to achieve better understanding of *Salat* and its similarities.

From the frequency plots of EEG signals, it was easily observed that there are some frequency components up to the range of 25-30 Hz but nothing can be deduced from the frequencies above 30 Hz. As a result, analysis of gamma waves is not significant from the frequency plot and a time-frequency approach is the preferred method (Chawla *et al.*, 2004).

1.2 Problem Statement

Though there is a growing scientific interest in *Salat*, yet its underlying neurophysiological mechanism is still under uncertainty. This research therefore investigates the *Salat* effects which is a form of meditation. It was observed the benefit of using *Salat* is encouraging, developing concentration, clarity and emotional positivity. This research tends to modify the power spectral density (PSD) in order to make it more robust for EEG signal processing during performing *Salat* to extract the features for analyzing the neurophysiology effects in gamma band (30-60Hz).

1.3 Objectives of Study

The objectives of the study include the following:

i. to compare the two situation of brain activity including the pre- and post-baseline of the spiritual feeling on Muslim prayer in terms of psychology and neurophysiology effects.

ii. to classify the *Salat* in Focus Attention (FA) meditation and Transcendental Meditation (TM) in terms of psychology.

1.4 Scope of the Study

The research is conducted under the following scopes:

i. Development of the method for EEG signals analysis in gamma band.

ii. Investigation of the psycho-physiological effects of *Salat* meditation for pre- and post-baseline of the *Salat* in gamma band.

iii. Determination whether the total power in gamma band after performing *Salat* (post-baseline) is higher than the pre-baseline.

iv. Analyzing the EEG signals of subjects in pre- and post-performance of the *Salat* to compute the power spectral density (PSD) by using Fast Fourier Transform (FFT) for total power.

1.5 Significance of the Study

The neurophysiological bases of meditation have been investigated widely in literature when the activity of meditation produces positive psychological effect both during and beyond the meditation. In this research, it was illustrated that the EEG signal of the people who produce spiritual feeling is categorized by an EEG oscillation and their temporal behavior.

The categorization of the *Salat* meditation emphasized on the combination of FA and TM meditation because there is no study to compare the psychophysiology effects before and after performing *Salat* meditation but there was an analysis on the EEG signals in gamma band for mentioned situation. Because high amplitude gamma activity is related to the cognitive functioning (Barry et al., 2010),current EEG investigation has seen an increased focus on activity in the gamma band.

1.6 Outline of the Report

This research is divided into five chapters and each of the chapters illustrating one aspect of the project. In Chapter I of this research, introduction and overview of the project on the subject, statement of the problem, objectives, and significant of the study are discussed. Chapter II presents an overview of the Electroencephalogram (EEG) and was followed by the characteristics of *Salat* meditation. The chapter also reviews the past literature on the effects of meditation in terms of physiology and neurophysiology.

Chapter III of this study discusses the methodology which is related to the methods, design, and details of signal analysis used in this research. Chapter IV discusses the result and discussion about comparison between the pre- and post-effects of *Salat* meditation in gamma band in terms of EEG analysis and psychological effects. Finally, chapter V proposes the conclusion of this study and discusses further work for the research.

2 Chapter II: LITERATUREREVIEW

2.1 Introduction

This chapter reviews the literatures regarding physiology of brain, EEG, meditation and *Salat*. The literatures on the physiological and neurophysiological effects of meditation were further reviewed.

2.2 Physiology of Brain

The brain is the majority organ which is a mass of pinkish-gray tissue in the human body. The brain function is still a mystery for the neurologists with approximately ten billion neurons. The scientific research of the nervous system and the brain is called neuroscience or neurobiology (Swanson, 2011). The cortex or cerebrum is the largest part of the human brain compared to the all parts of the brain which is divided into four lobes: occipital lobe, parietal lobe, frontal lobe, and temporal lobe (Figure 2.1).

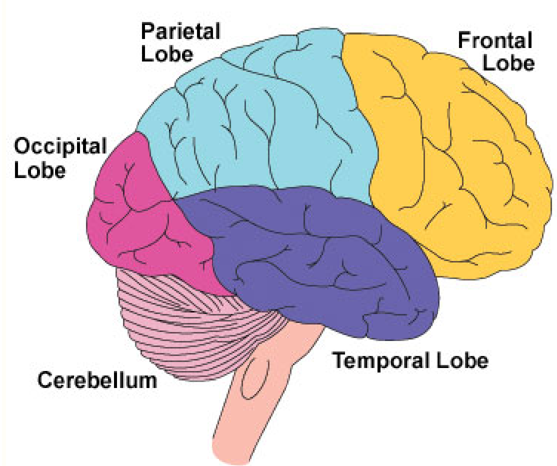

Figure 2.1: Lobes of the brain(Swanson, 2011).

Occipital Lobe: The occipital lobes are the smallest lobes which are located in the back portion of the skull. It is responsible for visual perception system. The functions of the occipital lobe include visual processing, color recognition and movement.

Parietal Lobe: The parietal lobe is related to the sensory information from different parts of the body. The functions of the parietal lobe consist of information processing, movement, spatial orientation, perception of touch and temperature.

Frontal Lobe: The frontal lobe is responsible for higher cognitive purposes. The functions of the frontal lobe consist of reasoning, short term memory, planning, movement, behavior, sexual urges, emotions, and organizing parts of speech.

Temporal Lobe: The temporal lobes are responsible for auditory processing as a primary auditory cortex. This lobe is responsible for arrangement of long term memory.

2.3 Electroencephalogram (EEG)

This chapter presents some basic information on neurophysiology which should be deemed to be necessary for understanding the experiments and further throw more light on the results described in the subsequent chapters. Contrarily, this chapter focused on the description of the electroencephalogram especially as it was applied to the study of meditation and brain oscillations.

The development of EEG was originally initiated to serve as a method for careful studying of mental processes. The EEG signal is an act of measuring the current-flows during synaptic excitations of the dendrites of many pyramidal neurons in the cerebral cortex. The synaptic currents are produced within the dendrites which could make it possible for the brain cells (neurons) to be activated (Sanei *et al.*, 2007). However, the measuring of EEG has been deeply studied to thoroughly examine the underlying brain physiological changes which have mutual relationship with various states of consciousness during meditation.

The study conducted by Berger (1929) stated that the first recording of brain electrical activity which was exposed in the brains of rabbits and monkeys were reported by

Caton in 1875. However, it was not fully developed in human beings till 1929 when Hans Berger made the report for the first measurement of brain electrical activity in humans.

2.3.1 Brain Oscillations

As it was earlier mentioned in this research, there are five major brain waves which were distinguished by their different frequency ranges. These frequency bands range from low to high frequencies which include the alpha (α), theta (θ), beta (β), delta (δ), and gamma (γ). The introduction of alpha and beta waves were done by Berger in the study he conducted in 1929. In the study conducted by Jasper and Andrews (1938), gamma as a frequency band was used to refer to the waves which were above 30 Hz. The delta rhythm was introduced in the study conducted by Walter (1936) to denote all frequencies below the alpha range. The introduction of theta waves was to denote those having frequencies within the range of 4–7.5 Hz .More so, theta wave was introduced by Walter and Dovey in 1944 (Sterman *et al.*, 1974; Walter & Dovey, 1944).

