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RESEARCH ARTICLE

Psychospiritual Healing from al-Quran: Internal Aesthetic Factor of Quranic Sound and Its Effects in Activating Greater Brain Regions

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Abstract Spiritual healing and Quranic sound therapy has long accompanied human tradition since decades. Quranic sound is perceived as rhythmical cues that portrays psychospiritual effects although it was not recited with external melodic intonation (tarannum). Its internal rhythms were believed to activate and synchronize its listeners' brain rhythms hence modulating their brainwaves to give the psychospiritual effect. However, there is lack of scientific investigation that elucidates source of Quranic linguistic rhythms which contributes to the greater neural activation in the Quran's listeners. This study aimed to evaluate a Quranic linguistic feature that contributes to high rhythmicity, and high energy that activates its listeners neural ensembles. As a result, Electroencephalography (EEG)'s electrode correlation will be presented as a predictive measure for neural connectivity compared with Arabic News listening. Fatihah Chapter recitation (tajweed without human speech. Spectrogram analysis was performed by using Praat: Doing Phonetics by Computer (PRAAT) software. The continuous brain electrical charges from twenty-eight normal subjects (14 male:14 female) with inclusion criteria of habitual daily Quran listeners were recorded by 128-channel EEG. These brain electrical data were pre-processed and analysed by Fast Fourier Transform (FFT) followed by multivariate analysis. Discriminant Analysis results which compare the mean values of the groups were followed by Multiple Linear Regression. From spectrogram analysis, we found that Fatihah Chapter sound is more rhythmic compared to Arabic news and brings higher energy. The correlation spectral power between EEG electrodes showed three types of relationship: short, long, and inversely correlated, indicating communication flow among brain regions. Comparatively, larger-scale integration of neural ensembles from the fronto-temporo-parieto-occipital areas was observed while listening to Quranic Fatihah Chapter recitation than the fronto-temporo-parieto regions from Arabic News listening, indicated of higher synchronisation and integration in neuronal communication during Quranic listening. We found that listening to the Quranic sound may induce neural activation and reorganisation in the global brain regions involving the frontal, temporal, parietal, motor and occipital areas. Dynamic brain network interaction is postulated in a desynchronised pattern, essential for normal brain functioning, reduced pathological tendencies, and emotion-health-cognition stability, offering psychospiritual effects.

Keywords: Brainwaves, neuroimaging, psychoacoustic, psychospiritual, signal processing, spectrogram and sound stimulation.

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Introduction

As one of the mind-body and soul therapy, Quranic listening has commonly used as psychospiritual therapy. Its sound harmonizes humans' soul and mental thus gives psychospiritual effects by improving emotional and physical well-being, relaxing, helping them in coping with disease, strengthening their immune system, increasing vitality, decreasing pain and stress, treating diseases, accelerating the healing process, increasing the duration of life, improving sleep quality, reducing side effects associated with treatment, and making them self-sufficient (Gul *et al*., 2014). Rhythmic sound can elicit behavioural effects in listeners. These elicited changes are induced through the physical characteristics of the sound such as loudness, dissonant, tempo, timbre that can evoke memory retrieval, crescendo that leads to specific modulation of cardiovascular activity (Kreutz, Murcia & Bongard, 2012) and consonance that could be associated with activation in paralimbic and cortical brain areas (Schaefer, 2017). This is why psychoacoustic medicine had been used in long history of healing. Psychoacoustic medicine was defined as the science of how music and sound can impact the nervous system psychologically and physiologically. It comprises of practices using sound and frequencies to impact the physical and emotional health of the body which covers from Gregorian chants in churches, the chanting of Tibetan monks, Native American drumming, Quranic healing, and any rhythmic sound which believed to have a catalyst in stimulating health and healing for the body and mind in all cultures. Simply, it is about how the vibration of sound impacts the mind and body psychologically and physiologically (David, 2017).

In Muslim community, Quranic sound is being used as a therapy for its curing nature as mentioned in the Chapter Al-Isra' verse 82 as, "And We reveal the Quran which is a cure". Besides of the meaning of verses which bring people to the connectedness to the God hence provides serenity and tranquillity, it was found that its rhythmic sound itself also contributing. Sound has its rhythms, as well as our brain, also has its rhythms. These two rhythms can interact and influence each other. The interaction between those rhythms is through the interaction of the physical elements of those rhythms like amplitude and frequency. Hence, the interaction produces synchronization where it impacts the human. Normally, when people are talking about the rhythms of Quranic sound, many believes that the rhythms are coming from its melodic performative mode, Tarannum, which makes its sound beautiful and melodious (Nelson, 2001). Tartil, on the other hand, is in its original sense, is distinct articulated verses, denoted with clear enunciation. Tartil means that the Quranic verses is recited in slow measured rhythmic tones, and the tone is coming from its internal factor, not from external factor of tarannum. Tartil is also means 'making the consonants and vowels clear, like the mouth with well-shaped teeth'. Furthermore, tajweed is an integral component of tartil. Tajweed is a discipline in reciting the Holy Quran. It is an obligatory to Muslim while reciting the Holy Quran which gives quality beauty cadence to the sound. It highlights the importance of enunciating each phoneme from point of articulation, and rules and processes governed include assimilation, nasality, extra-long vowel, pharyngealization, vowel epenthesis, pauses, and certain sense of rhythm (Quotah, 1995).

From linguistic study, the Holy Quran itself is rhythmic due to its internal factors. As proposed by Akbar (2009), there are three levels of aesthetic factors of the Holy Quran. They are firstly, text structure includes the composition and onomatopoeia, poetic and positional arrangement, end rhymes, codas, and refrains; secondly, aesthetic cadence that resulted from the tajweed system, and third; involvement of the Arabic musical tradition in beautifying the Quranic recitation by acting of cantillation techniques. The verses were recited the first factor is also known as internal factor while the second and third factors are the external factor contribute to aesthetic sound of the Quranic verses recitation. Hence, reciting the Holy Quran with slow measured rhythmic tones, or tartil, produces rhythms and can later interact with human brain's rhythms. The explanation was presented in the chart below:

