EEG ANALYSIS DURING SALAT AND ACT-OUT SALAT

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ABSTRAK

SOLAT adalah satu jenis ibadat khusus dalam Islam yang terdiri daripada pergerakan tubuh tertentu serta bacaan doa-doa dan ayat-ayat. Tesis ini menunjukkan analisa perubahan pada purata kuasa gamma (25-60 Hz) semasa melaksanakan SOLAT sebenar dan lakonan oleh lima orang subjek (20-29 tahun). Elektroensefalogram (EEG) keatas pelaksanaan SOLAT dirakam di lapan bahagian utama kepala (F3, F4, C3, C4, P3, P4, O1 dan O2). Kuasa ketumpatan spektra (PSD) daripada isyarat di setiap posisi dikira dengan menggunakan metod Welch kerana dalam metod ini, varians dari proses rawak menurun apabila dibandingkan dengan periodogram asa. Perbandingan purata kuasa gamma semasa melaksakan SOLAT sebenar dan lakonan menunjukkan bahawa pada posisi yang berlainan selama SOLAT sebenar, kuasa gamma lebih tinggi daripada SOLAT percubaan. Analisa statistik secara parametrik (Paired sample t-test) menunjukkan ada perubahan signifikan pada nilai purata kuasa gamma untuk pergerakan solat yang sebenar berbanding pergerakan lakonan solat ketika posisi berdiri dan tunduk. Semasa posisi sujud, perubahan signifikan kuasa gamma adalah pada bahagian frontal, parietal dan occipital. Ketika posisi duduk pula, kuasa gamma signifikan pada bahagian parietal. Hasil dari penyelidikan ini menunjukkan purata kuasa gamma di bahagian kiri hemisfera adalah lebih tinggi dari bahagian kanan ketika melaksanakan solat. Kajian terdahulu menunjukkan bahagian kiri otak lebih berinteraksi dengan aktiviti saraf parasimpatetik dan bahagian kanan berkaitan dengan saraf simpatetik. Kajian ini telah membuktikan bahawa SOLAT memperbaiki aktiviti saraf parasimpatetik yang bermaksud bahawa konsentrasi memberikan pengenduran kepada minda orang yang bersembahyang.

ABSTRACT

Salat is a specific worship in Islam and consists of body movement and recitation of some religious phrases. This report presents the analysis changes in mean gamma (25-60 Hz) power during performing *Salat* and act-out *Salat* in five normal subjects (age between 20 and 29 years old). During *Salat*, electroencephalography (EEG) record were obtained from eight main regions of scalp (F3, F4, C3, C4, P3, P4, O1 and O2). Power spectral density (PSD) of the signal in each position was computed by using Welch's method because, in this method, variance of the random process decreases in comparison to basic periodogram. The comparison of mean gamma power between *Salat* and act-out *Salat* indicated that during different positions of *Salat* praying, gamma powers are higher than act-out praying. Parametric statistical analyses (Paired sample t-test) results indicated during standing and bowing positions mean gamma power of *Salat* had significant differences with act-out praying. During prostrating position, the significant differences of gamma power were at frontal, parietal and occipital regions. In sitting position the gamma power was significant at parietal region. Investigation of all channels showed that changes of parietal channels were significant in all positions. The results of this study revealed that during performing *Salat* mean gamma power in the left hemisphere is higher than right side. Previous studies shows that left part of the brain interact more with parasympathetic nervous activity and the right part is related to sympathetic system. These results proved that performing *Salat* improves parasympathetic nervous activity it means that concentration provides significant relaxation for prayers mind.

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LIST OF ABBREVIATIONS

EEG	Electroencephalography
LF/HF	Low frequency/ High frequency
AD/HD	Attention-Deficit/Hyperactivity Disorder
PSD	Power spectral density
LORETA	Low Resolution Electromagnetic Tomography
ANOVA	Analysis of variance
SPSS	Statistical Package for the Social Sciences
FIR	Finite impulse response
IIR	Infinite impulse response
nuHF	Normalized unit of high-frequency
nuLF	Normalized unit of low-frequency
RPα	Relative alpha power

CHAPTER I: INTRODUCTION

1.1 Overview

Meditation is based on religious traditions as a form of understanding and learning for promotion of relaxation and concentration. During concentration meditations, meditators try to attention on a given object which helps them to bring back attention of the mind with attention deficit (Cahn & Polich, 2006; Raffone & Srinivasan, 2010). Some religions such as Buddhism, Christianity, Hinduism, Jainism and Islam use meditation in their worship. *Salat* is one of the subset of religions Meditation that consists of individual body movements and the recitation of some religious phrases (Alwasiti, 2010).

For investigation the effect of different actions on brain activity best method is studying the brain signal by electroencephalography. Electroencephalography (EEG) measured the summation of the electrical potentials and electrical activities of cortical neurons along the scalp (von Stein & Sarnthein, 2000; Wadhai *et al. 2011*).

Brainwave consists of different ranges of frequency, theta band with frequency between 4 and 8 Hertz, alpha band with frequency between 8 and 12 Hz, beta band with frequency 13 to 30 Hz and gamma band with above 30 Hertz frequency (Palaniappan, 2006).

Researchers have worked on gamma band activity for investigation of working memory, conscious perception, concentration, relaxation and effects of different method of meditation (Fries *et al.*, 2001; Tallon-Baudry *et al.*, 2005). The purpose of this research is investigation of mean power of gamma in different positions of *Salat* and act-out praying. Salat is performing of praying with concentration and use all holly phrases and act-out

Salat is praying without recitation and concentration and prayers just do all body movement same as act-out *Salat*.

1.2 Problem Statement

This research attempts to investigate the effect of *Salat* (Muslims prayer) on worshipper's brain signals. This research investigated the effect of concentration on relaxation during performance of the *Salat* by comparison of mean gamma power between *Salat* and act-out *Salat*. Researchers found that one of the main consequences of meditation is improving relaxation and concentration of meditators mind which can be investigated by considering changes of gamma power (Lehmann *et al.*, 2001; Lutz *et al.*, 2004).

The Comparison of gamma power between *Salat* and act-out *Salat* indicates significance of concentration during praying and effect of this attention on Muslims mentally relaxing during their worship.

1.3 Objectives of the Study

The objective of the study is to analyze the psychophysiological effect of performing *Salat* on Muslims mind.

1.4 Scope of the Study

The research is limited to following scopes:

1. Obtaining the changes of mean gamma power in four main positions of *Salat*
2. Obtaining mean gamma power in four main positions (standing, bowing, sitting, and prostrating) of performing *Salat*
3. Comparison of gamma power between the *Salat* and act-out *Salat* shows effect of performing *Salat* on Muslims mind

1.5 Significance of the Study

Unfortunately there are a few researchers have worked on *Salat* area while electroencephalographic (EEG) researches of meditative states have been conducted for more than 50 years (Cahn, *et al.*, 2006). With this research and obtaining the reliable results we can consider the effect of the *Salat* for improving relaxation and concentration for Muslims mind.

There is not any research on different positions of *Salat* in gamma band activity. Investigation of gamma activity is one of current scopes of research that researchers have used for consideration of meditation effects on human minds.

1.6 Outline of the report

In this report there are five chapters and each of them consists of one aspect of the project. Chapter one is introduction which shows overall information about this project and consists of objectives, scopes and significant of the study. Chapter two consists of previous studies which have been done on different meditation methods and shows important features in EEG signal processing in meditation field related to relaxation and cognition of practitioners. Chapter three explains completely about methods which were used and mentions different steps of the study. Chapter four explains and discusses the results of research. In this chapter results of gamma power in different positions of *Salat* are presented and also results of statistical analysis of them are investigated. The conclusion of this research and future work are proposed in chapter five.

Chapter II: REVIEW OF RELATED LITERATURE

1.7 Introduction

This chapter reviews the literature about meditation categories and some relevant researches about effect of the meditation on brain activity. Also this chapter consists of meditation studies about gamma power and finally reviews researches about brain signal processing of *Salat*.

