EXPLORING GAMMA BRAINWAVE OSCILLATIONS DURING PASSIVE LISTENING TO MELODIOUS RECITATION OF AYATUL KURSI USING SIMULTANEOUS EEG AND MEG RECORDING TECHNIQUE

MOHD WAQIYUDDIN BIN ABDULLAH

UNIVERSITI SAINS MALAYSIA

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by

MOHD WAQIYUDDIN BIN ABDULLAH

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LIST OF SYMBOLS

dB	decibel
Hz	Hertz
kOhm	kilo Ohm
n	number of subjects
s	seconds
SD	standard deviation

LIST OF ABBREVIATIONS

AAL3	automated anatomical labelling atlas 3
BOLD	blood oxygen level dependent
DAN	dorsal attention network
dlPFC	dorsolateral prefrontal cortex
DMN	default mode network
dmPFC	dorsomedial prefrontal cortex
ECG	electrocardiography
EEG	electroencephalography
EOG	electrooculography
EWM	emotional working memory
F0	fundamental frequency or pitch
F1	first formant
F2	second formant
FA	focused attention (meditation)
fMRI	functional magnetic resonance imaging
GUI	graphical user interface
HPI	head position indicator
MEG	magnetoencephalography
mPFC	medial prefrontal cortex
MCC	midcingulate cortex
MRI	magnetic resonance imaging
MTL	medial temporal lobe

OFC	orbitofrontal cortex
OM	open monitoring (meditation)
PBUH	peace be upon him
PCC	posterior cingulate cortex
PET	positron emission topography
PFC	prefrontal cortex
PSD	power spectral density
PTSD	post-traumatic stress disorder
PV	parvalbumin
ROIs	regions of interest
TM	transcendental meditation
ToM	theory of mind
TPJ	temporo-parietal junction
VAN	ventral attention network
vlPFC	ventrolateral prefrontal cortex
vmPFC	ventromedial prefrontal cortex

LIST OF ARABIC TERMINOLOGIES

Ahruf	recitation styles
Al-abrar	a group of the righteous
Al-muqarrabin	a group of the righteous who strive to be closer to Allah
Al-qalb as-salim	pure heart
Al-sirr	innermost being
An-nagham fil Quran	interesting melody of Al-Quran
Arsh	a Great Pavilion, a realm more tremendous than *kursiy*
Asmaul Husna	the names of Allah
Dammah	short vowel sound of 'u'
Dhikr	remembrance
Du'a	supplication
Fathah	short vowel sound of 'a'
Fikr	contemplation
Hadith	saying of the Prophet Muhammad (PBUH)
Hadr	fast tempo of Quranic recitation
Harakat	elongation
Huffaz	persons who memorize Al-Quran
I'tibar	contemplation
Isti'la	stressed Arabic letters
Istibsar	pondering
Jawwada	root word for *tajweed*
Juz	part

Kasrah	short vowel sound of ‘i’
Kursiy	throne
Lafzul jalalah	the name of ‘Allah’ in its full Arabic form i.e. الله
Mu’jizat	miracle granted by Allah to His messengers
Muqata’at	symbolic letters found in the beginning of certain surah
Murattal	adjective of *tarteel*
Nathr	examining
Qiraat	recitation of Al-Quran
Ruqyah	a practice of treating illness with Quranic verses
Shahada	testimony of Islamic faith
Sukun	absence of a vowel
Surah	chapter
Syukur	gratitude
Syaddah	emphasis enunciation by making a double consonant
Tadwir	medium tempo of Quranic recitation
Tafkhim	thickness
Tahajjud	night prayers
Tahqiq	slow tempo of Quranic recitation
Tajrid	inner refinement
Tajweed	rules of Quranic recitation
Tanwin	nunation
Taqwa	be mindful of Allah
Tarteel	clear and correct articulation

MENEROKA OSILASI GELOMBANG OTAK GAMMA SEMASA MENDENGAR BACAAN AYAT KURSI BERMELODI SECARA PASIF MENGGUNAKAN TEKNIK PENGIMEJAN EEG DAN MEG SECARA SERENTAK

ABSTRAK

Kebanyakan kajian lepas tentang kesan bacaan Al-Quran memfokuskan gelombang otak berfrekuensi rendah seperti theta dan alpha, kerana kedua-duanya dipercayai memainkan peranan penting terhadap kesan ketenangan yang disebabkan oleh bacaan Al-Quran. Oleh itu, kajian ini mengambil kira gelombang otak berfrekuensi tinggi iaitu gamma (30-80 Hz). Gelombang gamma sering dikaitkan dengan fungsi kognitif yang lebih tinggi seperti daya tumpu dan memori kerja. Kajian terbaru terhadap praktis meditasi berjaya membuktikan peningkatan aktiviti gelombang gamma di kalangan pakar meditasi, yang mungkin menyumbang kepada peningkatan daya tumpu. Dalam Islam, konsep meditasi boleh diterjemahkan dengan *Al-Muraqabah*, sebuah praktis untuk menyedari kewujudan Allah, dan salah satu cara untuk mencapainya adalah dengan membaca atau mendengar bacaan Al-Quran. Dalam kajian ini, 30 orang subjek yang sihat telah dipilih secara rawak, daripada dua kumpulan agama yang berbeza (15 Muslim dan 15 bukan Muslim). Dengan menggunakan teknik pengimejan *electroencephalography (EEG)* dan *magnetoencephalography (MEG)*, subjek diperdengarkan enam rangsangan audio yang berbeza. Ini termasuk tiga bacaan Al-Quran bermelodi yang berbeza, iaitu *Murattal Asim Hadr, Murattal Asim Tadwir* dan *Murattal Asim Tahqiq*, dua rangsangan audio bukan Al-Quran iaitu bacaan puisi bahasa Arab dan bacaan berita bahasa Arab, serta satu tanpa apa-apa rangsangan. Kesemua rangsangan audio diperdengarkan secara susunan rawak selama tiga minit setiap satu, dan satu minit selang di antara rangsangan tersebut. Beberapa ciri akustik yang relevan telah diekstrak dan dianalisis daripada setiap rangsangan audio