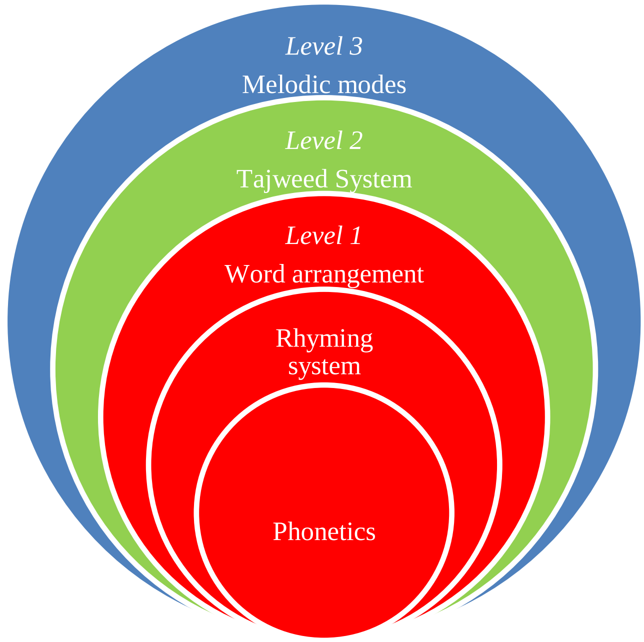


Figure 1. Internal and external factors that contribute to aesthetic and rhythmic Quranic sound (Akbar, 2009)

During rhythmic sound stimulation, brain regions function in concert rather than in independent manner (Weisz *et al*. 2011). These brain processing involve extensive brain network interconnections that encode, retain, retrieve, imitate, and reproduce rhythms. For instance, perceiving rhythms is associated with extended brain regions from the frontal, motor and cerebellar areas (Edagawa and Kawasaki 2017). The association between brain function and location during acoustic stimulation have also been well-established. For example, the prefrontal and tactile regions, the premotor areas, and the sound areas were mainly involved in processing time and tempo, rhythmic patterns, and acoustic beats respectively (Merchant *et al*. 2015). Furthermore, the prefrontal-parietal-cerebellar neural circuits play an essential role in rhythm encoding memory (Konoike *et al*. 2012). However, lack of study performed on processing the sound stimulus from Quranic recitation.

Listening to rhythmic sound may entails local and/or distant neural networks and affect different EEG frequency bands (Bhattacharya and Petsche, 2005) such as changes in the frontal/temporal region in the alpha (Samhani *et al*., 2018), occipital lobe in beta (Ismail *et al*., 2022, Samhani *et al*., 2022) and the right parietal region in gamma (Balconi & Lucchiari, 2008). Beta rhythms are always dominant in adults' wakefulness, in addition to being a sign of conscious thought and behaviour, alertness, and a focused mind. Different EEG electrode locations produce different time-varying signals. The exact positioning of electrodes can be assessed using linear or nonlinear measurements, and the correlation between these signals is thought to give essential information (Bhavsar *et al*. 2018). A link between EEG signals and distances from different areas of the brain has been demonstrated by a few researchers. The strong correlation between the signals from different electrodes indicated that the brain activity at multiple measurement sites was similar, while the low correlation indicated that the brain activity in different measurement sites was relatively independent. Short inter-electrode distances, on the other hand, showed more information flow than long distances, which provides the foundation for neuronal connection across regions and highly interconnected cortical networks, which allow quick communication between spatially diverse brain regions (Thatcher *et al*, 2016). Only neuronal groups in separate brain regions that oscillate in lockstep can connect effectively, sustaining cognitive flexibility (Fries, 2005).

The 10-20 system is the most often used approach for describing electrodes placement. Its value refers to the distance between adjacent electrodes, which is either 10% or 20% of the total front-to-back or right-to-left distance over the skull, as measured from the Nasion, a point between the forehead and nose, to the Inion, the lowest point of the skull from the back of the head indicated by a prominent bump, or right and left as measured from the left and right preauricular ear points. As a result, distance information may have an impact on the correlation between electrodes and other neurons or other processing contexts. Correlation is a statistical term that describes the strength of a link on a scale of -1 to +1. A positive correlation denotes a strong link in which an increase in one variable leads to an increase in the value of the other. The negative correlation, on the other hand, suggests that an increase in the first variable corresponds to a reduction in the second. There is no connection between the two variables if the correlation is 0. A mathematical approach to identifying the relationship between the independent variable (predictor) and the dependent variables is regression analysis. To forecast the value of the output or dependent variable, it is written as a regression model (Juahir *et al*., 2004).

Multivariate correlation analysis is useful for evaluating correlation across brain regions, which can be viewed as a neural network signature. Regression analysis was used to look at the correlation of brain regions from a statistical standpoint. The magnitude denotes the amount of phase coupling, whereas the correlation reflects the phase interrelation (Lang *et al*., 2012) . The correlation strength is represented by this magnitude value. As a response to seeing the rhythmic structure of the Fatihah, the direction shows the flow of information throughout the linked network for the association between the right temporal and other brain areas. Acoustic stimulus for the chapter. Correlation functions are connected to the Fourier Transform and are identical to spectral functions in the time domain. They describe the relationship between signals with different levels of time delay in the same frequency of brainwaves (Huang *et al*., 2020). Inter-channel correlation investigations, for example, revealed that certain disorders caused specific anomalies in correlations, according to Stein and colleagues (Cannon *et al*., 2014). Because spindling is not necessarily simultaneous or of the same pattern across channels, signal correlation is required. Its functional relevance could be explained by the delicate inter-channels that present diverse activities.

Our hypothesis is that the Fatihah Chapter is more rhythmic which resonates and activates greater neural ensemble for cognition advancement compared to non-Quranic sound from the same Arabic language. This study aimed to uncover a linguistic feature from Fatihah Chapter sound that contributes to high rhythmicity. We also aimed to compare the EEG's electrode correlation during listening to Fatihah Chapter and Arabic News as a predictive measure for neural connectivity for the impact of synchronization.

Materials and Methods

Sound Selection

Fatihah Chapter was chosen as Quranic sound stimuli due to its commonness. It represents Classical Arabic and is a very common Quranic Chapter which is used in everyday life of Muslim in their prayers, and this is the first chapter in the Holy Quran. The Fatihah Chapter audio stimulus was downloaded as a dot wave (.wav) file from the Internet open source. The sonic stimulus for the Fatihah Chapter in this experiment is a recitation by Sheikh Abdul Basit bin Abdul Samad, a renowned Egyptian Qari. This Fatihah Chapter was recited with tajweed without tarannum since the musical intonation not only comes from the external factor like melodic mode but from its recitation system (tajweed), phonetic characters, rhymes and letters composition.

Arabic News was chosen as positive control representing Modern Standard Arabic. Since Quran is a God's speech, Arabic News is then a human's speech that having same linguistic features. Due to the same language, they are from which is Arabic language, they share the same phonological characters and some other basic linguistic elements.