Delta rhythms (0.5-4 Hz): The delta rhythms are the waves which are primarily associated with deep sleep and may be present in the waking state.

Theta rhythms (4-7.5 Hz): The term theta which is presumed to be associated with the thalamic origin possesses the theta waves which appear as consciousness slips towards drowsiness. Theta waves were further seen to be associated with having access to unconscious material, creative inspiration and deep meditation. They are enhanced during sleep and play an important role in childhood. High theta activity is considered abnormal in the awaking adult state as it has relationship with different brain disorders.

Alpha rhythms (8-13 Hz): The alpha rhythms appear spontaneously in normal adults when they are awake, under relaxation and inactive mental conditions. The alpha rhythms could be best seen with eyes closed while mostly pronounced in occipital locations.

Gamma rhythms (30-60 Hz): These could be seen as the regions of high EEG frequencies and highest levels of attentive processes which are located in the frontal area.

2.4 Meditation

Meditation is the physiological state necessary for reducing metabolic activity which in turn brings physical and mental relaxation. Meditation has been viewed from the angle of enhancing psychological balance and emotional stability (Rubia, 2009).This chapter reviews meditation effects at the physiological, neurophysiological and affective levels as well as the scientific paradigms used to study these effects.

Meditation is a common term used to refer to different practices for self-regulation of emotion and attention which is invariably considered in most religious or philosophical traditions as an experiential practice (Gunaratana, 2002). More so, meditation usually involves making one's attention to be concentrated on a particular physical or mental object. Practitioners who are involved in meditation are instructed to bring their attention back to the meditative task whenever their minds start wandering about.

The practice of meditation frequently involves altering the states of consciousness although meditation could arise when there are intensive practices for meditation for several hours on daily basis. The practitioners of meditation frequently perform daily meditation for a certain period of time which could range from 15 minutes to several hours. There were assumptions that different conscious states could result to different neurophysiological states while neuroscientific approaches towards meditation focuses on altered sensory, cognitive and self-awareness experiences.

Some studies have discovered that the neurophysiological changes which could be influenced by meditation are of two kinds. The first of these changes occurred when meditation practices are referred to as state changes. The second part of the changes (trait changes) which could be built up over months or years (Cahn & Polich, 2006). However, emphasis has been made on the importance of the study of meditation states for consciousness as a means of exploring the effects of meditation on the brain.

It was clearly stated in some studies that there are a large number of meditative practices but based on the fact that self-regulation of attention is one of the components that is common, it is imperative to classify styles of meditation based on how the attention processes are directed (Cahn, *et al.*, 2006). In other studies, meditation practices were divided into two categories. The first category is the focused attention meditation which involves the voluntary and sustained attention on a chosen object while the second category is the open monitoring meditation which involves non-reactive monitoring of the moment-to-moment content of experience (Lutz *et al.*, 2008).Another study suggested the third category of meditation practice and automatic self-transcending which includes techniques designed to transcend their own activity (Travis & Shear, 2010).

Focus Attention (Concentration meditation): The focus attention (FA) meditations involve continuous sustained attention on a selected object. The object of focus could include a repeated sound or word (mantra), the breath or body sensations as well as the imagined mental image. Meditation based on focused attention involves narrowing of awareness so that the mind only contains the object of focus.

Open monitoring (mindfulness meditations): Many studies have observed that in mindfulness, practitioners are ordered to permit any thought, feeling or sensation to arise in consciousness as there is maintenance to a non-reactive awareness to some experiences (Cahn, *et al.*, 2006; Gunaratana, 2002; Kabat-Zinn, 2003; Lutz, *et al.*, 2008).

Meditation practices which involved having one's attention focused to a specific object in the experiential field may lead to a higher activity in the beta and gamma bands including the meditations from Chinese traditions, Buddhist, and Tibetan Buddhist. However, the open monitoring which is characterized by theta activity (Austin, 2006; Gyatso & Jinpa, 1995; Lutz*, et al.*, 2008).

Transcendental Meditation (TM): Transcendental meditation is a form of mantra (prayer meditation) and is presented in Tibetan Buddhism and Hinduism(Braboszcz *et al.*, 2010). Mantra could be in the form of religious or mystical sound, word or poem that can be either recited aloud or sub-vocally. Those who meditate mantra are instructed to focus their full attention on the recitation as they repeat it and also focus their attention on its meaning. The practices involving mantra meditation are present in all religions and spiritual traditions as sutras texts are involved in Buddhism (discourse from the Buddha). Another instance is Muslim practices (*Salat*) based on the recitation of a prayer phrase which involves the slow reading of the Quranic phrases.

As a result, we can classify the *Salat* as a Focus Attention (FA) and Transcendental Meditation(TM). In Figure 2.2, It is summarized all findings about meditation categories.

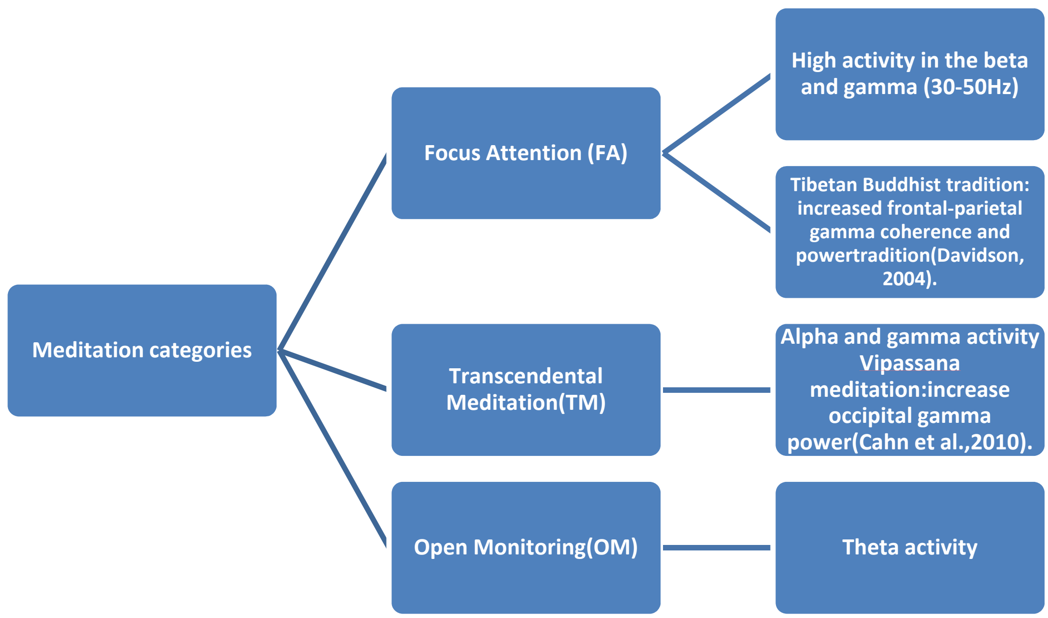

Figure2.2: Effects of different meditation categories on gamma frequency band

2.5 *Salat*

This could be seen as a form of meditation and also a mandatory practice which must be performed following certain sets of conditions, set of sequence and at certain set of times in the Muslim prayer (Alwasiti, 2010). Some studies have observed that religious meditations and prayers were meant to possibly promote relaxation and healthier conditions suitable for the human mind and body (Lee *et al.*, 2007; Reibel *et al.*, 2001).*Salat* has been considered in the researches for a few years.