menggunakan perisian *Praat*. Daripada analisis durasi sukukata, didapati bacaan Al-Quran mengandungi ritma yang tidak sekata, tidak seperti yang didapati dalam pusi Arab. Namun, kesemua gaya bacaan Al-Quran dan puisi Arab menunjukkan tenaga yang tinggi dan nada yang turun naik secara berterusan, berbanding rangsangan berita Arab yang memiliki kedua-dua ciri tersebut yang tidak stabil. Isyarat otak yang direkod kemudiannya dianalisis menggunakan perisian analisis otak dari sumber terbuka iaitu *Brainstorm*. Sumber aktiviti gelombang gamma dikenalpasti daripada beberapa bahagian otak yang terpilih. Ketika diperdengarkan dengan rangsangan audio, didapati aktiviti gamma dikesan di lebih banyak bahagian otak termasuk di bahagian *prefrontal cortex (PFC)* dan *parietal*, yang menunjukkan hubungkait dengan daya tumpu dan fungsi memori. Seterusnya, magnitud perubahan aktiviti gamma ketika diperdengarkan rangsangan audio diukur dan dibanding beza berdasarkan ketika keadaan rehat. Terdapat beberapa bahagian dalam otak yang dikenalpasti menunjukan peningkatan aktiviti gamma semasa subjek mendengar bacaan Ayat Kursi, seperti di bahagian *PFC* bagi kedua-dua kumpulan agama, *anterior cingulate cortex (ACC)* dan *midcingulate cortex (MCC)* bagi kumpulan Muslim dan *posterior cingulate cortex (PCC)* bagi kumpulan bukan Muslim. Berdasarkan analisis statistik menggunakan teknik *ANOVA* campuran, tiada interaksi yang signifikan didapati antara perbezaan kumpulan agama dan perbezaan rangsangan audio. Pun begitu, daripada hasil pengimejan *EEG*, aktiviti gamma didapati lebih tinggi secara signifikan di kalangan kumpulan Muslim berbanding kumpulan bukan Muslim bagi kesemua rangsangan audio. Data pengimejan daripada *MEG* pula menunjukkan terdapat beberapa bahagian otak yang mempunyai aktiviti gamma yang signifikan ketika diperdengarkan rangsangan yang berbeza termasuk bahagian *ACC, PFC, amygdala, hippocampus, parahippocampal* dan *parietal*. Sebagai kesimpulan, ciri-ciri akustik

yang terdapat pada bacaan Al-Quran beritma memiliki persamaan dengan ciri-ciri yang terdapat pada muzik atau nyanyian, di mana dengan mendengar bacaan Al-Quran akan memberi kesan kepada aktivit gelombang gamma di dalam otak, yang mungkin mempunyai hubungkait dengan fungsi daya tumpu, memori dan emosi.

EXPLORING GAMMA BRAINWAVE OSCILLATIONS DURING PASSIVE LISTENING TO MELODIOUS RECITATION OF *AYATUL KURSI* USING SIMULTANEOUS EEG AND MEG RECORDING TECHNIQUE

ABSTRACT

Studies on the effects of Quranic have been focusing on low frequency brainwaves i.e. theta and alpha, the neural candidates indicating calmness and relaxation effects induced from listening to Quranic recitations. The present study examined the high frequency i.e. gamma brainwaves (30-80 Hz), previously unexplored in Quranic recitation studies. Gamma waves have been postulated to play important roles in high cognitive functions such as attention and working memory. Recent studies on non-Islamic approach of meditation had shown an increment of gamma activities among expert meditators, thus higher attention stimulated compared to the novices. In Islam, the concept of meditation can be best explained by *Al-Muraqabah*, a practice to be self-aware of Allah's existence which is linked to the act of reciting and listening to Quranic recitations. In the present study, 30 healthy participants from dual faith groups (n Muslim = 15, n non-Muslim = 15) were randomly recruited. By using electroencephalography (EEG) and magnetoencephalography (MEG) techniques, participants were subjected to passive listening of six different auditory stimuli. The stimuli were three different Quranic recitation styles *(Murattal Asim Hadr, Murattal Asim Tadwir and Murattal Asim Tahqiq)*, two non-Quranic (Arabic poem and Arabic news), and one without any stimulus (i.e. resting state). All stimuli were presented randomly for three minutes each and a minute gap in between. Acoustic features of the auditory stimuli including rhythm, stress and pitch were analyzed with Praat software. From the duration analysis of syllables, it was shown that Quranic recitations contained irregular rhythmic structure unlike Arabic poem which had regular rhythm. All Quranic recitations and Arabic poem also contained high intensity and rise-fall