Spectrogram Analysis of Fatihah Chapter and Arabic News

The linguistic rhythms were investigated through acoustic phonetic analysis which focusing on spectrogram. PRAAT, a freeware program for analysis and reconstruction of acoustic speech signals was employed. This software was downloaded from the website of http://www.fon.hum.uva.nl/praat/. PRAAT is a flexible tool to do speech analysis that offered a wide range of standard and non-standard procedures including spectrographic analysis, articulatory synthesis and neural networks. Spectrogram is a visual illustration to represent the frequency component in speech signals. It is one of the application of Fourier transform (Altalmas, Ahmad, Sediono, & Hassan, 2015). Spectrogram represents three essential dimensions in acoustics: time, frequency and intensity. Time is represented along the horizontal axis, allowing the spectrogram to be read from left to right. Frequency is scaled along the vertical axis, and increased frequency is showed by marking in upward direction. Intensity is represented by the grey scale or as a variation in the darkness. The darker the spectrogram, the more energy concentrated in the speech. In the spectrogram, a voice bar is seen at the very bottom of the spectrogram reflects the energy of the fundamental frequency of voicing. Temporally we can see how energy concentration changes with time.

Participants Selection

Participants were selected among Malay Muslims: 28 healthy normal adults (14 males:14 females) who routinely performing prayer. They might understand or not understand the Fatihah Chapter. We are not aiming to evaluate up to their understanding of the verses from the Fatihah Chapter but to the rhythm interaction between the acoustic from the Fatihah Chapter recitation with their brainwaves rhythms. This is due to the knowledge that brainwave rhythms can interact with the Quranic acoustic rhythms where the interaction will synchronise and modify the brain rhythms, known as the brainwave entrainment process. The mean age of participants was 31.12 years, with a range of 20.3 to 50 years (Table 1).

Table 1. Participant demographic data

Variable	Category	Frequency
Race	Malay	28
Gender	Male	14
	Female	14
Age (in years)	20-29	18
	30-39	4
	40-49	5
	50-59	1
Handedness	Right	26
	Left	2

Brainwaves Recording

The scalp electrical activity generated by brain areas was read using EEG, a non-invasive medical imaging technology. Local current flows are formed when brain cells are stimulated, according to the theory because the apical dendrite of pyramidal neurons are parallel to one another and always oriented perpendicular to the brain surface, their electrical activity is the primary source of EEG potentials. Additionally, they frequently cross many layers, allowing input from various cortical layers to be incorporated throughout the dendritic tree.

EEG Data Acquisition

EEG data were collected from fourteen healthy average adult non-Arabic speakers musing the Geodesic EEG System (GES) (Electrical Geodesics, Inc.) with 128 electrode channels and an impedance of less than 50 kΩ. The enhanced version of the International 10-20 system was used to install GSN sensor arrays, EEG acquisition software (Net Station), and necessary GES hardware over the frontal, parietal, occipital, and temporal lobes.

Stimulation Paradigm

The audio stimulations from Fatihah Chapter, Rest and Arabic News are presented in a random order and last 5, 8, 6, 6, 10, 8, and 20 seconds, respectively, with a 65 dB intensity. This research was carried out at the Hospital Universiti Sains Malaysia's Event-Related Potential/Magnetoencephalography Laboratory (HUSM). During the experiment, participants closed their eyes and sat comfortably in a sound-proofed chamber with subdued lighting.

EEG Signals Pre-processing

EEG signals were pre-processed by using EGI Net Station software 4.5.1., (Magstim EGI, USA). Data were filtered through high pass of 0.3 and low pass of 50 Hz, artefact detection for the bad channel, eye blink and the eye movement, bad channel replacement and montage operation. Finally, the .ref files were transferred to EDF files.

EEG Signal Processing

The EDF files were then opened by the Brain Electrical Stimulation Analysis (BESA Research 6.1 Software, Germany), and the waveform was built. The raw waveform lengths were selected and transferred into the Fast Fourier Transform (FFT) - a spectrum from delta (0.5-3 Hz), theta (4-7 Hz), alpha (8-13 Hz), beta (14-30 Hz) and gamma (31-50 Hz). Each subject acquired the power spectrum of the brain oscillations from verse 1 to verse 7 from all three stimulations. Signals from the 128-electrode channels were analysed according to the 10-20 system, reduced to 19 spectral power values using the Independent Component Analysis (ICA) algorithm equipped with the BESA software.

Statistical Analysis

The FFT spectral power data from the 19 electrodes of Fp1, Fp2, F3, F4, F7, F8, Fz, C3, C4, Cz, P3, P4, P7, P8, Pz, T7, T8, O1 and O2 were opened by Microsoft Excel. They were checked for their outliers and then recorded and normalised using SPSS 21.0. The normalised data underwent statistical analysis of Discriminant Analysis from the XLstat statistical package. DA was a multivariate statistical technique commonly used to build a predictive model of group discrimination to classify the observed predictor variables into one group. It constructs a discriminant function (DF) for each group by the equation (1):

$$f(G_i) = k_i + \sum_{j=1}^{n} w_{ij} P_{ij} \quad \ldots (1)$$

Where *i* is the number of groups (G), Ki is the constant inherent to each group, n is the number of parameters used to classify a set of data into a given group, and w*j* is the weight coefficient assigned by DF analysis (DFA) to a given parameter (P*j*).

In this study, DA was applied to determine whether the stimulation groups of Fatihah Chapter and Arabic News differed significantly different from Rest, with a *p-value* below 0.05 concerning the mean of each electrode spectral power value. Then the Multiple Linear Regression (MLR) was applied in this study to predict the relationship between the 19-EEG electrode channels from the Beta frequency upon perceiving acoustic stimulations. MLR, also known as multiple regression, is a statistical technique that uses several explanatory variables to predict the outcome of a response variable. It extends linear regression (OLS) that uses just one explanatory variable. The goal of MLR is to model the linear relationship between the 19-EEG electrode channels, which indicates neural intercommunication between the different brain areas (Cao *et al*., 2021).

MLR model takes the form:

$$Y = \beta 0 + \beta 1 x 1 + \beta 2 x 2 + \cdots + \beta p - 1 x p - 1 + \varepsilon \quad \ldots (2)$$

Where Y is the response variable, and there are p-1 explanatory variables *x*1, *x*2, …, *x*p1-. With *p* parameters (regression coefficients) β0, β1, β 2, …, β*p*-1. The result explains how much of the variance in each electrode is accounted for by the regression model.