Doufesh *et al.* (2011) investigated EEG signal for alpha band in the different position of the actual and acted *Salat* in Muslim prayer(Doufesh, *et al.*, 2011). Their results indicated that a significantly higher alpha power was recorded during the prostration position. In other researches, for instance, Haider *et al*.(2010)illustrated that alpha and theta power did not increase in their studies but the database was small as they collected the database from one subject(Alwasiti, 2010).However, the previous studies confirmed the high alpha activity with a relaxed state .Alwasiti (2010) research is not valuable to make decision for effects of *Salat* (Arambula *et al.*, 2001; Lee*, et al.*, 2007; Reibel*, et al.*, 2001).

The practice of *Salat* is regarded as being important in Islam because it is deemed to be beneficial both physically and mentally to the human body. However, the recently conducted scientific studies revealed that the *Salat* brings physical and mental benefits to the body (Ibrahim *et al.*, 2008). Additionally, there are involvements of the physical movements of the body to the fundamental part of the Muslim prayer in the recitation of verses in Quran and specific supplications. Despite the fact that there must be verbal words during meditations, the worshipper should assume certain positions and perform specific movements. The four main positions and movements involved in the prayers include standing, bowing, prostrating and sitting in figure 2.3 (Ibrahim*, et al.*, 2008; Yucel, 2008).

Standing: This involved subjects having to stand upright. While on the standing positions, they worshippers' hands are placed on the top of the other. This is a situation where the right hand was placed over the left and both hands placed above the navel.

Bowing: In bowing position, hands are raised until they are

positions

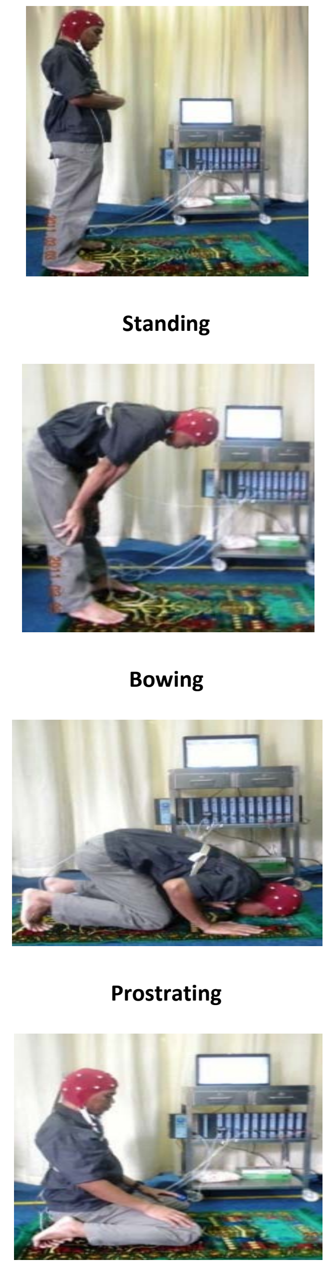

Figure2.3: Different Positions of performing Salat(Doufesh *et al.*, 2011).

level with the ears or shoulder. This is followed by a 90-degree bow, with the hand touching the knees and pressing down so that the back of the body is horizontal.

Prostrating: This is used in *Salat* and should be as a situation where the worshipper brings the hands and knees to the floor. Properly executed prostration involves seven parts of the body (the forehead, both palms, both knees, the ends of both feet with toes bent) coming into contact with the floor. The procedure involved in prostration includes the situation where the hands assume the following positions:

i. The hands are kept away from the sides of the body

ii. The elbow is raised off the floor

iii. The forehead and face are placed in between both palms

iv. The fingers are brought close together

Sitting: The sitting posture which occurs between two prostrations involves resting the buttocks on the left leg thereby cushioning the leg. In the sitting position, both palms rest on the thighs with the elbows being placed on the thighs too while the fingers were rested on the edge of the knees. However, the heel would press on the main muscle at the start of the thigh which is close to the hip joint when the worshiper is in the sitting position.

2.6 Physiological Effect (Autonomic System)

As earlier mentioned, apart from the general relaxation response, the key subjective experiences in meditation include the reduction of mental activity and the generation of positive effects. The obvious target of this present study is to explore the clinical effects of *Salat*. The most recent researches on the clinical application of meditation effects are still very much in infancy but there are still some emerging and concrete evidences that meditation has positive effects on stress-related diseases and on some neuropsychiatric disorders(Rubia, 2009).

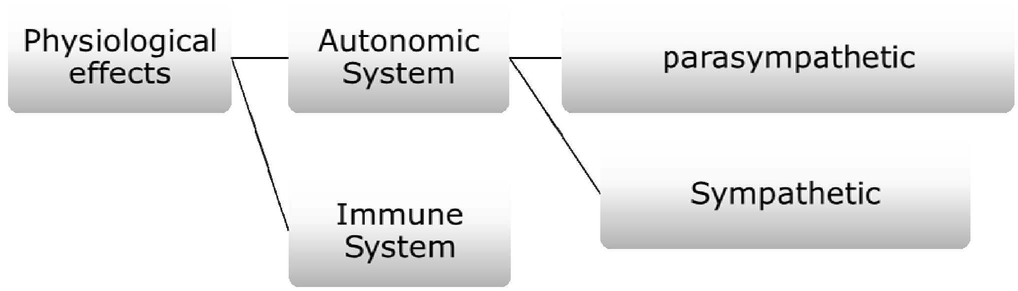

Figure 2.4: Physiological effects of meditation on the brain

The activities of the organs and viscera in the body are being controlled by the autonomic nervous system as it is composed of the sympathetic and parasympathetic neural pathways in Figure 2.4. Although this could be seen as a schematic view but there is complication in its reality as the two components are usually believed to have opposite actions on their targeted organs or tissues. Many studies have shown that the physiological changes during meditation has the suggestion that wakeful hypometabolic state which has the characteristics of decreasing in sympathetic nervous activity which is important for fight and flight mechanisms and increased parasympathetic activity meant for relaxation and rest (Cahn, *et al.*, 2006; Jevning *et al.*, 1992; Rai *et al.*, 1988; Young & Taylor, 1998).

Meditation has strong effects on various parts of the body as they function for daily meditation practices and maximum meditation experiences. It has been stated in some studies that standard daily meditation practices create low arousal states and maximum meditation experiences thereby fostering high arousal states (Cahn, *et al.*, 2006). This present research therefore focuses on the daily meditation more than the maximum meditation based on the similarities which daily meditation have with *Salat*. Craig (2005) reviewed how the left part of the brain cooperates more with the parasympathetic system and the right part interacts with the sympathetic system.