pitch pattern from the spectrogram and pitch contour analysis, opposite to Arabic news which had both but with rapid fluctuations. Next, the recorded raw EEG-MEG signals from the brain responses were pre-processed and analyzed using Brainstorm software. Volume sources of gamma wave oscillations were estimated from the selected regions of interest (ROIs). In the presence of auditory stimuli, compared to resting state, wider distributions of gamma activities were observed such as prefrontal cortex (PFC) and parietal areas for both groups that could reflect higher attention, as well as memory process. The magnitude of gamma oscillations from resting state was measured to observe pattern of gamma fluctuations during the presentation of auditory stimuli. Several deep brain ROIs demonstrated higher gamma activities from listening to rhythmic recitations of *Ayatul Kursi*, depicting that emotion maybe involved. The areas included PFC for both groups, anterior cingulate cortex (ACC) and midcingulate cortex (MCC) for Muslim group and posterior cingulate cortex (PCC) for non-Muslim group. From mix ANOVA analysis, there were no statistically significant interactions found between independent variables i.e. different religious groups and different auditory stimuli on relative gamma power. However, from EEG recordings, significantly higher relative gamma power was recorded in Muslim group than non-Muslim group for all auditory stimuli. Meanwhile, data from MEG recordings revealed significant effects of different auditory stimuli on relative gamma power within several ROIs, including ACC, PFC, amygdala, hippocampus, parahippocampal and parietal lobe. To conclude, the acoustic features of rhythmic recitations of Al-Quran made them comparable with the characteristics of music or singing, in which listening to the rhythmic recitations affect gamma activities in regions related to attention, memory and emotion.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

According to World Health Organization (WHO), more than 450 million people worldwide suffer from mental illnesses. Mental, psychiatric and substance-abuse diseases accounted for 13% of the global disease burden. One out of every four people will experience mental illness at some point in their lives (World Health Organization, 2001). In 2015, the National Health and Morbidity Survey (NHMS) conducted by the Ministry of Health (MOH) found that 29.2 percent of Malaysians aged 16 and above had mental health issues (Ministry of Health Malaysia, 2016). It was estimated that issues pertaining to mental health has become the second most common health problem, after heart disease, for Malaysians in 2020. Indeed, the concurrent Covid-19 pandemic at present is expected to cause an upsurge of issues related to mental illness among Malaysians (Shanmugam, Juhari and Nair, 2020), and the need for psychological and mental health support is paramount, including for psychospiritual therapy such as meditation.

Meditation is a mentation practice which has received rising attention because it is linked to improvements in mental health (Cloninger, 2007; Yang, Su and Huang, 2009; Schneider *et al.*, 2012; Kasala *et al.*, 2014; Behan, 2020), being promoted as part of treatment in psychotherapy (Weiss, Nordlie and Siegel, 2005; Allen, Chambers and Wendy, 2006). Besides, meditation had also been shown in some studies to be effective in reducing stress and improving overall well-being, with some argued that it can be beneficial in the treatment of anxiety, addiction, aggression, suicidality and

depression (Walton and Levitsky, 2003; Birnbaum and Birnbaum, 2004; Hofmann *et al.*, 2010; Priddy *et al.*, 2018; Lopez-Maya, Olmstead and Irwin, 2019).

Meditation is practised by maintaining attention on the present moment and avoiding distractions like self-referential thought and mind wandering (Bishop, 2004). From neuroscientific perspective, the meditative state is linked to lower activity in a network of brain regions involved in self-referential processing known as the default mode network (DMN) in expert meditators over the novices (Brewer *et al.*, 2011). Consistent findings have shown that DMN activity appears to be reduced across various meditation techniques and multiple neuroimaging studies of meditation, involving either concentrated attention or the repetition of sentences, based on a recent meta-analysis (Tomasino *et al.*, 2013). On the other hand, DMN has been reported to be activated when people are left alone to think or when they perform tasks that include self-related processing, and less active when they execute tasks that require cognitive effort (Raichle *et al.*, 2001; Buckner, Andrews-Hanna and Schacter, 2008).

Music is a compelling sensory stimulus which contributes to physiological, psychological and social positive effects (Hodges, 1996; Davis, Gfeller and Thaut, 2008; Wheeler, 2015). For instance, when music is used in a clinical setting in a purposeful and systemic manner, it is said to help children with special needs grow more quickly (Robb, 2003). Music interventions have also been found to result in a positive effect on attention in certain studies. Attention is a necessary skill for good cognitive functioning, and it plays a crucial role in cognitive, social, and communication development (Muris, 2006; Cornish and Wilding, 2010; Janzen and Thaut, 2018). It has been suggested that musical elements such as rhythm, melody, and harmony include therapeutic factors that improve attention skills; for example,

rhythmic patterns drive attention focus, and musical elements such as rhythm, melody and harmony provide multidimensional stimuli that promote switching attention (Thaut and Gardiner, 2014). The emphasis and organization of human attention flow may be influenced by individual perception of rhythmic, melodic, harmonic and dynamic patterns in music or sound (Thaut, Thaut and LaGasse, 2008).

In Islam, meditation is defined as the growth of body, heart and mind presence in prayer and religious reflection. Muslims supposed to focus on Allah during prayers and supplications by reciting verses from Al-Qur'an and *dhikr* (remembering Allah). Despite all of life's distractions and turbulences, that act of meditation by performing prayers assists a person to be guided to the truth and maintain internal peace. The prayers serve as a daily remembrance of Allah, as well as awakened meditation and worship, even though the person is engaged with essential works. Apart from daily prayers and supplications, Muslims are also recommended to recite and listen to Al-Quran to attain calmness. Al-Quran is unique, unlike other religious scriptures whose sources are unknown and whose translations and interpretations are uncertain. Allah asserted in Surah Az-Zumar, verse 23 that: "Allah has unveiled the best of revelations, a book that is self-contained and repeats its teachings in different ways. The skins of those who fear their Lord shiver at the sight, but their skins and hearts soften as they join in the praise of Allah festivities."