Results

Spectrogram Analysis

From spectrogram analysis on Verse 1 to verse 4 of Fatihah Chapter compared to Arabic News, it is found that spectrogram shows constantly darker shading in Fatihah Chapter indicates of high energy produced. While in Arabic News, dark shades also observed but they are interrupted with white shades which indicates of losing energy as shown in the figures below.

Verse 1 of Fatihah Chapter (A) and Arabic News (B)

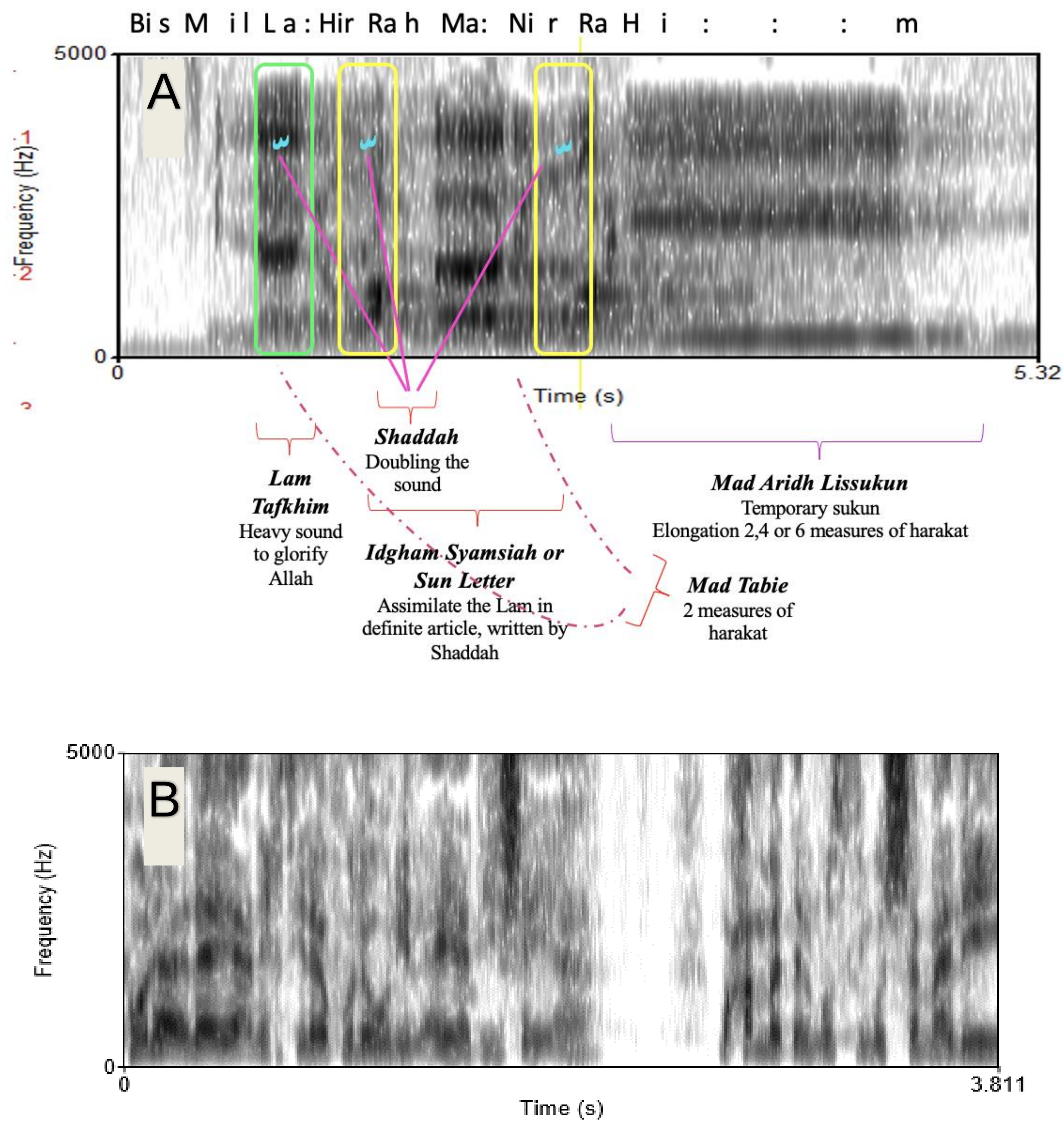


Figure 2. Spectrogram analysis for verse 1 of (A) the Fatihah Chapter and (B) Arabic News

Verse 2 of Fatihah Chapter (C) and Arabic News (D)