1.2 Physiology of Brain

The brain is the important part of the body which consists of around 10 billion neurons (Swanson, 2011). In general brain of the human divided into four main lobes, such as:

1. **Frontal Lobe:** This lobe represents short term memory, reasoning, movement, behavior and emotions. This area of scalp is important for this study because of the significant effect of the performing *Salat* is changing the prayers emotion and praying have recitation and body movement during *Salat*.
2. **Temporal Lobe:** This lobe represents the long term memory and primary auditory cortex.
3. **Parietal Lobe:** this part of the brain is responsible for sense of the different part of the body. It represents movement of the body, awareness of temperature and touch.
4. **Occipital Lobe:** this part of the brain is responsible for recognition of the colors, visual processing and movement.

1.3 Relaxation

In general relaxation can be improved by muscle relaxation, biofeedback and meditation. There are different bases for relaxation methods such as, a) Passivity, enabling to return back the consciousness to normal direction, b) Focusing, providing the concentration and return attention c) Receptivity, ability to improving the acceptance of negative emotions and tolerance of paradoxical experiences (Smith *et al.*, 1996). Relaxation consists of some physiological changes such as: slowing breathing, slowing of heart rate, reduces oxygen consumption, reduces conductance of skin. All these changes are cause of decrease of the nervous system activity (Benson *et al.*, 1975; Greenwood & Benson, 1977). Lazar et al. (2000) for their research used long term breathing meditators. They found that activation of neural structures and autonomic nervous involved in attention are decreased during slower breathing period. One of the current methods for investigation of the relaxation through brain activity is studying of the EEG signal. During different emotion states, brain activity shift to different area of scalp. During positive emotion brain activity shifts to right hemisphere and during negative state brain activity shifts to front/temporal areas (Lazar *et al.*, 2000).

1.4 Meditation

Meditation methods can be divided into two main groups: first group is movement meditation (like dancing, singing or walking) and second group is silent meditation that mostly is done in sitting position. Mediation tries to increase concentration by focusing on part of the body, using imagining or external objects (Vaitl *et al.*, 2005). One of the important experiments for proving the effects of meditation on brain activity is Electroencephalographic (EEG) studies which researchers have been worked in this field

around 50 years. Meditation has been used for treatment the mental and physical problems by engaging the patients to a specific physical or mental practices.

Meditation style is also has different categories for study the different types of meditation, concentrative and mindfulness and this category shows how the attention procedures are directed (Davidson & Goleman, 1977). Mindfulness practice involves allowing any feeling and any thoughts and awareness of important feathers as an attentive without analysis or judgment. This practice includes different methods such as; Vipassana, Zen and western mindfulness meditation (Kabat-Zinn, 2003). Focusing on specific activity is the main technique for concentrative meditation. This concentration is made by imagination of an image, repeated sound or breathing. *Salat* performance is one of the concentration meditation methods. During performing *Salat* prayers focus on existence of the GOD and repeat some individual phrases. Their period of breading decrease and concentration and relaxation rate of their mind are increased. Some meditation methods also used this technique such as: Buddhist and Yogic meditations.

Researchers have found some references and evidence related to earliest meditation belong to 1400 B.C. But the modern meditation, introduced by Maharishi Mahesh Yogi in 1966 and they called it "mantra" meditation. Mantra meditation has quite procedure. The closest meditation type to *Salat* performance is Mantra meditation which during this meditation the meditator should repeat silently some syllables in a passive manner.

The consciousness has been related with periods of breathing. Short breath period during transcendental consciousness decelerates the heart rate magnitude and improves skin conductance (Travis & Wallace, 1997). Improvement of knowledge about mental actions is main goal of most meditations (Goleman, 1988).

1.5 Brain Oscillations

In general there are five main brain frequency ranges in EEG signal which each of them reveals important information from brain activities. These frequencies are gamma, beta, theta, alpha and delta (Sterman *et al.*, 1974).

Delta frequency band: the range of delta band is between 0.5 to 4 Hz and mostly is used for expressing deep sleeping situation.

Theta frequency band: Theta frequency has range between 4 to 7.5 Hz. Hiving high theta activity shows abnormal in awake adult state for considering different brain disorders.

Alpha frequency band: has range between 8 to 13 Hz which is used widely for investigation of relaxation.

Gamma frequency band: there is not exact range for this frequency range but mainly is assumed between 30 to 60 Hz and is related to level of attentive processes (Walter & Dovey, 1944).

1.6 Electroencephalogram (EEG)

Electroencephalographic (EEG) studies of meditative states have been conducted for almost 50 years. Researchers have found that long term meditation can be detected by measurement of theta EEG activity. Long term meditator have higher theta band activity over the frontal region of the scalp compare to normal group and also researchers showed positive emotions can increase the theta activity over the left prefrontal region (Aftanas & Golocheikine, 2001).

Meditation methods have significant effects on EEG signal in different frequency bands. Santhosh et al. investigated the effect of the Maha Mudra Meditation on brain frequency bands. Their research showed increase in delta power and theta power and slight decrease in alpha over of frontal parietal and midline of brain region(santhosh *et al.,2006*).

In study of analyzing the effect of the Zen meditation on brain action researchers observed increase in fast theta power and slow alpha power on EEG predominantly in the frontal area. This study showed an increase in the normalized unit of high-frequency (nuHF) power (as a parasympathetic index) and decreases in the normalized unit of low-frequency (nuLF) power and LF/HF (as sympathetic indices) were observed through analyses of heart rate variability.

Takahashi et al. (2005) analyzed the possible correlations among these changes in terms of the percent change during meditation using the control condition as the baseline. The percent change in fast theta power in the frontal area, reflecting enhanced mindfulness, was positively correlated with that in nuHF. These results suggest that internalized attention and mindfulness as two major core factors of behaviors of mind during meditation are characterized by different combinations of psychophysiological properties and personality traits (Takahashi *et al.*, 2005).

1.7 Gamma band

Researches show the gamma band frequency has main role in mental processes such as learning, concentration and working memory. One of the applications of study the gamma band power is investigation of the concentration and some researchers have shown that in subject that they have lower attention the gamma range power is lower than normal range. Robert J. Barry (2010) worked on gamma activity in children with Attention-Deficit/Hyperactivity Disorder. This study results showed, in AD/HD group delta and theta increased and beta was lower compare to control group. They found gamma range power of the AD/HD group is lower than control group. This research showed, in gamma band AD/HD children have lower relative and absolute activity compare to healthy group. Reduction of the absolute gamma was higher in left hemisphere and posterior regions.

Reduction of relative gamma in hemispheres region was higher (Barry *et al.*, 2010). This study shows that improving the concentration in subject can cause increasing in their gamma band power and another hand left hemisphere and posterior regions are important for investigation of subject's concentration.

In a research on Buddha meditations showed significant different in gamma band activity (35-44 Hz). The three-dimensional distribution of the 35-44 Hz 'gamma' band generators was analyzed by using Low Resolution Electromagnetic Tomography (LORETA). This study found relationship between different meditation methods and different center of gravity of gamma EEG activity (left central: verbalization, right posterior: visualization) (Lehmann, *et al.*, 2001). Verbalization is an important feature of performing *Salat* which can change gamma activity in left central region of scalp.

Faber et al. in their research on Zen meditation found that theta coherence during meditation increased and gamma coherence decreased. The study on Vipassana meditation showed increased in frontal theta power (4–8 Hz) and significantly increased parietal-occipital gamma power, but no other state effects were found in other frequency bands (Cahn *et al.*, 2010).

Longer duration of meditation has significant effect on concentration of meditators. Lutz et al. (2004) research showed that ratio of the gamma to slow rhythm in long term Buddhist meditation is higher than control group. The comparison between the long term meditators and control group was investigated in this study than in this research they proved that ratio of the gamma to slow rhythm is higher than control group. The results of this research show that expert meditator has higher gamma power ratio in compare to control group (Lutz, *et al.*, 2004). This results showed that there is direct relation between amount of changging gamma power and concentration of meditators. This fact shows that

for having significant differnce between *Salat* and act-out *Salat*, using subjects with higher concentration is very useful.

1.8 SALAT

Recent researches revealed that performing *Salat* has significant effects on Muslims mind and bring physical benefits for their body. Electroencephalographic (EEG) studies of *Salat* states have been conducted for a few years. One of important step in performing *Salat* is prostrating.