There has been a growing body of literature on the therapeutic effects of reciting and listening Quranic recitations on general well-being (Abdullah and Omar, 2014). Quranic recitations incited relaxation due to the fact that Al-Quran has special effects on the human heart (Shekha, Hassan and Othman, 2013). The harmonic tone of Quranic recitation is regarded as a type of spiritual music (Khatoni, 1997) which

consists of audio wave of a specific frequency and wavelength. Allah said "And what we sent from the Quran is healing and mercy for believers" (Al-Israa:82). Previous studies demonstrated that listening to the rhythmic recitations of Quranic verses induced low frequency brainwaves such as theta and alpha, which helped people to feel calm and at ease (Kamal, Mahmood and Zakaria, 2013; Shab *et al.*, 2018). *Murottal* (from the root word *tarteel*) is a method of reading the Quran at a moderate pace (i.e. neither too fast nor too slow). The treatment of reading the Quran at a slow and soothing pace which reduce feeling of fear, anxiety or tension (Fitri Hamidiyanti and Pratiwi, 2019).

Gamma oscillations are rhythmic electrical fluctuations observed in local field potentials that occur at frequencies ranging from 30 to 80 Hz (Colgin *et al.*, 2009; Jia and Kohn, 2011; Colgin, 2016; Ren *et al.*, 2019). The presence of gamma activities was reported to be observed in many parts of the brain, including hippocampus, where they were believed to play important role in attentional selection and memory (Colgin and Moser, 2010). Studies on meditation practice have shown quick gamma activities in bilateral hemispheres with peak frequencies around 40 Hz, which were only seen in highly advanced meditators (Fell, Axmacher and Haupt, 2010). In a more recent study, advanced practitioners from various meditation techniques have shown increased gamma activities too, that was hypothesized to induce neuroplasticity through technique repetitions (Braboszcz *et al.*, 2017).

1.2 Problem statement and gap in knowledge

Al-Quran is regarded as a *mu'jizat* revealed to Prophet Muhammad (PBUH) from Allah via the archangel *Jibril*. For Muslims, the holy book contains the words of

Allah constituting every corner of human's life and acts as a guidance detailing how to become pious and faithful servants. Apart from the meaning behind every word or verse of Al-Quran, it is also believed that the rhythmic recitations of Al-Quran comprise of unique and distinctive acoustic characteristics over other human-made Arabic texts which make the holy book outstanding and incomparable. Previous studies discussing on the acoustic features of Al-Quran have covered mostly the physical and temporal features of Quranic verses. The present study has applied different approach in explaining the acoustic features of Al-Quran, where prosodic features, instead of physical and temporal, have been explored. The commonly reported features of prosody for a rhythm are typically represented by duration, intonation (pitch) and energy (intensity). Appreciating the existence of these acoustic features in Quranic recitations offer us better understanding of their relationships with the underlying neuronal correlates.

Although there have been numerous well-established studies on the therapeutic effects of Quranic recitations psychologically and physiologically, the majority have focused on the calmness and relaxation effects obtained from the recitation. These were commonly reported in relation to low frequency range of brainwaves, namely delta (1-4 Hz), theta (4-8 Hz) and alpha (8-13 Hz) from functional neuroimaging studies. To the best of our knowledge, no previous Quranic recitation studies had explored its rhythmic melody and the oscillations of higher brainwave frequency particularly gamma, despite its established roles in cognition. Many cognitive studies have postulated that gamma played an important role during demanding mental processes such as memory encoding and retrieval, decision making, arithmetic, as well as attention. Recently, studies on non-Islamic meditation found that gamma activities were highly activated during meditation, with expert meditators depicted stronger

oscillations than the novices. Hence, the present study was the first to explore and examine the activities of gamma brainwaves during melodious Quranic recitations.

Previous studies examining the effects of Quranic recitations on the electrical brain response have also applied a single modality of either structural or functional imaging technique. Each technique has its own advantages and disadvantages in recording the brain responses, where most of the studies had applied electroencephalography (EEG) to capture the neuronal responses because, apart from its non-invasiveness and cheaper cost than other techniques, EEG offers an excellent temporal resolution. However, the data recorded by EEG can easily be distorted by head tissues such as skull and scalp, and non-neural bio-signal artefacts including eye movements and heart beats. To tackle the issue with signal distortions, the present study employed EEG simultaneously coupled with another functional imaging technique, magnetoencephalography (MEG). Because of MEG's capability in capturing the magnetic field from the same neurophysiological processes as EEG but with less distortions, combining EEG with MEG technique resulted in more accurate and enhanced neural correlate findings.

1.3 Research questions

The present study investigated the brain responses towards Quranic recitations with different recitation styles and the recitations of non-Quranic stimuli. Several main prosodic features of each stimulus were explored to find the acoustic differences which made one recitation different from the other. Neuronal activities in the form of brainwaves were recorded, with gamma waves were chosen as the frequency band of interest. Several brain regions of interest (ROI) were finalized to localize gamma

activities, in terms of source estimations, as well as the relative power of gamma. Hence, the research questions outlined for the present study are as follow:

1. Are there any differences in acoustic features of prosody between different recitations styles of Al-Quran and non-Quranic recitations?
2. How do the different Quranic and non-Quranic stimuli affect the oscillations of the brain gamma brainwave?
3. Which brain ROI show significant gamma activities during passive listening to auditory stimuli?
4. Is there any relationship between faith (Muslims and non-Muslims) and stimuli (Quranic and non-Quranic) differences on the gamma oscillatory activities from the passive listening?
5. Is there a significant interaction between faith (Muslims and non-Muslims) and stimuli (Quranic and non-Quranic) differences on the gamma oscillatory activities from the passive listening?

1.4 Research hypothesis

1. There are differences of prosodic features between styles of recitations of Quranic auditory stimuli.
2. There are differences of prosodic features between Quranic and non-Quranic auditory stimuli.
3. There are differences of gamma source estimations on the brain ROI during passive listening to rhythmic recitations of Quranic auditory stimuli between Muslim and non-Muslim groups.