In addition, we can prove the effect of meditation with other factors including respiratory, heart rate and blood pressure. Respiration control is one of the possible ways through which meditation acts on autonomic activity. Respiration was observed as one of the body's few autonomic functions that can be controlled and in turn affect functioning of the autonomic nervous system (Badra *et al.*, 2001; Eckberg *et al.*, 1985). Researchers have shown that breathing can involuntarily slow down during mantra chanting (Bernardi *et al.*, 2001) breath counting meditation and simple awareness of the breath (Lehrer *et al.*, 1999). However, it was also revealed that slower respiration rate during meditation practice brings about changes in cardiovascular activity which in turn corresponds with the increase in restorative parasympathetic system activities (Saul, 1990).

This increase in parasympathetic activity could also be assessed through the slowing down of basal heart rate in worshippers indulging in meditation (Pal & Velkumary, 2004). Studies have shown that slow breathing has significantly been associated with increased baroreflex sensitivity. It was also observed that blood pressure decreased after meditation practice by both healthy individuals and hypertension patients (Carlson *et al.*, 2007; Manikonda *et al.*, 2007). The improvement in the control of blood pressure is usually seen as the main sign of balance between parasympathetic and sympathetic activity.

Studies have maintained that Sahaja yoga meditation (daily meditation) has been indicated to reduce parasympathetic activity (Harrison *et al.*, 2004). This include the reduction in heart related ailments, respiratory and pulse rates, systolic blood pressure and oxygen metabolism as well as increasing the skin resistance in short- and long-term practitioners compared to controls (Rai *et al.*, 1988).

2.6.1 Neurophysiological Effects

Many studies on electrophysiological indicated that brain activity plays an important role in different concentrative meditation techniques. Low frequency rhythms can be used for investigation of attention and working memory and high frequency rhythms is mainly used for processing of the contents of experience (Razumnikova, 2007).

Gamma bands (30–50 Hz):

Gamma activity is one of the important frequency ranges which reflects short range connection for local processing of construction and object recognition (Singer, 1999).There is a direct relation between gamma activity, brain blood flow and rises of synaptic activity which is important for considering the long term memories (Niessing *et al*., 2005). Researchers found that gamma activity is higher in attended stimuli in compare to unattended stimuli (Jensen *et al*., 2007).

Lutz et al. (2004) in their research on long term Buddhist meditation found that ratio of the gamma to slow rhythm during meditation of long term meditators are higher than control group. This study shows that there is strong correlation ($r > 0.6$) between relative gamma power and years of practice (Lutz *et al.*, 2004).

Research on Chinese and Buddhist meditations revealed that gamma activity in the post-baseline was higher than per-baseline while alpha activity after doing these meditations decreased to near zero (Litscher *et al.*, 2001).

Lehmann et al. (2001) researched on five meditation patterns. This study revealed that center of the gamma (35-44 Hz) gravity is related to meditation methods. Gamma power at right posterior of the brain changes during visualization and gamma power at left central of brain changes during verbalization (Lehmann *et al*., 2001).

2.7 Signal Processing

In studying the EEG signal processing, the literatures of many studies concentrated on the application of Fourier transform. In addition, it was revealed that the most common form of analyzing EEG signals is through analyzing these signals in time domain which invariably means direct reading of the potentials coming out from the brain in an amplitude-time plot (Fisch & Spehlmann, 1999)**.** While as earlier mentioned in this present research, another way of analyzing EEG signal is through frequency domain which in turn means viewing its Fourier transform. In addition, the Fourier Transform is computationally very attractive when it will be calculated by using an efficient algorithm called the Fast Fourier Transform (Cooley & Tukey, 1965) .

However, analyzing EEG signals with the help of wavelets is of great utility unlike the Fourier transform where the frequency components cannot be localized. The wavelet transform is used to dictate when the frequencies are present, determine the duration and the things that are of great importance to the neurologist. More so, wavelet transforms have been used for studying EEG signals in different ways whereas the Gabor transforms have been used to find time-varying spectra (Makeig, 1993). Similarly, some studies have revealed that discrete wavelets were used to get better time-frequency representation (Bertrand *et al.*, 2001).

3 CHAPTER III: METHODOLOGY

3.1 Introduction

This chapter illustrates the design and implementation, methodology and data analysis in the research.

3.2 Subjects

The databases collected in this research were selected from ten male Muslim students in the Medical Informatics Laboratory, University of Malaya (average age 24 years). Participants were asked to fill the informed consent form and procedures of EEG recording were explained to them. All subjects were free from neurological and psychiatric disorders.

3.3 EEG Recording and protocol

The EEG signals were collected by eight AgCl electrodes on the scalp at a sampling frequency of 500Hz according to the International 10-20 Placement System. The electrodes were located at frontal (F3, F4), central (C3, C4),parietal (P3, P4), occipital (O1, O2), and reference electrode and electrical ground placed at the vertex (Cz) and ear lobe electrode, respectively (Figure 3.1).

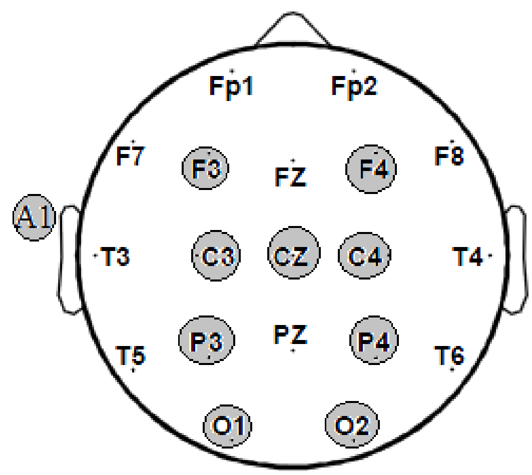

Figure 3.1: Electrode positions on the scalp

The EEG was collected by eight Biopac EEG100C amplifiers (BIOPAC Systems Inc., California, USA) .In addition, the output of amplifiers analyzed with the Biopac MP150 acquisition system. The signals were collected at a sampling frequency of 500Hz.

The subjects lied on the bed to be relaxed in the supine position for 15 minutes. The first pre-baseline data were collected with the eyes open for a minute and eye closed for a minute. Furthermore, EEG signal were collected as a post-baseline after the subjects perform the *Salat*, similar in procedure to the pre-baseline data collection.

3.4 Data Analysis

The EEG signals were analyzed by AcqKnowledge 4.0 software (BIOPAC Systems Inc, Goleta, CA).The data was filtered using (IIR) Butterworth band-pass filter between 1 and 100 Hz. Furthermore, a digital Fast Fourier Transform based on power spectrum analysis (Welch technique, Hanning windowing function) compute the total power of EEG rhythms with 60sec epoch for pre- and post-baseline in open eye state for each subjects. The total power spectral density (PSD) were calculated (in μv^2) for the gamma (30-60 Hz) band.

3.4.1 Filter

3.4.1.1 Comparison between FIR and IIR

The filter algorithms are related to infinite impulse-response (IIR)filters which were designed in analog filters .In this way, the algorithm were developed with several real coefficients for resulting in digital filter.IIR filters have the feedback in their algorithms in contrast with FIR filters(Lutovac *et al*., 2001). Because of feedback, IIR filters have considerably better frequency response than FIR filters of the same order (Fig 3.2).