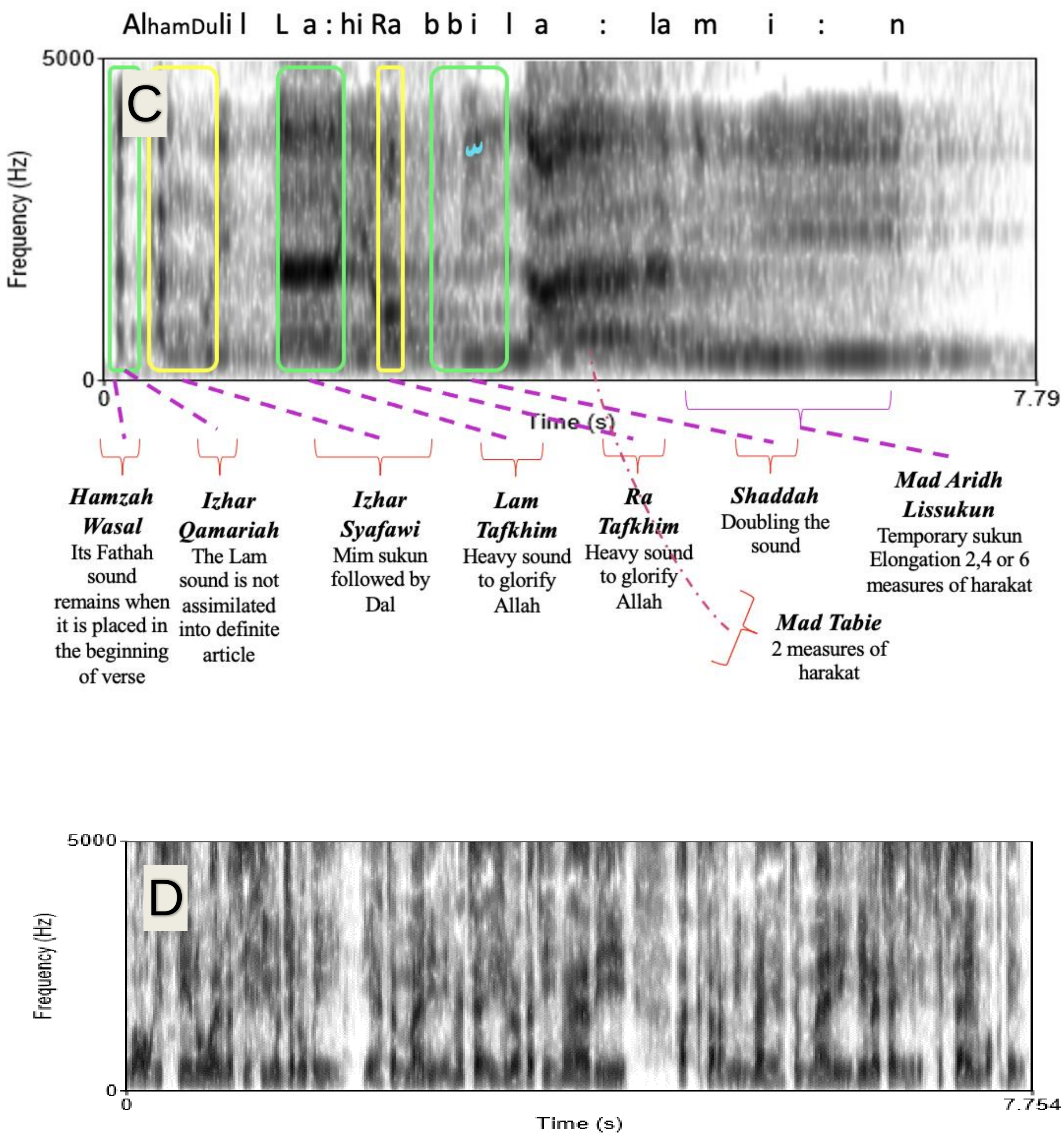


Figure 3. Spectrogram analysis for verse 2 of (C) the Fatihah Chapter and (D) Arabic News

Verse 3 of Fatihah Chapter (E) and Arabic News (F)

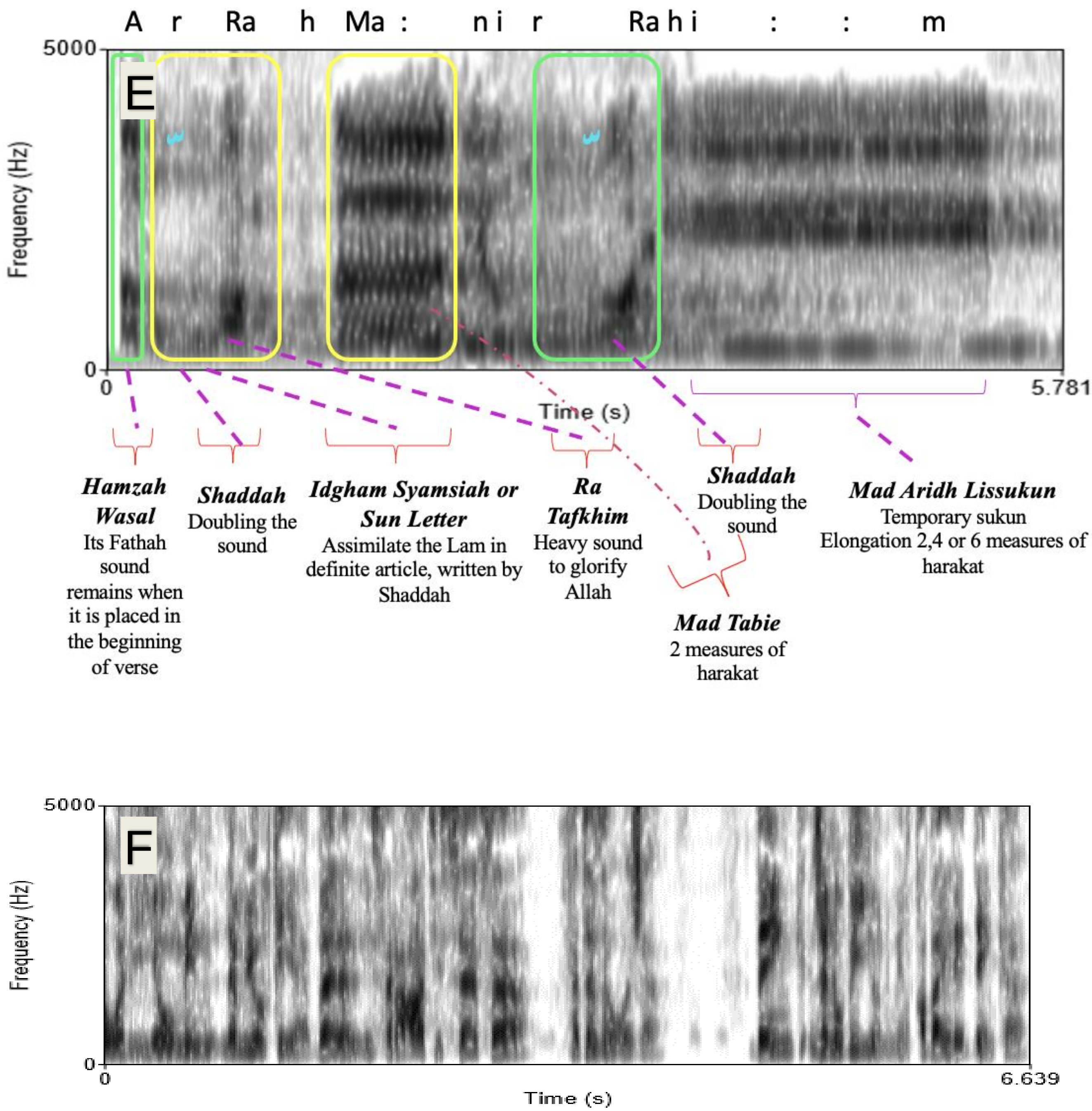
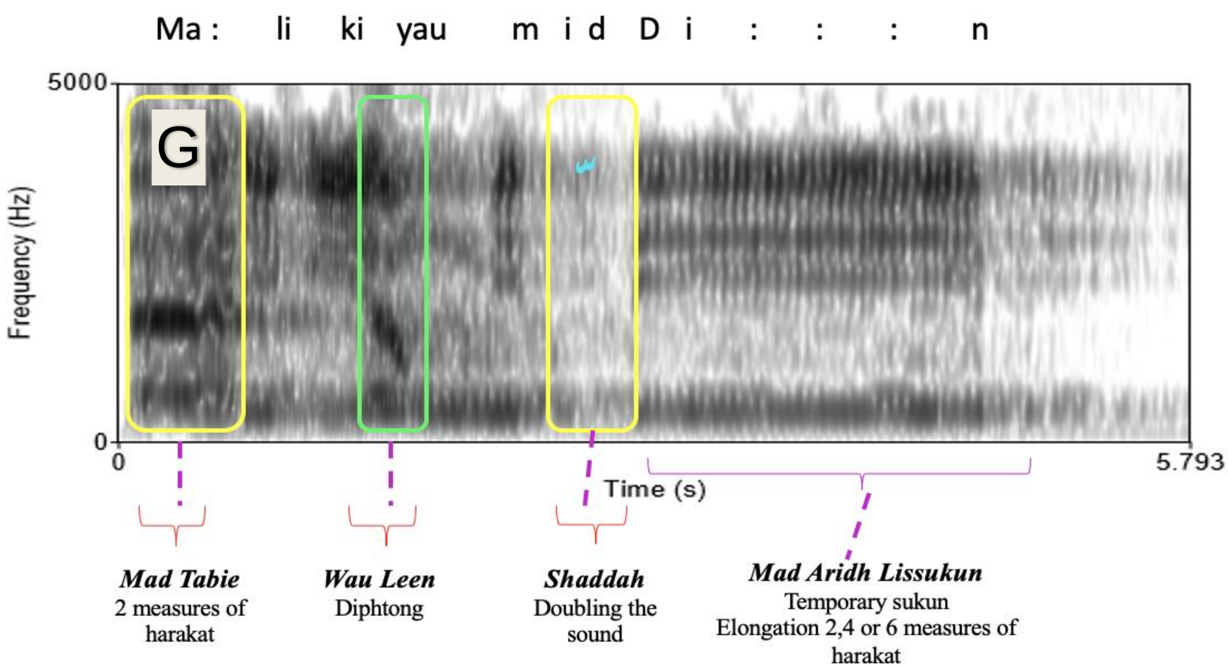