Salleh et al. in their research showed that prostrating during *Salat* generates higher alpha relative power (RPα) in compare to act-out prostration. In this study, they used AR method for analyzing the EEG signal. This finding concludes that prostration may promote a remarkable relaxation state to human mind and body. The results have proved effect of the *Salat* on brainwave. This study showed that during *Salat* prostrating position all eight channels have higher amount of relative power than act-out prostrating. These results improved that concentration during performing *Salat* has significant effects on alpha power in different regions of scalp (Salleh *et al.*, 2009).

Doufesh et al. (2011) investigated the proportion of relaxation after performing *Salat* by measuring the relative power of alpha. In this research they obtained relative alpha power for four main positions of *Salat* and provided a comparison between *Salat* and act-out *Salat* at these positions. The result of the variance (ANOVA) tests showed that there were no significant differences of relative alpha power between *Salat* and act-out *Salat (Doufesh, et al., 2011).*

Mohd Fatihilkamal et al. analyzed EEG signal of prayers before and after performing *Salat*. Also they investigated effect of listening music and performing *Salat* on Muslims mind. By using Principal component Analysis (PCA) they found that highest

percentage of brain signal was belong to gamma band (39.931%). This study by comparison of before and after performing *Salat* found that amplitude of gamma band after *Salat* is higher than before *Salat* and also higher than amplitude of gamma band after listening the music .

CHAPTER III: DESIGN, METHODS AND PROCEDURE

1.9 Introduction

This chapter explains about the structure of this research. It also describes the procedure of obtaining the pure signals from database and all the methods which were used for calculation of mean power of gamma band in each position of *Salat*.

1.10 Methodology

For this study five Muslims subjects between 20 and 29 years old were recruited. The consent form was obtained from each of them and they did not have any psychological and neurological disorders. This research consists of three steps, first step initial base line which is ask subjects to sit on the comfortable chair for 180 seconds and during this time EEG signal was collected as an initial resting. In second step subject performed *Salat* and act-out *Salat*. The *Salat* is praying with all correct body movement and using all holly phrases. During *Salat* we asked to subjects to do their praying as same as every day without trying to have higher concentration than before. The act-out *Salat* is just mimicking *Salat* performance that consists of body movement without recitation of phrases and concentration. In this research subjects preformed *Salat* in four cycles. The main goal of this research is investigation of effect of the concentration on relaxation is each position of *Salat*.

Third step is resting after performing *Salat* which subjects sitting on the chair for 180 seconds and EEG signal collection was repeated again. For this research a quiet place was prepared for subjects to have enough concentration on their performance. The subjects were verbally instructed to begin the resting steps and asked subjects to open, close and open their eyes for 60 seconds, respectively.

1.11 Salat Instruction

Before the starting the performance of the *Salat* asked to subject to relax for about three minutes. The Fig. 3 shows 4 main steps in each cycle of performing *Salat*.

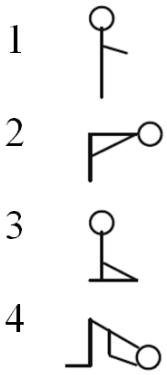

Figure 3.1: this figure shows different steps of performing *Salat*.

1) Standing
2) Bowing
3) Sitting
4) Prostrating (Doufesh *et al.*, 2011).

1.11.1 Standing: Standing is upright standing position which takes approximately between 30 to 60 seconds

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

The prayer ends the act of bowing by moving to a standing position and this action takes approximately 5 seconds.

1.11.3 Prostrating: In this position the frontal area of head touches the ground. The position of the hands while prostrating is as follows:

a) The hands are kept away from the sides of the body

b) The elbow is raised off the floor

c) The forehead and face are placed in between both palms

d) The fingers are brought close together

This step approximately takes around 5 minutes.

1.11.4 Sitting: Sitting is resting step on the floor with specific recitation. Left foot is placed under the right foot, and the right foot is positioned upright. While moving from a prostration position the muscle of the pelvic floor will be activated. Sitting step takes around 30 to 60 seconds.

In this study five subjects performed *Salat* in four cycles which showed in Fig 4.

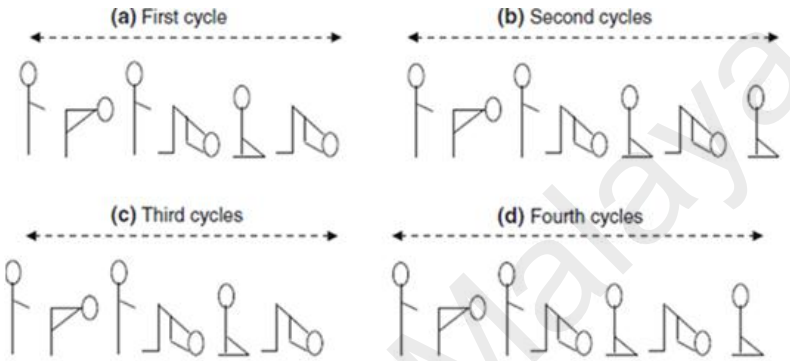

Fig 3.2: body position during four cycles of *Salat* (Doufesh, *et al.*, 2011).

In general each subject had eight standing and prostrating, four bowing and six sitting positions during their four cycles *Salat*. Between these body positions during performance of four cycles *Salat* for all subjects two positions of standing, bowing, prostrating and sitting were used. After performing *Salat*, subjects were instructed to perform act-out *Salat* without concentration on praying or reciting phrases. Prayers did all steps of *Salat* and remained in each position approximately 15 seconds.

The protocol of time duration in each position were, 10 minutes of standing position, 5 minutes of bowing position, 10 minutes of sitting and 5 minutes of prostrating position.

1.12 EEG Recordings and Protocol

EEG data were collected by 8 channel MP150 EEG acquisition system (BIOPAC systems Inc., California, USA). The electrodes impedance was less than 5 k ohm and Sampled at 250 Hz. Eight electrodes selected for this research which showed in Fig 5 are

homologous frontal (F3, F4), central (C3, C4), parietal (P3, P4) and occipital (O1, O2) regions and their position adjusted by international 10-20 system. Channel Cz used as a reference in this study.

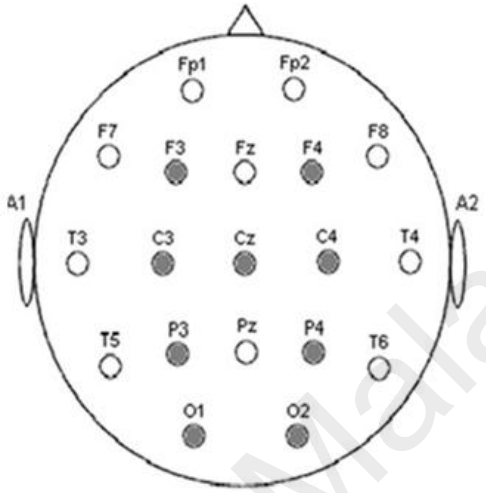

Fig 3.3: Electrode positions on the scalp/

1.13 Spectral Analysis

There are a lot of noise sources which can affect EEG signal and one of these artifacts is eye movement and eye blinking. Eye blinks and eye movement noises are subsets of non-neural noises but they are not in gamma range frequency. Other important noise is muscle artifacts which produce by movement of the body during EEG collecting.

1.13.1 Extraction of static position

Each position of *Salat* is connected to next step by changing the body position. For removing this artifact each position of the *Salat* investigated separately. Static position in four positions (standing, bowing, prostrating and sitting) during *Salat* and act-out *Salat* were extracted and tried to remove manually artifacts which produced by eye and body movement.

1.13.2 Filtering

Second step after selecting the static position of the body is filtering the signals. In this study IIR filter was used. This filter applied to the signal as a band pass filter between 1.0 and 100 Hz. There are two main digital filter types in signal processing, infinite impulse response (IIR filter) and finite impulse response filter (FIR filter). They have their own limitation for using; IIR filter has much better frequency response than FIR filter because of it is recursive filter, less complex and have lower order. Another hand IIR filter due to non-linear phase characteristics is not good for phase response investigation (Selesnick & Burrus, 1998).

Some of the IIR filter characteristics are, low filter order, non-linear phase. This filter has the feedback which is known as recursive filter (Fig. 3.4 shows block diagram of IIR and FIR filters).