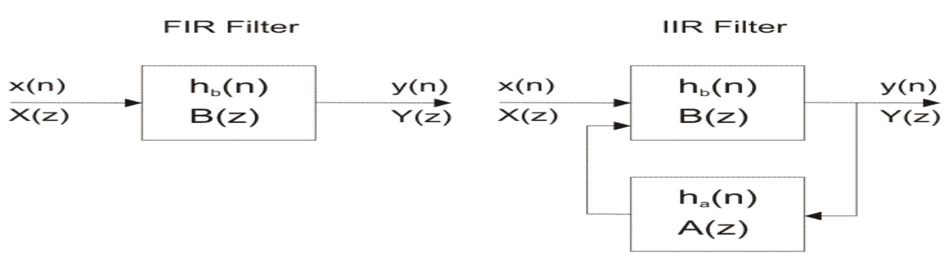

Figure3.2: Block diagram of FIR and IIR filter

3.4.1.2 IIR filter (Butterworth)

In this section, we compare analog filter approximation including Butterworth, Chebyshev, and elliptic approximations.

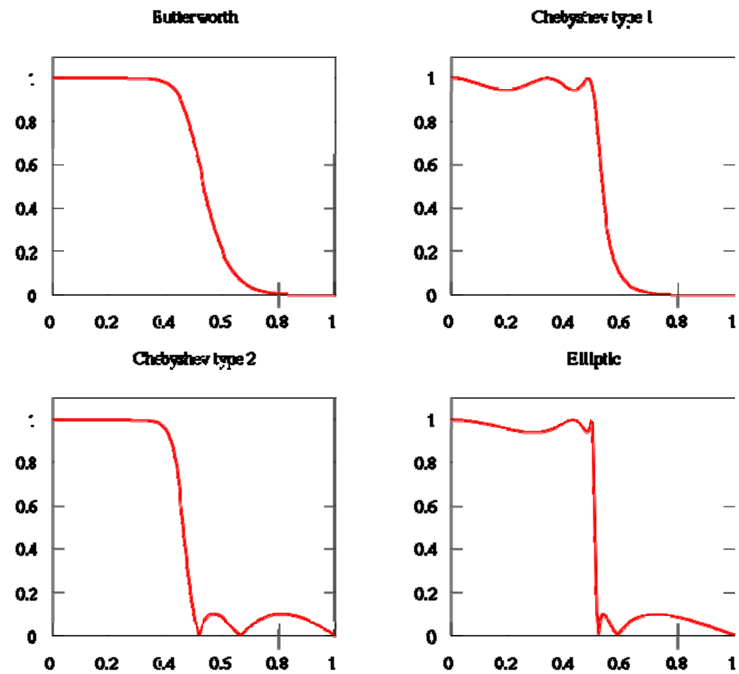

Figure 3.3: Comparison between Buterworth, chebyshev and elliptic filters

The Butterworth filter rolls off more slowly without ripple around the cutoff frequency than the Chebyshev filter or the Elliptic filter (Fig 3.3).

Butterworth filters were developed with cut-off frequency. The Butterworth filter indicates the rolls off towards zero in the band stop and maximally flat in the pass band. These filters are widely used in the continuous-time domain and discrete-time domain which required an suitable transformation.

The advantage of the Butterworth is related to the flat band pass meaning that it is excellent at simulating the band pass of an ideal filter. We present simple algorithms for band-pass Second order Butterworth filters as a cutoff frequency that can be applied online or offline during EEG recordings and analysis(Lutovac, *et al*., 2001).

3.4.2 Power Spectral Density (PSD)

The power spectral density (PSD) function $\Gamma_x(e^{j\omega})$ is described as the Fourier transform of the autocorrelation function of a given random process (Hyvarinen, 1999).

$$\Gamma_Y(e^{j\omega})=\Gamma_x(e^{j\omega})\left|H(e^{j\omega})\right|^2 \quad 3.1$$

Consequently, the output PSD function is defined by the input PSD function multiplied by the squared magnitude response of the linear system. This equivalent is frequency domain description for random signals which is related to the input–output relationship of a linear time domain system.

Power spectra indicate the distribution of signal's power for each frequency bands. This can be computed by square of FFT's magnitude. When there are not accessible more data points for each FFT calculation, the frequency resolution (tradeoff) will be decreased(Kay, 1998).

The spectral windowing increased the accuracy of power spectral density for each segment is windowed. However, the windowing reduces the contribution of the signal near the end of segment.

3.4.3 Welch Method

The Welch periodogram can be applied same as the Bartlett periodogram. Similar to Bartlett's method, the Welch computes the sample of length N by dividing a long sequence of samples into a set of shorter segments. Moreover, the shorter segments can be applied to their neighbors for some segment of their length(Kay, 1998). Before each spectrum of segment's sample is calculated, w[n] as a data window is concerned to each segment.

Advantages of Welch method:

1. The variance of the random process decreases in comparison to basic periodogram and Bartlett method in Welch methods.

2. All the windowing techniques can apply to the Welch method.

Welch periodogram are computed by four specific steps.

a. Divide the accessible sample sequence into P overlapping segments of D samples each, with a shift of S<D samples between consecutive segments. If the original sequence is x[k],the pth segment can be expressed as

$$x_p[n] = x[pS + n] \qquad 3.2$$

b. W[n] performas data windowto each segment:

$$y_p[n] = w[n]x_p[n]p = 0,1, \dots, P - 1 \qquad 3.3$$

c. Compute discrete frequency sample spectrum for each of the P windowed segments:

$$s_P[m] = \frac{T}{UD} Y_p[m]^2 m = 0,1, \dots, D - 1 \qquad 3.4$$

Where

$$U = \sum_{n=0}^{D-1} |w[n]|^2 \qquad 3.5$$

d. Compute the arithmetic average of the P different sample spectra at each frequency:

$$S_w[m] = \frac{1}{P} \sum_{p=0}^{p-1} S_p[m]\, m = 0,1, \dots, D - 1 \qquad 3.6$$

The result, S_w[m], is the Welch periodogram(Sanei, *et al.*, 2007).

3.4.4 Wavelet transforms

The wavelet transform is a suffusion method in the time- frequency domain (Chawla, *et al.*, 2004) . Due to this characteristic wavelet transform has widely an application in signal processing field.

Average of Wavelet function $\psi \in L^2(R)$ is zero

$$\int_{-\infty}^{+\infty} \psi(t)dt = 0 \tag{3.7}$$

Below equation defines continuous wavelet transform (CWT):

$$CWT_{\psi} x(a,b) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{+\infty} x(t)\psi(\frac{t-b}{a})dt \tag{3.8}$$

Where x(t) is signal and $\psi(t)$ is mother wavelet, a and b are scaling parameters. The oscillatory frequency and wavelet length is presented by scale translation parameter a parameter b shows the shifting position. Discrete wavelet based on discrete translation parameter (b) and scaling parameter (a):

$$\psi_{m,n}(t) = a_0^{-m/2}\psi(a_0^{-m}t - nb_0) \tag{3.9}$$

In general, $a=a_0^m$, $b=nb_0a_0^m$, m shows frequency location and n indicates time location(Daubechies, 2006).