Figure 4. Spectrogram analysis for verse 3 of (E) the Fatihah Chapter and (F) Arabic News

Verse 4 of Fatihah Chapter (G) and Arabic News (H)



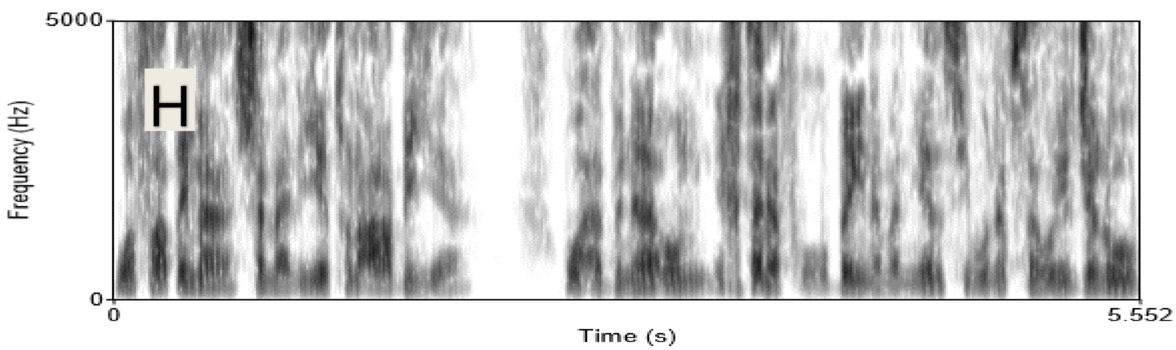


Figure 5. Spectrogram analysis for verse 4 of (G) the Fatihah Chapter and (H) Arabic News

It was postulated that higher energy was produced during recitation of Fatihah Chapter while lower energy produced during reciting Arabic News which is believed to activates greater neural ensemble in listeners. It also shows the presence of tajweed system makes the intensity, duration of every syllable in the Fatihah Chapter verses different. The darker spectrogram shows the more stress given. Clearly shown here the alternate high and low intensity of spectrograms indicating the rhythmicity in the verse construction. While for the Arabic News, spectrogram shows the words pronounced without Tajweed system.

Electrodes Correlation

The correlation between the EEG electrodes was investigated to find the possible neural mechanism underlying the EEG presentations during listening tasks. This correlation was the basis for the neurophysiological mechanism underlying the cognitive processing during listening activity towards Fatihah Chapter recitation. Multiple Linear Regression was employed to investigate the relationship of each significantly different EEG electrode channel compared to Rest. The positive control, Arabic News was also compared to Rest.

Figure 3. In Rest, significant correlations were observed for all EEG channels (r_{Fp1}=0.273, r_{F3}=0.506, r_{F7}=0.665, r_{Fp2}=0.285, r_{F4}=0.614, r_{F8}=0.829, r_{C3}=0.554, r_{C4}=0.765, r_{P4}=0.812, r_{P8}=0.701, $r_{O10.}$=0.465, r_{Fz}=0.483, p<0.0001). This shows how the variables influence each other. F8 has a high influence on T8, with a positive direction of influence, followed by P8. While F3, F7, Fp2, and F4 have a minor impact on T8, their effect is beneficial. While F4, C3, P4, and O1 have a small negative impact on T8, F4, C3, P4, and O1 have a large positive impact on T8.

In Arabic News, significant correlations were observed for eight EEG channels (r_{Fp1}=0.231, r_{F3}=0.313, r_{F7}=0.521, r_{C3}=0.491, r_{C4}=0.576, r_{P4}=0.564, r_{P8}=0.473, r_{Fz}=0.245, p<0.0001) while non-significant correlation was observed for Fp2 electrodes, (r_{Fp2}=0.185, p>0.0001). This shows how the variables influence each other. T8 is strongly influenced by FP1, F7, C4, and C8, and this influence is in a positive way. C3 has a little but favourable affect on T8, and it is in a good direction. While F3, Fp2, P4, and Fz have a small negative impact on T8, they have a large positive impact on T8.