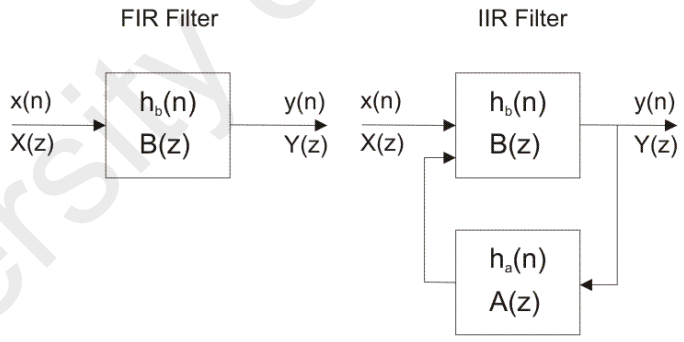

Fig 3.4: Block diagrams of FIR and IIR filters.

One of the current methods for designing the IIR filters is using the reference analog proto-type filters (Fig 3.5). Using the analog prototype filter is the best method for designing of high pass, low pass; band stop and band reject filters.

Fig 3.5: Block diagram of design method using reference analog prototype filter.

Analog counterparts have significant rules for designing the digital IIR filters because there are not any resources, straightforward designed methods concerning digital feedback filter designed while finding them is easy for analog filters. For implementation of digital IIR filter, an analog filter should first designed and after that by applying the discretization techniques it is converted to a digital filter. Examples of analog IIR filters are: Butterworth, Chebyshev and Elliptic filters which produce different kinds of IIR filters, IIR Butterworth filter, IIR Bessel filter and IIR Chebyshev filter. The Butterworth filter is one of the current filtering methods in signal processing which designed to generate flat (no ripples) frequency response in the cutoff frequency. The main advantages of using this method as a filter are rejection of unwanted part of signal without destroying the information of whole signal and have uniform and high sensitivity for wanted frequencies. Angular frequency was used for designing the Butterworth filter to have a monotonically changing magnitude function, but other kinds of filters have non monotonic change that provides ripples in cut off frequencies (Bianchi & Sorrentino, 2007). Fig 3.6 shows the gain of the some common filters and discrete time Butterworth filter. This figure shows that rolls off the Butterworth filter more slowly around the cutoff area and does not have any ripples around the cutoff frequency (all of filters have fifth order) (Daniels, 1974).

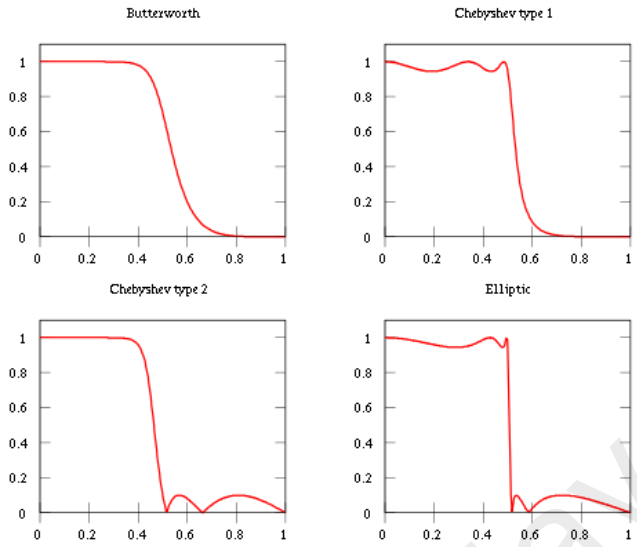

Fig 3.6: Butterworth filter has slower roll off and more linear phase response than Chebyshev Type I/Type II and elliptic filters/

After designing the analog filter we should go through the last step which is conversion of analog to digital filter. The most common converting method is bilinear transformation method and the final result is always stable. In this study band pass and band stop of IIR filter were used (Daniels, 1974).

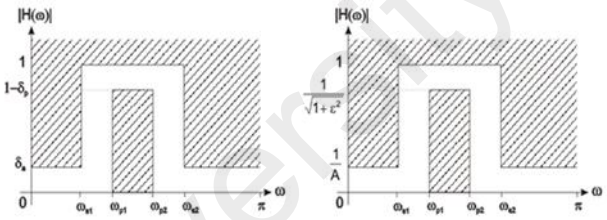

Fig 3.7: Band pass digital filter specification.

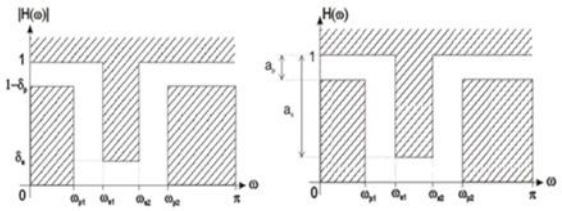

Fig 3.8: Band stop digital filter specification.

ω_p – normalized pass-band cut-off frequency; ω_s – normalized stop-band cut-off frequency

δ_1 – max pass-band ripples; δ_2 – min stop-band attenuation

ε – pass-band attenuation parameter; A – stop-band attenuation parameter

a_p – max pass-band ripples [dB]; a_s – min stop-band attenuation [dB].

$$\delta_p = 1 - 10^{-\frac{a_p}{10}} = 1 - \frac{1}{\sqrt{1+\varepsilon^2}} \qquad 3.1$$

$$\varepsilon = \frac{\sqrt{\delta_p(2-\delta_p)}}{1-\delta_p} = \sqrt{10^{\frac{a_p}{10}} - 1} \quad 3.2$$

$$a_p = -20\log(1-\delta_p) = 10\log(1+\varepsilon^2) \quad 3.3$$

Frequency normalization can be expressed as follows:

$$\omega = \frac{2\pi f}{f_s} \quad 3.4$$

- Where f is the frequency to normalize, f_s is the sampling frequency and ω is the normalized frequency (Eriksson, 2007).

1.13.3 Power spectral density

Power spectral density function (PSD) is used for obtaining energy of the signal. PSD shows that which frequencies have higher and lower energies. With integrating PSD in specific range of frequency we can obtain the energy of this duration. Welch method is one of the classical methods for obtaining the PSD of the signal. Welch method based on FFT is a nonparametric method and based on Bartlett's idea of dividing of the signal into segments and obtaining the average of their priodogram (Naderi & Mahdavi-Nasab, 2010).

Welch method is one of the popular methods for calculating the PSD of the signal in time sequence. All the sequences are allowed to overlap and Welch method applied to each of them. The Welch power spectral density is given by:

$$P_d(f) = \frac{1}{MU}\left|\sum_{n=0}^{M-1} x_d(n)w(n)e^{-j2\pi fn}\right|^2 \quad 3.5$$

Where $x_d(n)$ is the sequence, w (n) is the windowed data, signal intervals are d=1, 2, 3,…,L and length of each interval enter to equation by M.

The power normalization factor in the windows function is given by:

$$U = \frac{1}{M}\sum_{n=0}^{M-1}|w(n)|^2 \qquad 3.6$$

The average of the Welch power over modified periodgram (P_{Welch}) selected as:(Subha *et al.*, 2010)

$$P_{welch}(f) = \frac{1}{L}\sum_{i=0}^{L-1}P_d(f) \qquad 3.7$$

The variance of the estimators is reduced by increasing the number of the segments. For this reason in the Welch method with reduction of the variance we can improve the resolution more than Bartlett's method. The variance of the Welch method with 50% overlapping is around 9/16 of the variance of the Bartlett's method (Naderi, *et al.*, 2010). The Variance of the Welch PSD for 50% overlapping is given by:

$$\mathrm{var}(P_w(f)) = \frac{9}{8S}\mathrm{var}(P_I(f)) \qquad 3.8$$

Where $P\hat{}_w(f)$ is PSD of the signal according to Welch method and $P\hat{}_I(f)$ is the periodogram of each signal interval . After obtaining the PSD of the signal, mean power calculated by averaging of power spectrum in a certain epoch.

1.13.4 Statistical analysis

SPSS (Statistical Package for the Social Sciences) used to test changes of the mean gamma power between *Salat* and act-out *Salat* in different positions. In this research Paired sample t-test was utilized. The main reason for using paired t-test method in this study is paired sample t-test mainly used for comparison two groups of variables from same people which there are an underlying relationship between their amounts (Wellman). In this software for classification of differences between variables they defined a range is called that P-value. For having significant difference this amount should be under 0.05.