4. There are differences of gamma source estimations on the brain ROI during passive listening between Quranic and non-Quranic auditory stimuli.
5. There are differences of magnitude gamma oscillations on the brain ROI from resting state during passive listening to rhythmic recitations of Quranic auditory stimuli between Muslim and non-Muslim groups.
6. There are differences of magnitude gamma oscillations on the brain ROI from resting state during passive listening between Quranic and non-Quranic auditory stimuli.
7. There are significant relationships between faith (Muslims and non-Muslims) and stimuli differences on the gamma oscillatory activities from the passive listening.
8. There are significant interactions between faith (Muslims and non-Muslims) and stimuli differences on the gamma oscillatory activities from the passive listening.

1.5 Research objectives

1.5.1 General objective

The present study aims to explore acoustic features of rhythmic recitations of Al-Quran and the oscillations of high frequency range of gamma brainwave activities during passive listening to Quranic recitations.

1.5.2 Specific objectives

1. To analyze the acoustic features of rhythmic recitations of Al-Quran and control stimuli (non-Quranic) by exploring their prosodic features using Praat audio software.

2. To identify gamma source estimations on the brain ROI during passive listening to rhythmic recitations of Al-Quran between Muslim and non-Muslim groups using 61-channels EEG recording.
3. To identify complementary gamma source estimations on the brain ROI during passive listening to rhythmic recitations of Al-Quran between Muslim and non-Muslim groups using 306-channels MEG recording.
4. To compare the magnitude of gamma oscillations on the brain ROI from resting state during passive listening to rhythmic recitations of Al-Quran between Muslim and non-Muslim groups using Brainstorm software.
5. To compare the magnitude of gamma oscillations on the brain ROI from resting state during passive listening to rhythmic recitations of Al-Quran between Quranic and non-Quranic auditory stimuli using Brainstorm software.
6. To determine significant effects of between-subject factors (different religions) and within-subjects factors (different stimuli) on the relative gamma power.
7. To determine significant interactions between between-subject factor and within-subject factor on the relative gamma power.

1.6 Significance of the study

The practice of meditation has been well studied using different neuroimaging techniques and found to enhance cognitive processes. In Islam, *Al-Muraqabah* has been proposed to be comparable with meditation practice, and one technique in achieving *Al-Muraqabah* is by reciting or listening to Al-Quran. Previous studies on listening to Quranic recitations have considered relaxation and calmness effects on the brain, proposing theta and alpha brainwaves as neural correlates. Recently, there has

been a growing body of knowledge on studies of meditation effects on the activation of gamma waves. To our best knowledge, there is no study on Quranic recitations which has deemed gamma as the neural correlate. Hence, this is the first Quranic study investigating gamma activities from passive listening to rhythmic recitations of the verses from Al-Quran. In addition, this study has also explored the acoustic features of rhythmic recitations of Al-Quran, which might have impacted the pattern of gamma activities during brain recording sessions.

1.7 Operational definition of the study keywords

Ayatul Kursi contains several verses extracted from among the last part of chapter Al-Baqarah of Al-Quran. As guided by Prophet Muhammad (PBUH), *Ayatul Kursi* is held with high regards for Muslims as a powerful verse in protecting themselves from the evils (i.e., from their surrounding and/or within themselves), in addition to having its own healing effects. Muslims are taught to recite Al-Quran, including *Ayatul Kursi*, with distinct, connected and melodious utterances/sounds. This beautification leads to the rhythmic aspect of Quranic recitations, which is guided by a set of recitation rules known as *tajweed.* Any Quranic verse including *Ayatul Kursi* can be recited through different tempos namely *hadr* (fast), *tadwir* (medium) and *tahqiq* (slow), depending on the situation and the need of the reciter that are frequently rituals-based in practice.

Acoustic features comprise of temporal and physical characteristics of a sound. Prosody or suprasegmental is one of them, which is known to be the most relevant feature to discuss for connected speech or sound such as that of Quranic recitations. The widely discussed features for prosody include rhythm, intensity, and pitch.

Rhythm heavily depends on the duration of vowels, hence syllables, which is measured in second or millisecond (s/ms). Intensity represents the amount of energy or stress within the voiced-unvoiced pattern of speech sound and is measured in decibel unit (dB). Pitch, or sometimes referred as fundamental frequency (F0), is intrinsic in the periodic signal and demonstrates the perceived pitch by human auditory, and measured in hertz (Hz) (Gibbon, 2017; Lunden, 2017).

Gamma brainwaves are neural oscillations that occur at the frequency range of 30-80 Hz (Buzsáki, 2006; Ren et al., 2019), with the smallest amplitude compared to other types of brainwaves. Gamma oscillations have also been linked to diverse cognitive functions, including a general neural correlate of human attention and content of consciousness. The high frequency of gamma resulted from the integration of electrical signals of neurons, like other type of brainwave bands, can be captured by using neuroimaging technique, namely electroencephalography (EEG). The corresponding magnetic fields resulted from these electrical activities can be measured by using magnetoencephalography (MEG).

Brain signal recording of EEG and MEG emerged from the same sources which are the synchronized postsynaptic currents in and around apical dendritic of pyramidal cells (Hämäläinen et al., 1993). EEG and MEG are known to have different sensitivities in recording the brain responses, in particular MEG is only sensitive to tangentially oriented sources, but EEG is able to capture sources from both tangential and radial sources (Hämäläinen et al., 1993; Baillet, 2017). Therefore, the combination of both techniques, simultaneous EEG-MEG recording, is expected to contribute to more accurate findings, in particular to determine the source of gamma activities during passive listening to Quranic recitations. By using a brain analysis software i.e.

Brainstorm, the sources of gamma activities will be estimated within the selected ROIs, and the magnitude of gamma oscillations will be measured during the presence of auditory stimuli against resting state.