In Fatihah Chapter, significant correlations were observed for ten EEG channels (r_{F3}=0.427, r_{F7}=0.514, r_{F4}=0.327, r_{F8}=0.689, r_{C3}=0.452, r_{C4}=0.547, r_{P4}=0.638, r_{P8}=0.6627, r_{O1}=0.646, r_{Fz}=0.390 p<0.0001) while non-significant correlation was observed for two electrodes Fp1 and Fp2 (r_{Fp1}=0.156, p>0.0001, r_{Fp2}=0.119, p>0.0001). This shows how the variables influence each other. T8 is strongly influenced by F8, C4, and P8, and this influence is in a positive way. While O1, Fp2, Fp7, F3, and Fp1 have a minor impact on T8, their affect is beneficial. While F4, C3, P4, and Fz have a negative impact on T8, F4, C3, P4, and Fz have a positive impact on T8.

The size of the correlation between the population of neurons in distinct brain areas represented by the electrodes was shown in the correlation matrix above. The right superior frontal, F4 (r=0.327), the right inferior frontal, F8 (r=0.689), the left inferior frontal, F7 (the right motor area, C4 (r=0.589), the right inferior frontal, P8 (r=0.651), the left motor area, C3 (-0.586), the right superior parietal, P4 (r=-0.504), and the left occipital area, O1 (r=0.100), all showed However, when compared to the Rest, the correlation was lower in the left prefrontal cortex (Fp1). Also visible are the opposing directions with the same magnitude in the right and left motor hemispheres (C3 and C4) (-0.586 and 0.589). The right superior and inferior frontal (F4 and F8), on the other hand, showed the opposite tendency. In the same way, the superior and inferior parietal (P4 and P8) showed different orientations.

Table 2. The spectral power from EEG electrodes correlation was computed using MLR in three conditions: Rest, listening to Arabic News and listening to Fatihah Chapter. MLR was employed on the significantly changed spectral power electrode channels, $p<0.05$

(A) EEG electrodes correlation during Rest

Variables	FP1	F3	F7	FP2	F4	F8	C3	C4	P4	P8	O1	Fz	T8
FP1	**1.000**	0.748	0.611	0.773	0.572	0.385	0.548	0.506	0.482	0.239	0.449	0.720	0.273
F3	0.748	**1.000**	0.823	0.456	0.512	0.492	0.809	0.632	0.661	0.530	0.606	0.821	0.506
F7	0.611	0.823	**1.000**	0.501	0.718	0.743	0.792	0.704	0.695	0.522	0.550	0.665	0.665
FP2	0.773	0.456	0.501	**1.000**	0.718	0.539	0.400	0.466	0.399	0.152	0.272	0.511	0.285
F4	0.572	0.512	0.718	0.718	**1.000**	0.815	0.478	0.757	0.619	0.324	0.351	0.573	0.614
F8	0.385	0.492	0.743	0.539	0.815	**1.000**	0.521	0.751	0.720	0.461	0.360	0.479	0.829
C3	0.548	0.809	0.792	0.400	0.478	0.521	**1.000**	0.627	0.640	0.584	0.490	0.642	0.554
C4	0.506	0.632	0.704	0.466	0.757	0.751	0.627	**1.000**	0.866	0.606	0.513	0.631	0.765
P4	0.482	0.661	0.695	0.399	0.619	0.720	0.640	0.866	**1.000**	0.797	0.661	0.724	0.812
P8	0.239	0.530	0.522	0.152	0.324	0.461	0.584	0.606	0.797	**1.000**	0.627	0.570	0.701
O1	0.449	0.606	0.550	0.272	0.351	0.360	0.490	0.513	0.661	0.627	**1.000**	0.654	0.465
T8	0.273	0.506	0.665	0.285	0.614	0.829	0.554	0.765	0.812	0.701	0.465	0.483	**1.000**

(B) EEG electrodes correlation during listening to Arabic News

Variables	FP1	F3	F7	FP2	C3	C4	P4	P8	Fz	T8
FP1	**1.000**	0.662	0.390	0.748	0.497	0.496	0.503	0.294	0.643	0.231
F3	0.662	**1.000**	0.709	0.514	0.744	0.577	0.646	0.561	0.712	0.313
F7	0.390	0.709	**1.000**	0.486	0.687	0.478	0.538	0.484	0.397	0.521
FP2	0.748	0.514	0.486	**1.000**	0.414	0.345	0.355	0.288	0.531	0.185
C3	0.497	0.744	0.687	0.414	**1.000**	0.695	0.736	0.557	0.713	0.491
C4	0.496	0.577	0.478	0.345	0.695	**1.000**	0.852	0.454	0.592	0.576
P4	0.503	0.646	0.538	0.355	0.736	0.852	**1.000**	0.724	0.596	0.564
P8	0.294	0.561	0.484	0.288	0.557	0.454	0.724	**1.000**	0.409	0.473
Fz	0.643	0.712	0.397	0.531	0.713	0.592	0.596	0.409	**1.000**	0.245
T8	0.231	0.313	0.521	0.185	0.491	0.576	0.564	0.473	0.245	**1.000**

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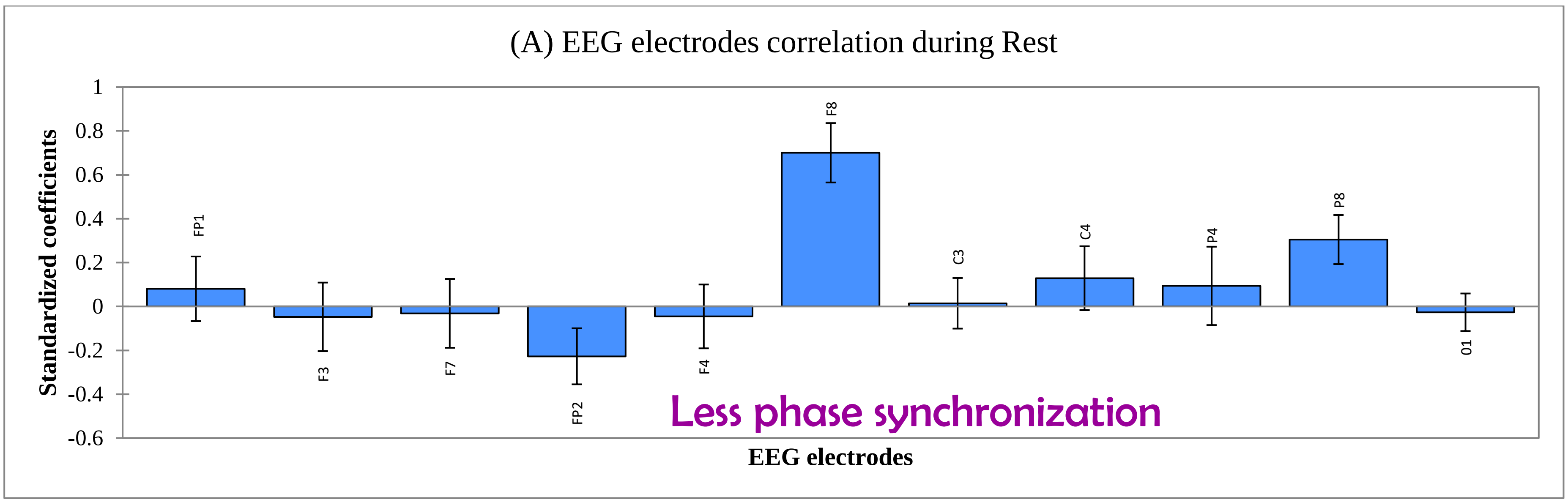
(C) EEG electrodes correlation during listening to Fatihah Chapter