The paired sample t-test compares two groups of data by comparing the means of two variable groups. In general when we have two variables/ intervals from the same people, paired sample t-test is useful test that can show us the value of this comparison. In this study changing in mean gamma power for each variable investigated individually.

CHAPTER IV: RESULTS AND DISCUSSION

1.14 Introduction

In this chapter, mean gamma band powers in different position of *Salat* are presented. Researchers in their studies found that higher concentration during meditation has direct relationship with gamma activity of the brain signal; it means that meditators who have higher concentration have higher gamma power over their scalps. *Salat* is a kind of religion meditation method and this study tried to show that during performing of *Salat*, prayers brain signals have higher gamma power in compare to performing act-out *Salat*.

1.15 Gamma power during *Salat*

Brain signal of five subjects (10 samples) were analyzed. In this chapter four main positions of *Salat* performance were considered. For each channel during *Salat* and act-out performance average of mean power and standard deviation were calculated. For clarifying the difference between *Salat* and act-out gamma power in each channel SPSS was used and for eight channels in all positions P-value were obtained.

1.15.1 Standing position

Table 4.1 shows mean gamma powers and their standard deviations in standing position of *Salat* and act-out *Salat*. The results in standing position clearly show that *Salat* standing has higher mean gamma powers than act-out in all channels.

Table 4.1: mean and standard deviation (SD) for the mean gamma power of standing in *Salat* and act-out *Salat.*

STANDING	F3	F4	C3	C4	P3	P4	O1	O2
Salat	7.76E-06 ±3.34E-06	7.49E-06 ± 3.79E-06	3.83E-06 ± 1.74E-06	4.18E-06 ± 2.29E-06	2.40E-05 ± 1.63E-05	1.28E-05 ± 5.23E-06	5.65E-05± 1.72E-05	3.70E-05± 2.77E-05
Act-out	6.08E-06 ± 3.39E-06	5.45E-06 ± 3.82E-06	3.23E-06 ± 1.74E-06	3.72E-06 ± 2.8E-06	1.73E-05 ± 1.1E-05	8.09E-06 ± 4.21E-06	5.18E-05± 1.98E-05	2.26E-05± 1.55E-05

Fig 4.1 shows the comparison of mean gamma power at eight channels between *Salat* and act-out *Salat* during standing position. Fig 4.1 same as table 4.1 indicates that all channels of standing position related to *Salat* have higher gamma power than these channels output during act-outstanding. Posterior region of the scalp has higher concentration of gamma power. As this figure shows, the gamma power at parietal and occipital regions have higher amount compare than other areas of scalp.

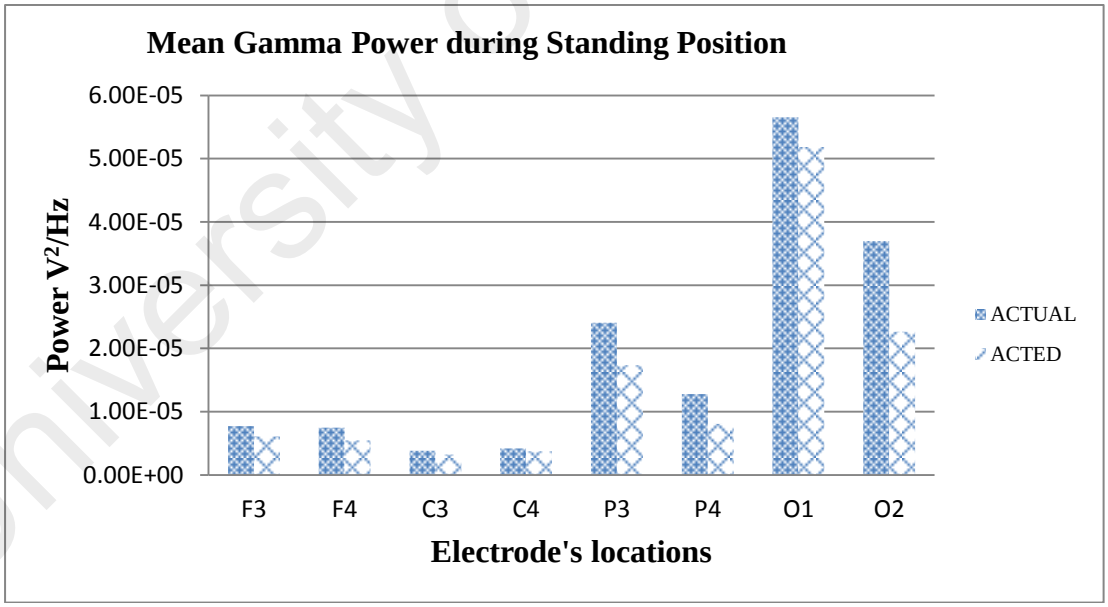

Figure 4.1: shows mean gamma power during standing position of *Salat* and act-out *Salat.*

The channels in the left side of the scalp (F3, C3, P3 and O1) have higher gamma power than channels at right region (F4, C4, P4 and O2).

The differences between variables should investigated by statistical analysis methods. These methods show that these changes are significance or not. For this reason SPSS as mentioned briefly in chapter three (Methodology) is one of the current statistical analysis methods. In this software for classification of differences between variables they defined a range is called that P-value. For having significant difference this amount should be under 0.05.

Table 4.2 shows statistical comparison between *Salat* and act-out *Salat* by using pair sample t-test. This table shows the mean and standard deviation, standard error, confidence interval and P-value of this comparison. Mean power of *Salat* in all eight channels are higher than act-out *Salat* but in five channels these differences are significant (under 0.05). P-value of other three channels were higher than 0.05 which could not categorized as a significant differences it means that in these three channels there were not differences between *Salat* and act-out *Salat*.

Table 4.2: mean and standard deviation, standard error, confidence interval and P-value of mean gamma power at standing position of *Salat* and act-out *Salat.*

Electrodes	Salat	Act-out	SE	Sig.(p-value)	CI. lower	CI. upper
F3	7.76E-06 ± 3.34E-06	6.08E-06 ± 3.39E-06	6.20E-07	0.02	2.74E-07	3.08E-06
F4	7.49E-06 ± 3.79E-06	5.45E-06 ± 3.82E-06	4.39E-07	0.001	1.05E-06	3.04E-06
C3	3.83E-06 ± 1.74E-06	3.23E-06 ± 1.74E-06	2.84E-07	0.06	-3.90E-08	1.25E-06
C4	4.18E-06 ± 2.29E-06	3.72E-06 ± 2.8E-06	3.41E-07	0.20	-3.09E-07	1.23E-06
P3	2.40E-05 ± 1.63E-05	1.73E-05 ± 1.1E-05	2.55E-06	0.02	9.94E-07	1.25E-05
P4	1.28E-05 ± 5.23E-06	8.09E-06 ± 4.21E-06	1.49E-06	0.01	1.31E-06	8.05E-06
O1	5.65E-05 ± 1.72E-05	5.18E-05 ± 1.98E-05	2.41E-06	0.14	-2.98E-06	1.23E-05
O2	3.70E-05 ± 2.77E-05	2.26E-05 ± 1.55E-05	7.07E-06	0.13	-8.17E-06	3.68E-05

1.15.2 Bowing position

Table 4.3 indicates mean gamma powers and standard deviations of bowing position during *Salat* and act-out d *Salat*. *Salat* bowing presented higher mean gamma power in all eight channels than act-out bowing. The results of this study on bowing action showed that concentration of the prayers during *Salat* is the main reason of these differences and provides more relaxation rate for prayers mind.

Table 4.3: mean and standard deviation (SD) for the mean gamma power of bowing in *Salat* and act-out *Salat*

BOWING	F3	F4	C3	C4	P3	P4	O1	O2
Salat	1.13E-05 ± 2.90E-06	7.67E-06 ± 3.33E-06	4.71E-06 ± 2.78E-06	4.32E-06 ± 2.67E-06	1.95E-05 ± 8.98E-06	1.44E-05 ± 4.05E-06	4.94E-05 ± 6.51E-06	5.33E-05 ± 1.48E-06
Act-out	6.38E-06 ± 3.79E-06	5.42E-06 ± 3.73E-06	3.67E-06 ± 2.50E-06	4.02E-06 ± 2.82E-06	1.61E-05 ± 6.56E-06	1.09E-05 ± 3.83E-06	4.83E-05 ± 1.91E-06	3.17E-05 ± 1.91E-05

Fig 4.2 presents the amounts of mean gamma powers during bowing and *Salat* channels have higher gamma power than act-out *Salat*. The mean gamma powers are higher in parietal and occipital areas of scalp (same as standing position). Gamma power during bowing position is higher in left region of scalp (except O1in *Salat* bowing) than right side.