The wavelet function is obtained by high pass filter and scaling function is obtained by low pass filter. The decomposition process is started by passing the signal through these filters, which divide the signal into details (high frequency components) and approximation (low frequency components). Outputs of filters are decimated by two for obtaining the approximation coefficients and detail coefficients in the first level (A1, D1). In the next level approximation coefficients are divided again into approximation and detail coefficients (A2, D2) until we reach to expected level(Sanei*, et al.*, 2007).

Parseval's theorem shows that energy of the signal can be classified at different levels of resolution(Chawla*, et al.*, 2004).

$$ED_i = \sum_{j=1}^{N} \left|D_{ij}\right|^2, i = 1,...,l \tag{3.10}$$

$$EA_i = \sum_{j=1}^{N} \left| A_{ij} \right|^2, i = 1,...,l \quad 3.11$$

Where level of the decomposition indicated by *i* (from 1 to *l*) and N is number of coefficient. EA_i and ED_i are energies of approximation at detail at decomposition level I respectively.

3.5 Statistical Analysis

The statistical analysis was used by SPSS to test the gamma power before and after *Salat* .In this study, we focus on the two groups of variable in the same subjects. For this reason, we applied the paired sample t-test to compare the relationship between the pre- and post-baseline.

The paired sample t-test compares the means of two variables. If the value of significance is less than 0.05, there is a significant difference. In this research, we applied the paired sample t-test to compare the mean gamma power in supine position for pre- and post-baseline.

4 CHAPTER IV: RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the results of gamma power are presented for pre- and post-baseline in ten subjects. Gamma activity were illustrated when subjects created a positive emotion or continuous attention on a selected object .In addition, the object of focus maybe on an area of the body or a repeated word(Quranic phrases).The previous researches investigated the increase of gamma power in the other prayer meditation(Cahn *et al.*, 2010; Davidson*, et al.*, 2008).*Salat* has also been demonstrated as a religious meditation in terms of focus attention (FA) and Transcendental meditation (TM).

4.2 Gamma power in the pre-baseline and post-baseline

EEG signal of ten subjects (all male) were analyzed for Pre-baseline (before) and Post-baseline (after).The Paired t-test analysis was performed in comparing measurements. Table 4.1 indicates the mean, standard deviation, and standard error of gamma power in each channel for pre- and post-baseline.

Table 4.1: Mean, standard deviation and standard error for gamma power (B=pre-baseline, A=post-baseline).

	Mean	Std. Deviation	Std. Error Mean
O1B	.000513565	.0004486682	.0001158456
O1A	.000781224	.0005923955	.0001529559
O2B	.000466239	.0003490482	.0000901239
O2A	.000645481	.0004906886	.0001266953
P3B	.000296574	.0002889243	.0000745999
P3A	.000719395	.0018581719	.0004797779
P4B	.000597583	.0005374781	.0001387762
P4A	.000570764	.0006445130	.0001664125
C3B	.000234754	.0001970740	.0000508843
C3A	.000418015	.0005065278	.0001307849
C4B	.000191529	.0002013935	.0000519996
C4A	.000218782	.0001725980	.0000445646
F3B	.000336198	.0002242707	.0000579064
F3A	.000418768	.0003094152	.0000798907
F4B	.000268992	.0001428525	.0000368844
F4A	.000726245	.0007074690	.0001826677

In addition, Table 4.1 shows that the gamma power in the post-baseline is higher compared to the pre-baseline of the *Salat*. The finding is reliable with previous studies on the neurophysiological correlation that reported an increase in gamma power after meditation (Davidson, *et al.*, 2008; Travis, *et al.*, 2010). To be more specific, the research also indicates the difference between right and left hemisphere in pre- and post-baseline of performing the *Salat*. The comparison between pre- and post-baseline will be described in terms of autonomic system (Fig.4.1).

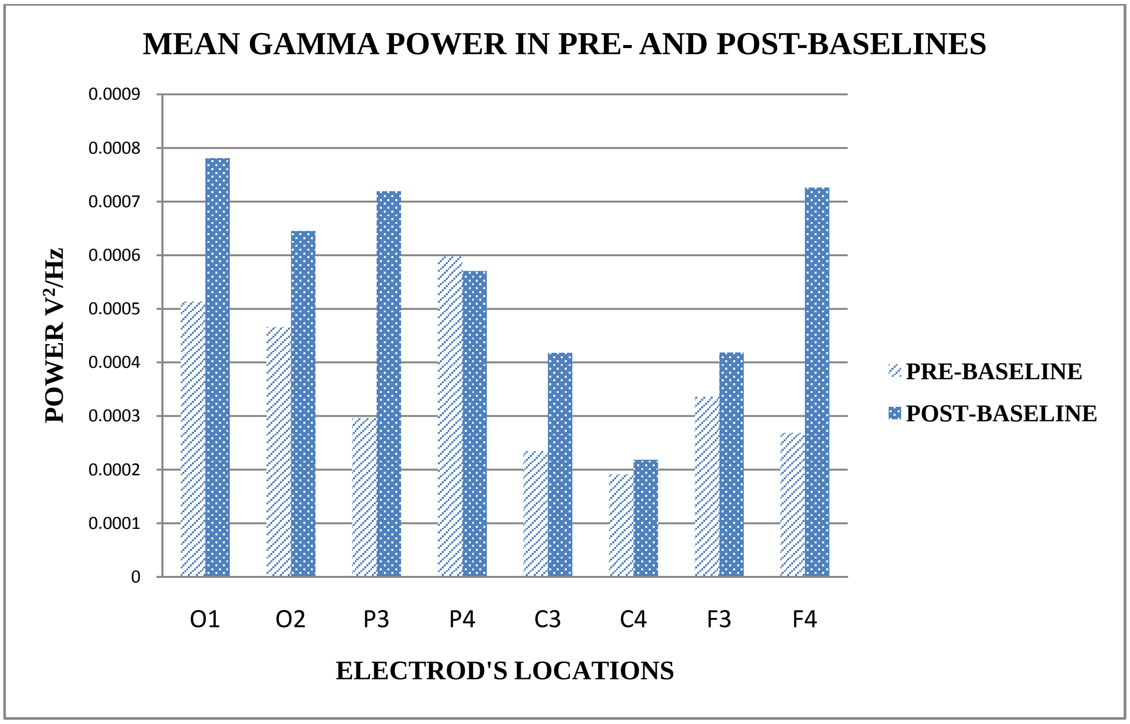

Figure 4.1: Mean gamma power in pre- and post-baseline in each channel

Fig 4.1 shows the comparison of mean gamma power at eight channels between pre- and post-baseline. The channels in the left side of the brain (O1, P3 and C3 except F3) have higher gamma power than the channels in the right region (O2, P4 and C4 except F4) after performing the *Salat* (Post-baseline).

As we mentioned, many studies have shown that the physiological changes during meditation indicate the effects on autonomic system. The wakeful hypometabolic state has the characteristics of decreasing in sympathetic activity which is significant for fight and flight mechanisms and increased parasympathetic nervous activity meant for rest and relaxation (Cahn, *et al.*, 2006; Rai, *et al.*, 1988). Craig (2005) also indicated how the left part of the brain cooperates more with the parasympathetic system and the right part interact with the sympathetic system. Furthermore, we can confirm our finding that the gamma power will be increased in the left side of the brain during performing the *Salat*. For this reason, we prove the positive effects of the *Salat* on the parasympathetic nervous system.