1.8 Summary

There is a dearth of exploration and discussion on the gamma brainwaves from previous related works i.e., on neuroscientific Quranic studies, which form the solid foundation and motive for the present study. By aiming to fill the gap of discovering gamma patterns during passive listening to melodious Quranic recitations (using a specific Quranic verse, *Ayatul Kursi*), this could be accomplished by examining its activities using simultaneous EEG and MEG imaging techniques. The activities of gamma may prove to be linked to the acoustic features which could provide plausible basis in expanding the neural correlate that underlie the melodious Quranic recitations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Arabic language

Arabic language is ranked among the top six languages being practised globally, making it as one of the official languages of the United Nation (United Nations, 2015). The language has a vast literary heritage dating back to the pre-Islamic era (5th and 6th centuries). As of today, Arabic has becoming the native language of over 200 million people as well as the liturgical language for over 1.5 billion Muslims worldwide (Kouega and Baimada, 2012; Lipka, 2017).

Arabic language is classified into two different structures, namely Modern Standard Arabic (MSA) and Classical Arabic (CA) (Fischer, 1997; Habash, 2010). MSA is claimed to be used more widely today in comparison with CA particularly in Arabic countries because it is regarded as the formal Arabic language, which being operated in most formal settings such as news broadcasting, national events and record documentations. Meanwhile, CA which has always been associated with Quranic Arabic is commonly used in literary texts such as poem or rhythmic prose (Atwell, 2018). MSA is regarded by some as the re-birth of CA in 19th century when many translation works into Arabic texts took place, leading to the birth of new words adopted from non-Arabic languages. However, the categorization of MSA and CA is normally referred by the Western linguists, while the native Arabic speakers make no such differentiation.

2.1.1 Arabic language as a stress-time language

Researchers in linguistic argued that spoken language in the world can be classified into two distinct groups; stress-time and syllable-time language (Ling, Grabe and Nolan, 2000; Ramus, Nespor and Mehler, 2000), the two distinctive groups are believed to be introduced by Abercrombie back in 1967, as quoted by Jenner (2001). Stress-time language is where the syllables are pronounced in nearly regular interval, so the unstressed syllables, sometimes vowels, are commonly shortened to fit into the interval. The Arabic language falls into this stress-time category, besides English and Russian. Meanwhile, syllable-time language is constructed from a combination of similar timing of syllables, hence lacks reduced vowels. Examples of syllable-time language include French, Spanish and Cantonese.

According to Alghamdi (1998) and Deller, Hansen, & Proakis (2010), Arabic language is comprised of 36 phonemes including 6 vowels (3 short vowels and 3 long vowels) and 2 diphthongs (Newman, 2002; Kotby *et al.*, 2011). Vowel is articulated from free flow of air pressure originated from the lungs into and along the vocal tract, while consonant is produced when there are some obstructions along the vocal tract by the articulators such as vocal cord, tongue, teeth and lips restricting the free flow. On the other hand, diphthong is a combination of two different vowels in one syllable where the sound of the first vowel is immediately followed by the sound of the second vowel.

2.1.2 Phonetics of Arabic language

As mentioned previously, vowels in Arabic are uniquely articulated by two different time durations forming short and long vowels. According to Nicolaidis, Reetz, & Jongman (2003), in general, vowels are linguistic component which are

important because vowel duration can influence the pattern of formant frequencies. Formant frequencies, extracted from speech sound are employed to determine the vocal tract shaped by its filters, most importantly formant one (F1) and formant two (F2) for vowel type discriminations (Hillenbrand *et al.*, 1995). Vowel duration can be represented and measured by its physical properties in time domain by examining the sound waveform.

Every syllable in Arabic phonology contains at least one vowel and can appear either between consonants or at the end of a syllable. However, there are duration length differences resulted from the composition of vowel and consonant in a syllable. Vowel which is followed by a consonant phoneme is longer than the voiceless consonant, and vowel appears before stop consonant phoneme is shorter than vowel followed by fricative consonant (Almisreb, Abidin, & Tahir, 2016; Byrd & Kreiman, 2006). Thus, Arabic language contains different combination of vowel and consonant contributing to different durations, for examples consonant-vowel (CV), consonant-vowel-consonant (CVC) or consonant-vowel-consonant-consonant (CVCC). These are demonstrated in Table 2.1 and Table 2.3.

Table 2.1 Phonology of Arabic consonants.

Place and way of articulation	Types of consonant (phonetic symbol)							
	Plosive	Fricative	Affricate	Nasal	Lateral	Semi-vowel	Trill	Continuant
Bilabial -upper and lower lips close to each other	ب			م		و		
Labiodental -lower lip touches upper teeth		ف						
Interdental -tip of the tongue touches upper teeth		ذ ث						
Alveolar -the tongue touches between palate and upper teeth		ز س **ص ظ**		ن	ل		ر	
Dentialveolar -tip of the tongue touches ridge behind upper teeth	ت د **ض ط**							
Palatal -body of the tongue touches hard palate with small gap causing turbulence		ش	ج			ي		
Velar -body of the tongue touches soft palate	ك							
Uvular -back of the tongue and uvula	**ق**	**خ غ**						

Pharyngeal -back of the tongue and pharynx		ح						ع
Glottal -glottis narrowly opens to create turbulence	أ	ه						

Bold letters :-also known as emphasis *(isti'la)* letters, articulated with more stress

2.1.3 Place of articulation

In general, human voice is originated from the vibration of vocal cord. The air is released from the lungs before flowing into vocal tract via the cord with some restrictions from the vocal tract like the tongue and the lips causing multiple articulations sound different from one another (Docio-Fernandez and Garcia-Mateo, 2009). Each unique sound is placed at different position within human vocal tract as shown in Figure 2.1.