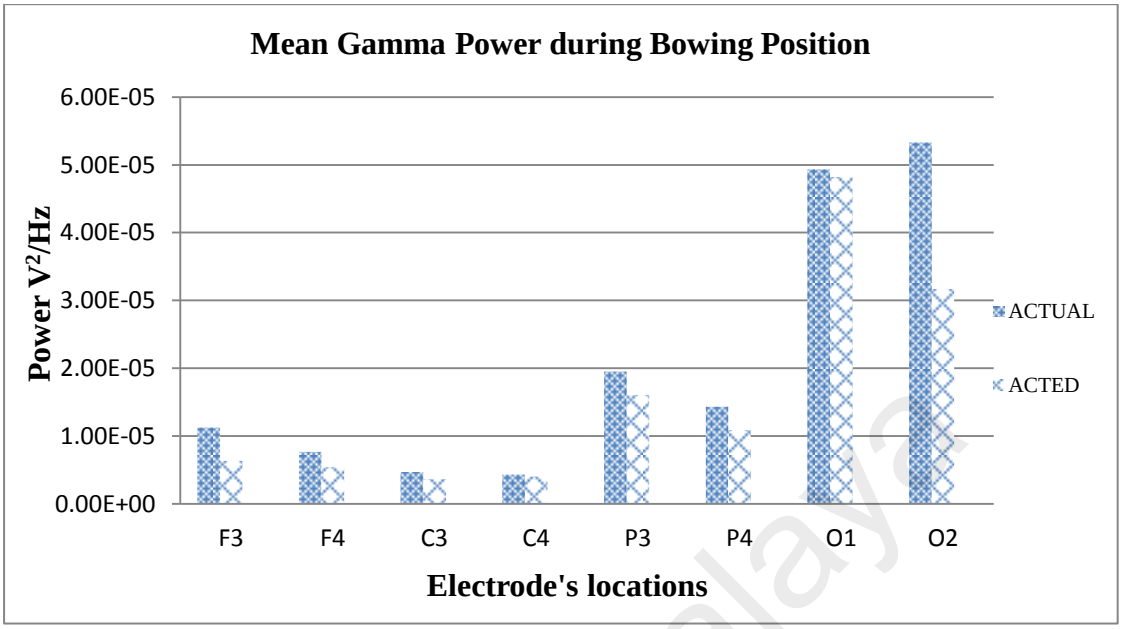

Figure 4.2: shows the comparison of mean gamma power at eight channels between *Salat* and act-out *Salat*.

Table 4.4 shows statistical comparison between *Salat* and act-out *Salat* by using pair sample t-test. Mean power of *Salat* in all eight channels are higher than act-out *Salat*. These differences are significant in four channels (F3, F4, P3 and P4). P-value of other four channels was higher than 0.05 which could not categorized as a significant differences in another word for these three channels there were not differences between *Salat* and act-out *Salat*.

Table 4.4: mean and standard deviation, standard error, confidence interval and P-value of mean gamma power at bowing position of *Salat* and act-out *Salat.*

Electrodes	Salat	Act-out	SE	Sig.(p-value)	CI. lower	CI. upper
F3	1.13E-05 ± 2.90E-06	6.38E-06 ± 3.79E-06	1.11E-06	0.0016	2.39E-06	7.41E-06
F4	7.67E-06 ± 3.33E-06	5.42E-06 ± 3.73E-06	5.70E-07	0.003	9.63E-07	3.54E-06
C3	4.71E-06 ± 2.78E-06	3.67E-06 ± 2.50E-06	5.10E-07	0.07	-1.06E-07	2.20E-06
C4	4.32E-06 ± 2.67E-06	4.02E-06 ± 2.82E-06	5.89E-07	0.61	-1.03E-06	1.64E-06
P3	1.95E-05 ± 8.98E-06	1.61E-05 ± 6.56E-06	1.28E-06	0.024	5.40E-07	6.31E-06
P4	1.44E-05 ± 4.05E-06	1.09E-05 ± 3.83E-06	1.08E-06	0.01	1.02E-06	5.93E-06

O1	4.94E-05 ± 6.51E-06	4.83E-05 ± 1.91E-06	3.25E-06	0.78	-4.01E-05	4.24E-05
O2	5.33E-05 ± 1.48E-06	3.17E-05 ± 1.91E-05	1.25E-05	0.33	-1.37E-04	1.80E-04

1.15.3 Prostrating position

Table 4.5 shows mean gamma powers and standard deviations during prostrating position of *Salat* and act-out *Salat. Salat* prostrating same as standing and bowing position presented higher gamma power in all eight channels than act-out *Salat.*

One of the important positions of *Salat* performance is prostrating. Salleh et al.(2009) in their research showed that during prostrating position Muslims scalp generates higher alpha relative power (RPα) as compare with act-out prostration (Salleh, *et al.*, 2009).

Table 4.5 also proves that during prostrating position of *Salat* mean gamma power has higher range in compare to act-out or act-out *Salat.*

Table 4.5: Mean and standard deviation (SD) for the mean gamma power of prostrating during *Salat* and act-out *Salat*

PROSTARTING	F3	F4	C3	C4	P3	P4	O1	O2
Salat	1.05E-05± 9.90E-06	1.00E-05± 9.44E-06	5.44E-06± 3.31E-06	6.64E-06± 6.58E-06	2.45E-05± 1.27E-05	2.41E-05± 1.38E-05	5.21E-05± 1.98E-05	4.83E-05± 1.22E-05
Act-out	5.61E-06± 4.80E-06	5.27E-06± 5.14E-06	3.83E-06± 2.60E-06	4.61E-06± 3.82E-06	1.42E-05± 7.29E-06	1.50E-05± 5.66E-06	3.09E-05± 1.29E-05	2.50E-05± 7.60E-06

Fig 4.3 shows the comparison of mean gamma power at eight channels between *Salat* and act-out *Salat* during prostrating position. This figure presents that amounts of mean gamma powers in all channels are higher in parietal and occipital regions also channels in the left side of the scalp (F3, C3, P3 and O1) during prostrating have higher gamma power than channels at right region (F4, C4, P4 and O2).

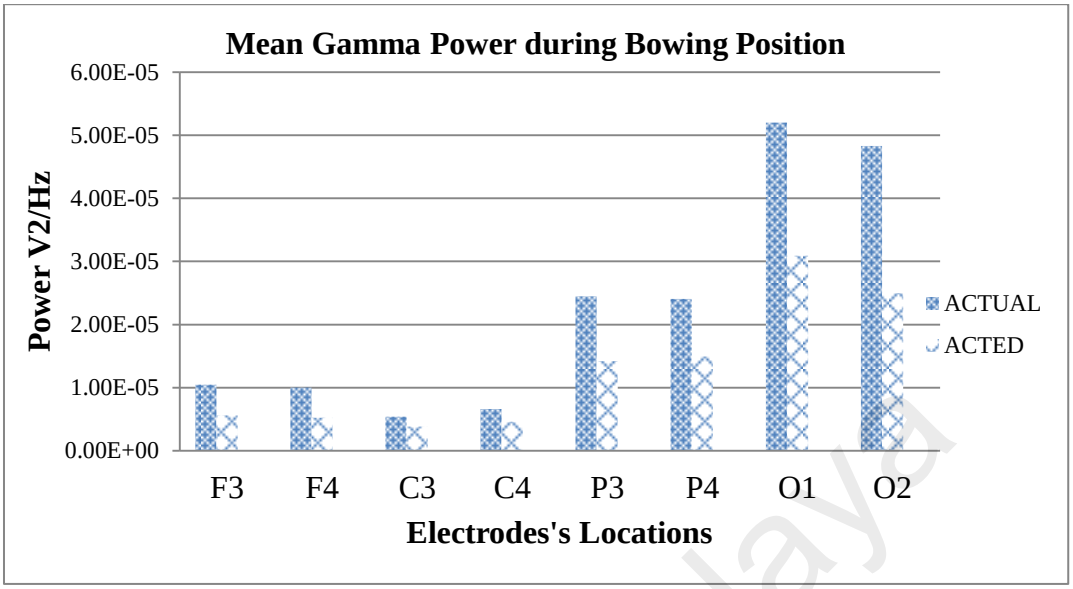

Figure 4.3: shows the comparison of mean gamma power between *Salat* and act-out during bowing position.