The differences between pre- and post-baseline should be investigated by statistical analysis methods. As mentioned in methodology, the paired t-test were used to detect the significant of differences for probability value of sig<0.05.

Table4.2: Mean and standard deviation (M±S.D) for gamma power in pre- and post-baseline

	Paired Differences					t	Sig. (2-tailed)
	Before(pre-baseline)	After(post-baseline)	Std. Error Mean	95% Confidence Interval of the Difference			
				Lower	Upper		
O1	.0005135±.000448	.0007812±.0005923	.000099	-.0004804853	-.0000548331	-2.697	**.017**
O2	.0004662±.0003490	.0006454±.0004906	.000045	-.0002778483	-.0000806357	-3.899	**.002**
P3	.0002965± .0002889	.0007193±.0001858	.000488	-.0020434147	.0000515230	-2.039	.061
P4	.0005975±.0005374	.0005707±.0006445	.000109	-.0002086544	.0002622932	.244	.811
C3	.0002347±.0001970	.0004180±.0005065	.000080	-.0003555865	-.0000109359	-2.281	**.039**
C4	.0001915±.0002013	.0002187±.0001725	.000013	-.0000569681	.0000024620	-1.967	.069
F3	.0003361±.0002242	.0004187±.0003094	.000036	-.0001600605	-.0000050791	-2.285	**.038**
F4	.0002689±.0001428	.0007262±.0007074	.000155	-.0007913923	-.0001231133	-2.935	**.011**

Table 4.2 shows the mean, standard deviation, standard error, confidence interval and P-value of the statistical analysis. There is a significant increase in gamma power in occipital and frontal regions and left side of the central region (C3). Previous researches have demonstrated the effects of vipassana and Tibetan Buddhist meditation in the frontal and occipital regions of the brain(Cahn, *et al*., 2010; Davidson, 2004). These results have proved that performing *Salat* indicates the positive emotion on prayers mind. In addition, there is no significant difference in the parietal and right side of the central regions as the probability value is more than 0.05.

5 Chapter V: CONCLUSIONS AND FUTURE WORK

5.1 CONCLUSION

In conclusion, *Salat* indicates that the gamma power in the post-baseline is higher compared to the pre-baseline. The higher gamma activity was described when subjects performing a continuous attention or positive emotion after performing other prayer meditation.

This study also showed that the mean gamma power on the left hemisphere is higher than in the right. Previous studies indicated that increase activity of the left part of the brain will be increased the parasympathetic system (Craig, 2005).Furthermore, we can prove our finding that the parasympathetic activity increases after performing the *Salat* in terms of physiological effects on the brain. This gamma power difference on the left-side hemisphere is related to increase of relaxation and a decrease of anxiety.

In addition, there is a significant increase in the occipital and frontal lobes during the post-baseline of the *Salat* which is correlated with other researches on vipassana and Tibetan Buddhist meditation (Cahn, *et al*., 2010; Davidson, 2004).

5.2 FUTURE WORK

The results of this study can be improved with other bio-potential signals for heart rate and blood pressure in terms of physiological effects. The research can be extended by analyzing the EEG signal during performing the *Salat* to compare it with the pre- and post-baselines. Finally, by using more subjects, more reliable results will be obtained.

REFERENCES

Alwasiti, H. H. EEG activity in Muslim prayer: A pilot study. *Maejo International Journal of Science and Technology, 4*.

Arambula, P., Peper, E., Kawakami, M., & Gibney, K. H. (2001). The physiological correlates of Kundalini Yoga meditation: a study of a yoga master. *Applied Psychophysiology and Biofeedback, 26*(2), 147-153.

Austin, J. H. (2006). *Zen-brain reflections: Reviewing recent developments in meditation and states of consciousness*: The MIT Press.

Badra, L. J., Cooke, W. H., Hoag, J. B., Crossman, A. A., Kuusela, T. A., Tahvanainen, K. U. O., et al. (2001). Respiratory modulation of human autonomic rhythms. *American Journal of Physiology-Heart and Circulatory Physiology, 280*(6), H2674-H2688.

Barry, R. J., Clarke, A. R., Hajos, M., McCarthy, R., Selikowitz, M., & Dupuy, F. E. (2010). Resting-state EEG gamma activity in children with Attention-Deficit/Hyperactivity Disorder. *Clinical Neurophysiology, 121*(11), 1871-1877.

Bernardi, L., Sleight, P., Bandinelli, G., Cencetti, S., Fattorini, L., Wdowczyc-Szulc, J., et al. (2001). Effect of rosary prayer and yoga mantras on autonomic cardiovascular rhythms: comparative study. *Bmj, 323*(7327), 1446-1449.

Bertrand, O., Tallon-Baudry, C., Fischer, C., & Pernier, J. (2001). *Object representation and gamma oscillations*.

Braboszcz, C., Hahusseau, S., & Delorme, A. (2010). Meditation and neuroscience: from basic research to clinical practice. *Handbook of Integrative Clinical Psychology, Psychiatry, and Behavioral Medicine: Perspectives, Practices, and Research. Springer Publishing Co Inc*.

Cahn, B. R., Delorme, A., & Polich, J. (2010). Occipital gamma activation during Vipassana meditation. *Cognitive processing, 11*(1), 39-56.

Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychological bulletin, 132*(2), 180.

Carlson, L. E., Speca, M., Faris, P., & Patel, K. D. (2007). One year pre-post intervention follow-up of psychological, immune, endocrine and blood pressure outcomes of mindfulness-based stress reduction (MBSR) in breast and prostate cancer outpatients. *Brain, behavior, and immunity, 21*(8), 1038-1049.

Chawla, G., Gupta, A., & Sengar, S. (2004, 11-14 Dec. 2004). *A wavelet based detection and analysis of GAMMA rhythms in EEG signals.* Paper presented at the Signal Processing and Communications, 2004. SPCOM '04. 2004 International Conference on.

Cooley, J. W., & Tukey, J. W. (1965). An algorithm for the machine calculation of complex Fourier series. *Math. Comput, 19*(90), 297-301.

Cooper, R., Osselton, J. W., & Shaw, J. C. (1980). *EEG technology*: Butterworths London.

Craig, A. (2005). Forebrain emotional asymmetry: a neuroanatomical basis? *Trends in cognitive sciences, 9*(12), 566-571.

Daubechies, I. (2006). *Ten lectures on wavelets*: Society for industrial and applied mathematics.

Davidson, R. J. (2004). Well-being and affective style: neural substrates and biobehavioural correlates. *PHILOSOPHICAL TRANSACTIONS-ROYAL SOCIETY OF LONDON SERIES B BIOLOGICAL SCIENCES*, 1395-1412.

Davidson, R. J., & Lutz, A. (2008). Buddha's Brain: Neuroplasticity and Meditation [In the Spotlight]. *Signal Processing Magazine, IEEE, 25*(1), 176-174.

Doufesh, H., Faisal, T., Lim, K. S., & Ibrahim, F. (2011). EEG Spectral Analysis on Muslim Prayers. *Applied Psychophysiology and Biofeedback*, 1-8.