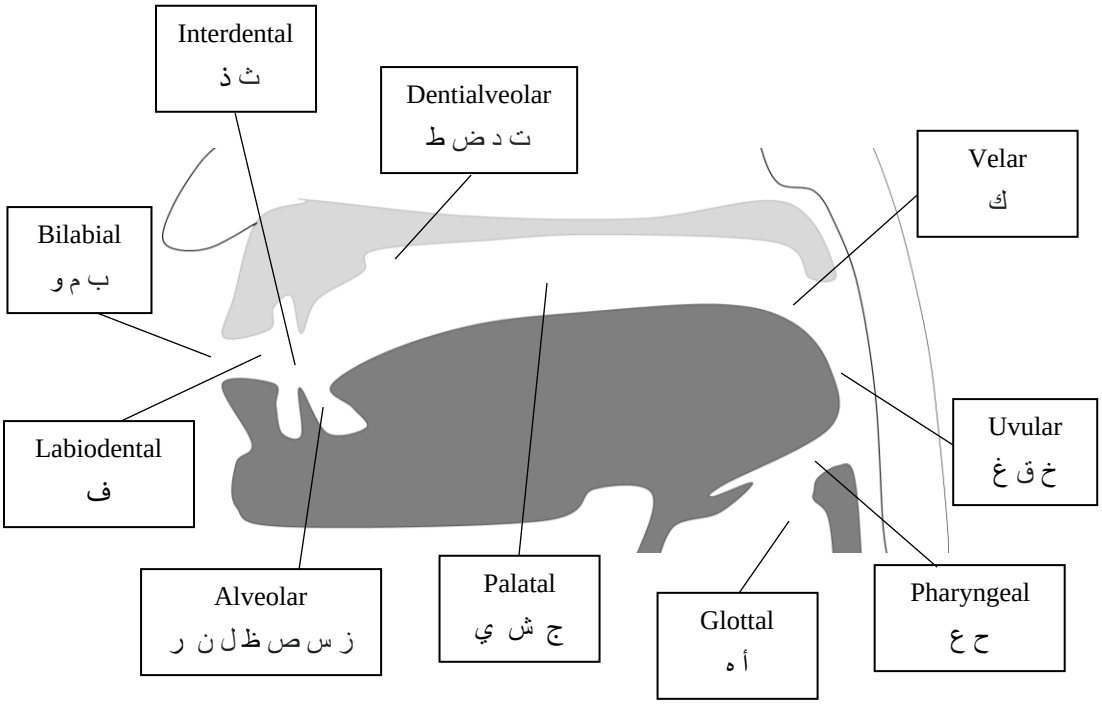

Figure 2.1 Place of articulation of Arabic letters.

2.1.4 Manner of articulation

Like many other languages, each Arabic letter is articulated at different place, with different combination of vocal tract components. The manner of Arabic letter articulations is demonstrated in Table 2.2.

Table 2.2 Manner of articulation of Arabic letters.

Type of consonant	Manner of articulation	Arabic letter
Plosive	Complete obstruction of airflow in the mouth letting air pressure to be built behind the obstruction before release.	أ ب ت د ض ط ك ق
Fricative	Narrowing vocal tract by few articulators creating narrow gap for air turbulence.	ث ح خ ذ ز س ش ص ظ غ ف ه
Affricate	Begin with complete obstruction followed by air friction when release.	ج
Lateral	Produced when air pressure passing along both or one side of the tongue.	ل
Semi-vowel	Front part of the tongue comes close to hard palate but to a lesser degree than fricative.	و ي
Trill	Articulator being held in its place and airflow causing it to vibrate.	ر
Continuant	Narrowing vocal tract but not enough to produce much turbulence in airstream.	ع
Nasal	Similar as plosive, but the air pressure is released via nasal instead of oral cavity.	م ن

2.1.5 Syllable and stress system

Rhythm of any language is associated with stress system on the syllable. Syllable structure constitutes components of phonological words division focusing on the pronounceable segments of words and how they are composed (Ryding, 2014). In Arabic, different level of stress is applied on different length of syllable composition, hence the stress is not placed in phoneme but the syllable itself (De Jong and Zawaydeh, 1999).

Syllable or word stress is also one of the key components in suprasegmental features, which means the stress occurs simultaneously as the pronunciation of a particular syllable, contributing to higher complexity (Ryding, 2014). There are six types of syllable structures commonly found in any Arabic texts or scripts grouped into light, heavy and super heavy syllables. The differences between theses syllables weight play an important role in Arabic, in particular with regard to stress placement. It is demonstrated in Table 2.3.

Table 2.3 Different syllable structure with different stress in Arabic.

Syllable stress category	Consonant	CV pattern	Phonemic transcription	Orthographical transcription
Light syllable	Consonant + short vowel	CV	*Ta*	ت
Heavy syllable	Consonant + vowel + vowel Consonant + short vowel + consonant	CVV CVC	*Maa* *Rab*	مأ رب
Super heavy syllable	Consonant + long vowel + consonant Consonant + short vowel + two consonants Consonant + long vowel + two consonants	CVVC CVCC CVVCC	*Zhiim* *Fasl* *Shaabb*	ظيم فصل شاب

According to Betti & Ulaiwi (2018), stress placement in Arabic is determined by syllable structure of the phonological words. Some key rules of stress placement in Arabic are;

i. If a word contains a sequence of multiple CV syllables, the primary stress is placed on the first CV, the rest of the CVs will carry weaker stress,
ii. If a word contains a long syllable, the primary stress is placed on this syllable, the rest will carry weaker stress,
iii. If a word contains two long syllables or more, the primary stress is placed on the syllable near the end of the word, the secondary stress is placed on the syllable near the beginning of the word (Betti and Ulaiwi, 2018).