Table 4.6 shows statistical comparison between *Salat* and act-out *Salat* during prostrating position. This table illustrates the mean and standard deviation, standard error, confidence interval and P-value of this comparison. Mean power differences are significant at seven channels (F3, F4, C3, P3, P4, O1 and O2). P-value of C4 was higher than 0.05 and it means that there is not different between *Salat* and act-out gamma power in this channel.

Table 4.6: mean and standard deviation, standard error, confidence interval and P-value of mean gamma power at prostrating

Electrodes	Salat	Act-out	SE	Sig.(p-value)	CI. lower	CI. upper
F3	1.05E-05± 9.90E-06	5.61E-06± 4.80E-06	2.14E-06	0.048	4.98E-08	9.73E-06
F4	1.00E-05± 9.44E-06	5.27E-06± 5.14E-06	1.81E-06	0.027	6.59E-07	8.83E-06
C3	5.44E-06± 3.31E-06	3.83E-06± 2.60E-06	4.48E-07	0.005	5.97E-07	2.62E-06
C4	6.64E-06± 6.58E-06	4.61E-06± 3.82E-06	1.00E-06	0.073	-2.37E-07	4.29E-06
P3	2.45E-05± 1.27E-05	1.42E-05± 7.29E-06	3.48E-06	0.016	2.41E-06	1.82E-05
P4	2.41E-05± 1.38E-05	1.50E-05± 5.66E-06	4.06E-06	0.05	-5.35E-08	1.83E-05
O1	5.21E-05± 1.98E-05	3.09E-05± 1.29E-05	4.53E-06	0.001	1.09E-05	3.14E-05
O2	4.83E-05± 1.22E-05	2.50E-05± 7.60E-06	4.37E-06	0.0004	1.34E-05	3.32E-05

1.15.4 Sitting position

Table 4.7 illustrates mean gamma powers of sitting position during *Salat* and act-out *Salat*. The results of investigation of sitting action showed that concentration causes difference between *Salat* and act-out *Salat*. Mean gamma power of *Salat* sitting position in all channels except channel F3 were higher than act-out *Salat*.

Table 4.7: mean and standard deviation (SD) for the mean gamma power of sitting during *Salat* and act-out *Salat*

SITTING	F3	F4	C3	C4	P3	P4	O1	O2
Salat	5.04E-06± 2.29E-06	3.80E-06± 1.28E-06	3.04E-06± 1.38E-06	2.64E-06± 7.11E-07	9.64E-06± 6.35E-06	8.08E-06± 6.24E-06	1.92E-05± 5.84E-06	1.38E-05± 4.08E-06
Act-out	6.00E-06± 4.16E-06	3.38E-06± 1.20E-06	2.69E-06± 1.18E-06	2.01E-06± 7.44E-07	5.03E-06± 2.17E-06	4.44E-06± 2.58E-06	1.41E-05± 6.83E-06	1.23E-05± 2.89E-06

Fig 4.4 shows the comparison of mean gamma power at eight channels between *Salat* and act-out *Salat* during sitting position and presents that amount of mean gamma power during sitting position is higher in the left region of the scalp.

Unlike other channels the amount of the channel F3 in *Salat* sitting position is lower than act-out sitting.

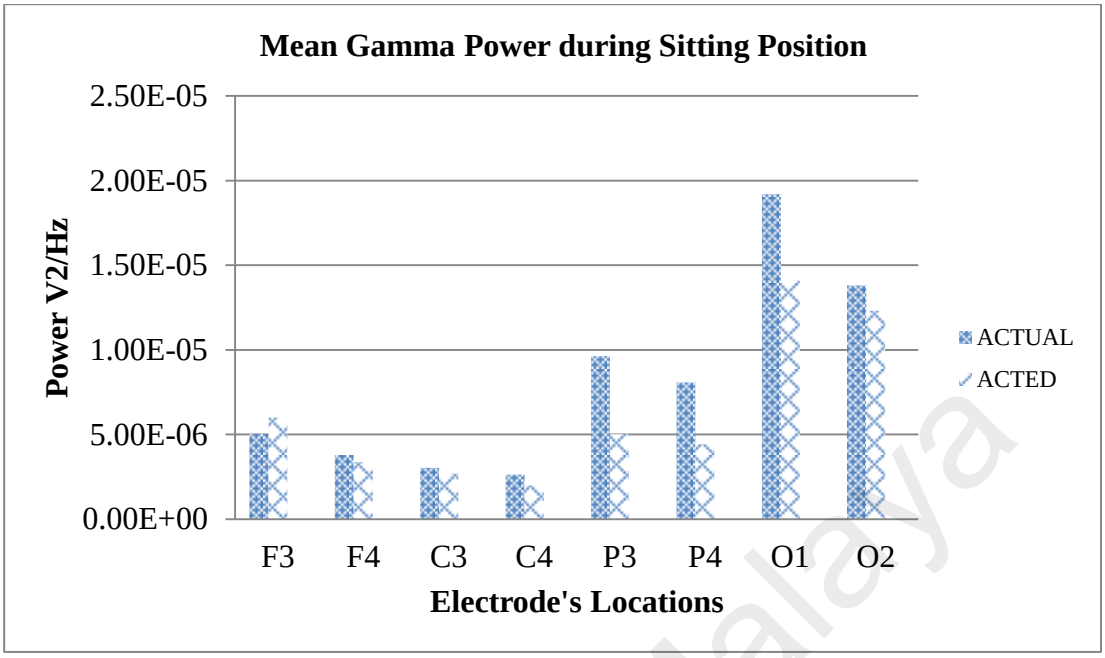

Figure 4.4: shows the comparison of mean gamma power between *Salat* and act-out *Salat* during sitting position.

Table 4.8 indicates statistical comparison between *Salat* and act-out *Salat* by using pair sample t-test. Mean power of *Salat* in seven channels are higher than act-out *Salat* and just three channels had significant difference (C4, P3, P4).

Table 4.8: mean and standard deviation, standard error, confidence interval and P-value of mean gamma power at sitting

Electrodes	Salat	Act-out	SE	Sig.(p-value)	CI. lower	CI. upper
F3	5.04E-06± 2.29E-06	6.00E-06± 4.16E-06	8.92E-07	0.305	-2.92E-06	1.01E-06
F4	3.80E-06± 1.28E-06	3.38E-06± 1.20E-06	2.17E-07	0.07	-5.19E-08	9.03E-07
C3	3.04E-06± 1.38E-06	2.69E-06± 1.18E-06	2.74E-07	0.22	-2.54E-07	9.54E-07
C4	2.64E-06± 7.11E-07	2.01E-06± 7.44E-07	1.87E-07	0.006	2.22E-07	1.04E-06
P3	9.64E-06± 6.35E-06	5.03E-06± 2.17E-06	1.33E-06	0.005	1.68E-06	7.54E-06
P4	8.08E-06± 6.24E-06	4.44E-06± 2.58E-06	1.42E-06	0.02	-5.04E-07	6.77E-06
O1	1.92E-05± 5.84E-06	1.41E-05± 6.83E-06	4.59E-06	0.34	-9.41E-06	1.98E-05
O2	1.38E-05 ± 4.08E-06	1.23E-05± 2.89E-06	1.57E-06	0.36	-1.97E-06	4.93E-06

The main goal of this study is investigation of effect of the concentration on Muslims mind during performing *Salat*. This research shows there are significant differences between mean gamma power in different channels of *Salat* and act-out *Salat.* Researchers found that one of the important sign of relaxation after meditation is increasing the gamma power and results of this research revealed that concentration during *Salat* has significant effects on Muslims mind and provides higher mind relaxation for prayers.

Investigation of the whole process of performing *Salat* indicated that during all positions parietal and occipital regions have higher gamma power (Fig 4.5).