Eckberg, D. L., Nerhed, C., & Wallin, B. (1985). Respiratory modulation of muscle sympathetic and vagal cardiac outflow in man. *The Journal of physiology, 365*(1), 181.

Engel, A. K., Fries, P., & Singer, W. (2001). Dynamic predictions: oscillations and synchrony in top-down processing. *Nature Reviews Neuroscience, 2*(10), 704-716.

Fell, J., Fernandez, G., Klaver, P., Elger, C. E., & Fries, P. (2003). Is synchronized neuronal gamma activity relevant for selective attention? *Brain Research Reviews, 42*(3), 265-272.

Fisch, B. J., & Spehlmann, R. (1999). *Fisch and Spehlmann's EEG primer: basic principles of digital and analog EEG*: Elsevier Science Health Science div.

Gunaratana, H. (2002). *Mindfulness in plain English*: Wisdom Pubns.

Gyatso, T., & Jinpa, T. (1995). The world of Tibetan Buddhism: An overview of its philosophy and practice. *Somerville: Wisdom Publications*.

Harrison, L. J., Manocha, R., & Rubia, K. (2004). Sahaja yoga meditation as a family treatment programme for children with attention deficit-hyperactivity disorder. *Clinical Child Psychology and Psychiatry, 9*(4), 479-497.

Hyvarinen, A. (1999). Fast and robust fixed-point algorithms for independent component analysis. *Neural Networks, IEEE Transactions on, 10*(3), 626-634.

Ibrahim, F., Abas, A. B. W., & Ng, S. C. (2008). *Salat: Benefit from Science Perspective*: Department of Biomedical Engineering, Univeristy of Malaya.

Jensen, P. S., Arnold, L. E., Swanson, J. M., Vitiello, B., Abikoff, H. B., Greenhill, L. L., et al. (2007). 3-year follow-up of the NIMH MTA study. *Journal of the American Academy of Child & Adolescent Psychiatry, 46*(8), 989-1002.

Jevning, R., Wallace, R., & Beidebach, M. (1992). The physiology of meditation: a review. A wakeful hypometabolic integrated response. *Neuroscience & Biobehavioral Reviews, 16*(3), 415-424.

Kabat-Zinn, J. (2003). Mindfulness-Based Interventions in Context: Past, Present, and Future. *Clinical psychology: Science and practice, 10*(2), 144-156.

Kay, S. M. (1998). Fundamentals of statistical signal processing, Volume II: Detection theory. *Upper Saddle River (New Jersey), 7*.

Lee, S. H., Ahn, S. C., Lee, Y. J., Choi, T. K., Yook, K. H., & Suh, S. Y. (2007). Effectiveness of a meditation-based stress management program as an adjunct to pharmacotherapy in patients with anxiety disorder. *Journal of Psychosomatic Research, 62*(2), 189-195.

Lehmann, D., Faber, P., Achermann, P., Jeanmonod, D., Gianotti, L. R. R., & Pizzagalli, D. (2001). Brain sources of EEG gamma frequency during volitionally meditation-induced, altered states of consciousness, and experience of the self. *Psychiatry Research: Neuroimaging, 108*(2), 111-121.

Lehrer, P., Sasaki, Y., & Saito, Y. (1999). Zazen and cardiac variability. *Psychosomatic Medicine, 61*(6), 812-821.

Litscher, G., Wenzel, G., Niederwieser, G., & Schwarz, G. (2001). Effects of QiGong on brain function. *Neurological research, 23*(5), 501-505.

Lutovac, M. D., Tošić, D. V., & Evans, B. L. (2001). *Filter design for signal processing using MATLAB and Mathematica*: Miroslav Lutovac.

Lutz, A., Greischar, L. L., Rawlings, N. B., Ricard, M., & Davidson, R. J. (2004). Long-term meditators self-induce high-amplitude gamma synchrony during mental practice. *Proceedings of the National Academy of Sciences of the United States of America, 101*(46), 16369.

Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Attention regulation and monitoring in meditation. *Trends in cognitive sciences, 12*(4), 163-169.

Makeig, S. (1993). Auditory event-related dynamics of the EEG spectrum and effects of exposure to tones. *Electroencephalography and Clinical Neurophysiology, 86*(4), 283-293.

Manikonda, J., Störk, S., Tögel, S., Lobmüller, A., Grünberg, I., Bedel, S., et al. (2007). Contemplative meditation reduces ambulatory blood pressure and stress-induced hypertension: a randomized pilot trial. *Journal of human hypertension, 22*(2), 138-140.

Niedermeyer, E., & Da Silva, F. H. L. (2005). *Electroencephalography: basic principles, clinical applications, and related fields*: Lippincott Williams & Wilkins.

Niessing, J., Ebisch, B., Schmidt, K. E., Niessing, M., Singer, W., & Galuske, R. A. W. (2005). Hemodynamic signals correlate tightly with synchronized gamma oscillations. *Science, 309*(5736), 948.

Pal, G., & Velkumary, S. (2004). Effect of short-term practice of breathing exercises on autonomic functions in normal human volunteers. *The Indian journal of medical research, 120*(2), 115.

Rai, U., Setji, S., & Singh, S. (1988). Some effects of Sahaja Yoga and its role in the prevention of stress disorders. *Journal of International Medical Sciences, 19*, 23.

Razumnikova, O. M. (2007). Creativity related cortex activity in the remote associates task. *Brain research bulletin, 73*(1-3), 96-102.

Reibel, D. K., Greeson, J. M., Brainard, G. C., & Rosenzweig, S. (2001). Mindfulness-based stress reduction and health-related quality of life in a heterogeneous patient population. *General Hospital Psychiatry, 23*(4), 183-192.

Rubia, K. (2009). The neurobiology of meditation and its clinical effectiveness in psychiatric disorders. *Biological psychology, 82*(1), 1-11.

Sanei, S., & Chambers, J. (2007). *EEG signal processing*: Wiley-Interscience.

Saul, J. P. (1990). Beat-to-beat variations of heart rate reflect modulation of cardiac autonomic outflow. *Physiology, 5*(1), 32-37.

Sterman, M., Macdonald, L., & Stone, R. K. (1974). Biofeedback training of the sensorimotor electroencephalogram rhythm in man: effects on epilepsy. *Epilepsia, 15*(3), 395-416.

Swanson, L. W. (2011). *Brain architecture: Understanding the basic plan*: Oxford Univ Pr.

Travis, F., & Shear, J. (2010). Focused attention, open monitoring and automatic self-transcending: Categories to organize meditations from Vedic, Buddhist and Chinese traditions. *Consciousness and cognition, 19*(4), 1110-1118.

Walter, W., & Dovey, V. (1944). Electro-encephalography in cases of sub-cortical tumour. *Journal of Neurology, Neurosurgery & Psychiatry, 7*(3-4), 57.

Young, J. D. E., & Taylor, E. (1998). Meditation as a voluntary hypometabolic state of biological estivation. *News in physiological sciences, 13*, 149-153.

Yucel, S. (2008). *The effects of prayer on Muslim patients' well-being.* BOSTON UNIVERSITY SCHOOL OF THEOLOGY.