The applications of syllable structure and stress system of Arabic language can be widely observed in both MSA and CA, this includes the Islamic holy book revealed to the Prophet Muhammad (PBUH) in full Arabic language i.e. Al-Quran.

2.2 The language of Al-Quran

Liddicoat (2012) emphasizes the importance of language in religion by highlighting its role in religious communication and how believers engage in it. The complex relationship between language and religion can be observed from Islam and the Arabic language, Judaism and the Hebrew language, as well as Hinduism and the Sanskrit language. Al-Quran is the main reference in which Muslims refer to in adhering to the Islamic principles. The original text of Al-Quran was disclosed in the Arabic language and it has remained unchanged since its first revelation. Al-Quran is regarded by Arabs as the first text to reflect and preserve the Arabic language

(Alhirtani, 2018; Al Shlowiy, 2019). The content of Al-Quran addresses three major aspects of Muslims' life including faith, law and morality (Abou El Fadl, 2017; Rahman *et al.*, 2017). Many non-Arab Muslims had to learn Arabic language in order to read and/or to understand Al-Quran in order to embrace the Islamic teaching in their daily lives (Hewer, 2006).

2.2.1 Al-Quran as The Holy Book

Al-Quran is regarded as the holy book for Muslims, its purpose of revelation acts as the principal guidance in delivering words and commandments from Allah. The contents of Al-Quran are not only limited pertaining to religious issues but are also believed to contain all matters concerning every corner of human life. Additionally, some of Quranic verses are considered to exhibit positive therapeutic effects, therefore being applied in alternative treatment including in clinical settings (Allameh *et al.*, 2013; Ramly *et al.*, 2018; Elcokany and Abd El Wareth, 2019). It has been mentioned in Al-Quran:

يَا أَيُّهَا النَّاسُ قَدْ جَاءتْكُم مَّوْعِظَةٌ مِّن رَّبِّكُمْ وَشِفَاء
لِّمَا فِي الصُّدُورِ وَهُدًى وَرَحْمَةٌ لِّلْمُؤْمِنِينَ

Figure 2.2 *Surah Yunus* (10:57) – O mankind, there has come to you an instruction (Al-Quran) from your Lord and healing for what is in the breasts and guidance and mercy for the believers.

Muslims are encouraged to read Al-Quran on daily basis because it is considered as one way to get rewarded and recorded as good deed by Allah. In fact, some Quranic verses such as chapter *Al-Fatihah* (the first chapter in Al-Quran) is compulsory to be memorized and recited in its original Arabic form during the daily

obligatory prayers, regardless of the nationality/ethnicity/racial background of a Muslim. Because of the supremacy of Allah's words, Muslims believe that Al-Quran was revealed as a *mu'jizat* to the Prophet, not just because of the richness of its contents, but Al-Quran is also believed to soften the stubborn hearts. During the times of Prophet Muhammad (PBUH), there had been several incidents where the non-believers accepted Islam just by listening to few verses recited from Al-Quran. Umar Al-Khattab is one of many popular stories among them, accepted Islam after listening to first five verses from chapter *Taha* recited by his own sister.

2.2.2 Rhythmic recitation of Al-Quran

According to Islamic scholars, Al-Quran was revealed in parts in Arabic language throughout the Prophet Muhammad's (PBUH) prophethood. Allah said:

كَذَٰلِكَ لِنُثَبِّتَ بِهِ فُؤَادَكَ

Figure 2.3 *Surah Al-Furqan* (25:32) – We have sent it as such in stages so We may reassure your heart with it.

During the prophethood, the Quranic verses have been revealed and taught to the Prophet by archangel *Jibreel*. It has been passed down to the Prophet's companions via the medium of recitation. However, the recitation styles were not unified among the Prophet's companions due to different *ahruf* (recitation styles) being taught by the Prophet for different companions, considering their different backgrounds (Khatib and Khan, 2019). Therefore, Al-Quran can be learned and recited through various ways, but one must strictly comply to certain recitation rules known as *tajweed*, to avoid any mistake in pronouncing words or syllables, hence, to preserve its meaning.

The wordings of the holy book are organized in a systematic order such that even with the absence of musical instruments, Quranic recitation still has its own unique rhythm, melody and pleasant tone to listen to (Nayef and Wahab, 2018). According to Mustapha *et al.* (2016), the pleasure feeling (i.e. 'Quranic chills') experienced by Muslims from listening to melodious Quranic recitations could regard the holy book as a meditative Islamic scripture, and the experience in some ways is similar with the concept of 'musical chills' resulted from listening to music (Rasha, 2003). Rhythmic recitations of Al-Quran contains the attractive values and eloquence of poetry, as well as the elegance observed in rhymed prose though not depending too much on rhyme or rhythm, which are commonly found in singing or poetry (Dayyani, 2008). Being in harmony with the meaning, Quranic rhythm and the tune of its words also create an ambience of purity, passion and enthusiasm and lure into the human soul that helps to intoxicate it. The beauty that lies within the Quranic recitation touches the heart of whoever listen to it, including non-Arab speakers. The correct pronunciation of each character and word is believed to be the essential element of Quranic recitation, and the climax is achieved when it is recited in a sombre ambience. This is also complemented by applying specific tone and intonation along with precise high-low pitches and the arrangement of punctuations and pauses, which the combination of all these elements embellishes the recitation, affecting how the listeners perceive it. Abu Hurairah reported:

> I heard the Messenger of Allah (PBUH) saying, "Allah does not listen so attentively to anything as He listens to the recitation of the Quran by a prophet who recites well with a melodious and audible voice." (Sunnah.com, no date as cited in Sahih al-Bukhari, Hadith 7544)