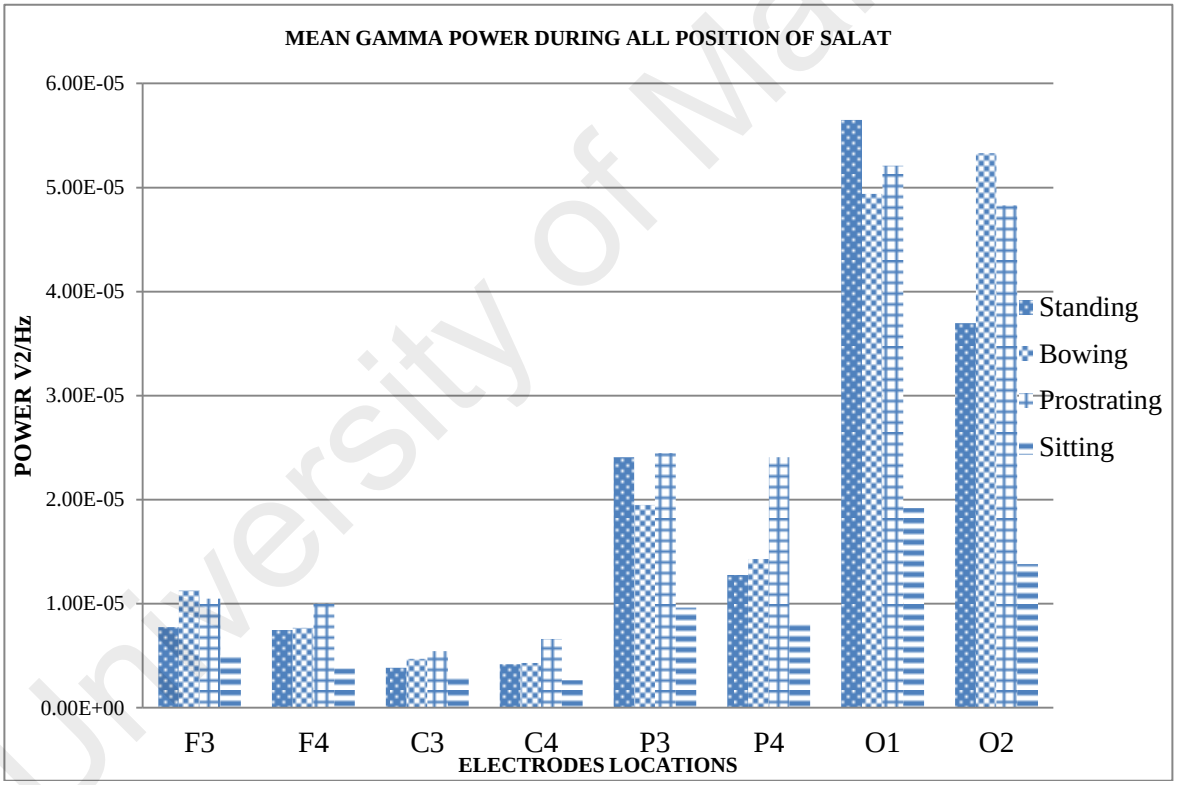

Figure 4.5: Mean gamma power of all positions of performing *Salat.*

This figure also shows that left hemisphere of the scalp has higher gamma power in compare to right region which reveals that performing *Salat* improves Parasympathetic nervous activity another word provides positive emotion for prayers mind.

Investigation of the whole process of performing act-out *Salat* indicated that also during act-out *Salat* parietal and occipital regions same as *Salat* have higher gamma power (Fig 4.6).

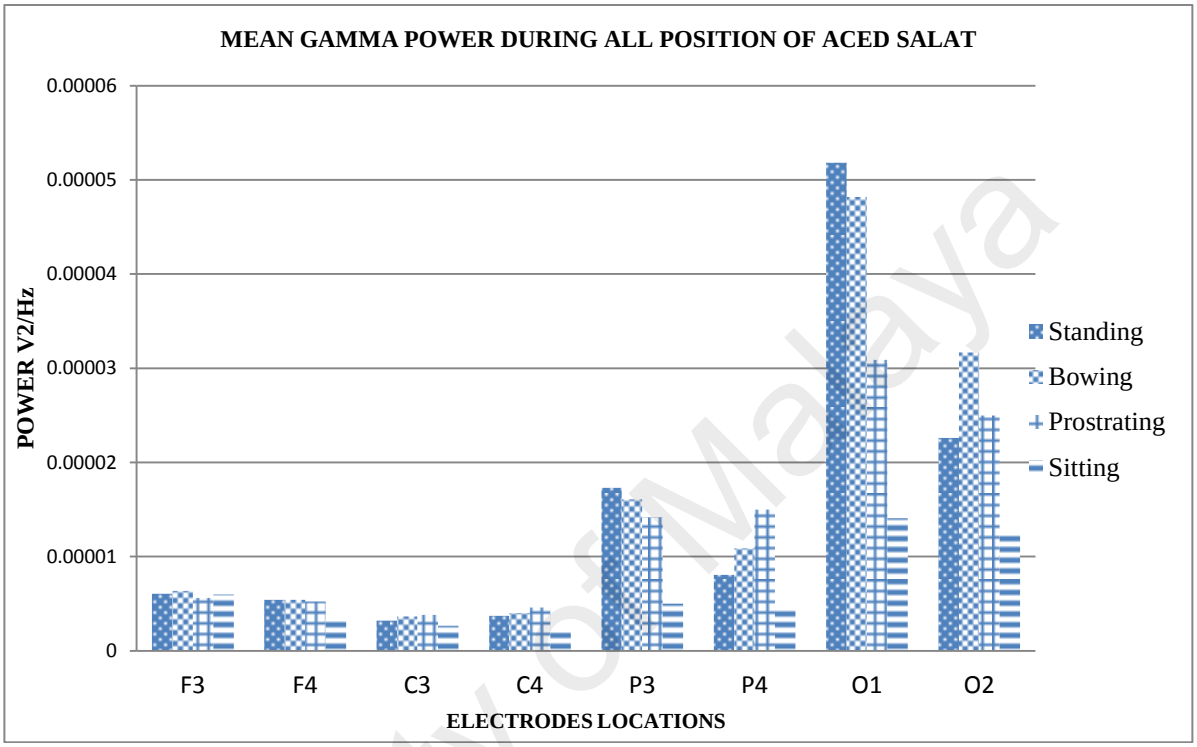

Figure 4.6: Mean gamma power in all positions of act-out *Salat*

This figure shows that there is no difference between left and right hemispheres of the scalp at frontal, central and also at parietal region. These results reveal that act-out *Salat* without any concentration does not have any effects on prayers mind.

Chapter V: CONCLUSIONS AND RECOMMENDATION FOR FUTURE WORK

1.16 Conclusion

The results of this study showed that during *Salat*, worshippers have higher mean gamma powers in compare to someone doing a *Salat* act-out. Mean gamma power of *Salat* at parietal channels had significant difference with their values during acy-out *Salat* performance in all positions. Performing *Salat* with concentration provides more relaxation for prayers mind and it is possible to categorize *Salat* as a subset of meditation.

One of the main reasons for significant difference in parietal regions is working memory of the prayers. Prayers for reminding the phrases should use their memory more and researchers found reminding action causes inducement of gamma power in frontal and parietal/ occipital area of scalp (Michels *et al.*, 2010). Furthermore this study found during performing *Salat* gamma power of the left region of the scalp has higher amount in compare to right area. Researchers found that during positive emotion brain activity shifts to left hemisphere compared to negative emotions (Lazar, *et al.*, 2000). These results proved that performing *Salat* improves parasympathetic nervous activity. Parasympathetic activity is important for rest and relaxation of the mind (Rubia, 2009). This study results show that gamma mean power is a worthwhile feature for investigation of differences between *Salat* and act-out performing *Salat.*

1.17 RECOMMENDATION FOR FUTURE WORK

By providing a comparison for whole procedure of *Salat*, consists of gamma power range in before, during and after performing *Salat* we can provide significant study about effect of *Salat* on prayers mind. Also using more subjects helps us to having lowest error rate in our results. By using stronger methods for feature extraction with higher accuracy

and using different methods for removing all the external and internal artifacts we can obtain more reliable differences between our variable groups.

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