Variables	FP1	F3	F7	FP2	F4	F8	C3	C4	P4	P8	O1	Fz	T8
FP1	**1.000**	0.679	0.209	0.732	0.500	0.233	0.402	0.411	0.418	0.186	0.427	0.730	0.156
F3	0.679	**1.000**	0.642	0.511	0.506	0.460	0.742	0.606	0.665	0.559	0.716	0.822	0.427
F7	0.209	0.642	**1.000**	0.277	0.457	0.710	0.763	0.591	0.583	0.365	0.436	0.454	0.514
FP2	0.732	0.511	0.277	**1.000**	0.747	0.275	0.356	0.309	0.293	0.133	0.345	0.668	0.119
F4	0.500	0.506	0.457	0.747	**1.000**	0.654	0.539	0.536	0.520	0.280	0.482	0.697	0.327
F8	0.233	0.460	0.710	0.275	0.654	**1.000**	0.672	0.662	0.692	0.379	0.515	0.493	0.689
C3	0.402	0.742	0.763	0.356	0.539	0.672	**1.000**	0.848	0.800	0.514	0.603	0.598	0.452
C4	0.411	0.606	0.591	0.309	0.536	0.662	0.848	**1.000**	0.855	0.488	0.643	0.563	0.547
P4	0.418	0.665	0.583	0.293	0.520	0.692	0.800	0.855	**1.000**	0.765	0.763	0.608	0.638
P8	0.186	0.559	0.365	0.133	0.280	0.379	0.514	0.488	0.765	**1.000**	0.796	0.493	0.627
O1	0.427	0.716	0.436	0.345	0.482	0.515	0.603	0.643	0.763	0.796	**1.000**	0.731	0.646
Fz	0.730	0.822	0.454	0.668	0.697	0.493	0.598	0.563	0.608	0.493	0.731	**1.000**	0.390
T8	0.156	0.427	0.514	0.119	0.327	0.689	0.452	0.547	0.638	0.627	0.646	0.390	**1.000**



Correlation model:
[T8 = 0.10192+0.10176*FP1+0.02987*F3-0.06012*F7-0.25911*FP2+0.01244*F4+0.61076*F8+0.01588*C3+0.08620*C4+0.18961*P4+0.35348*P8-0.01404*O1-0.15386*Fz

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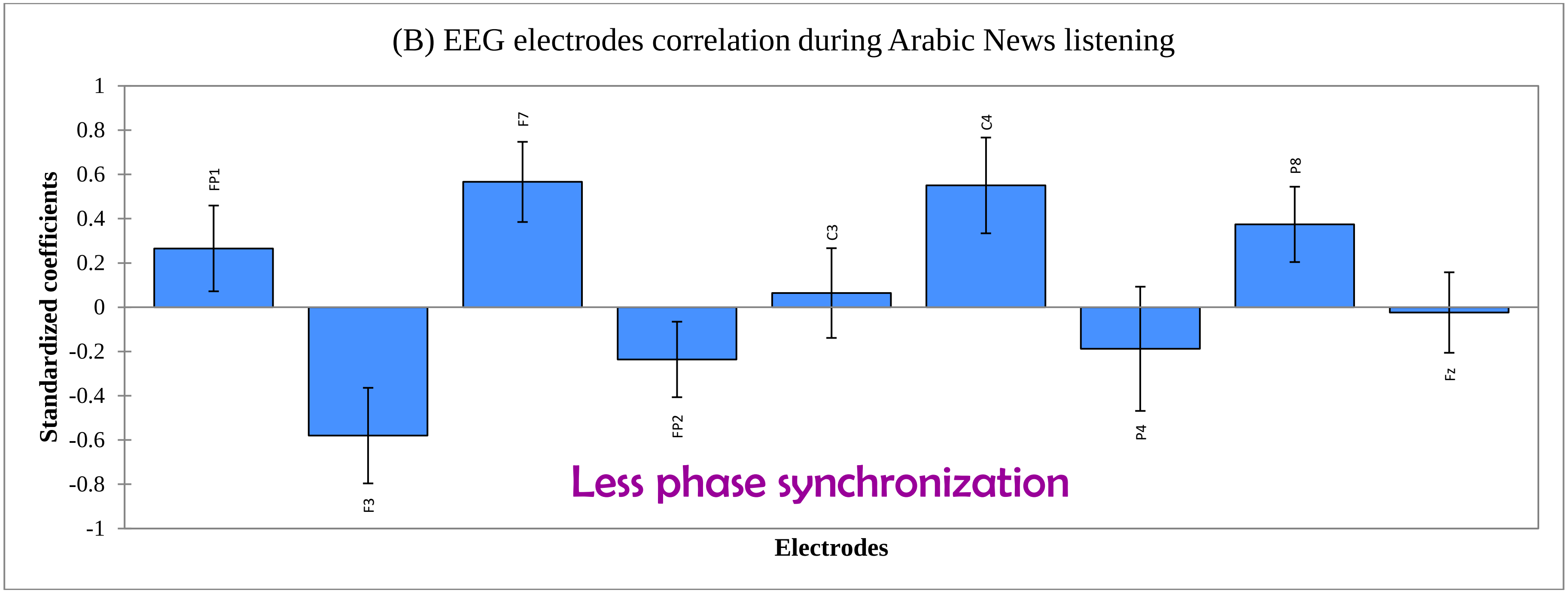
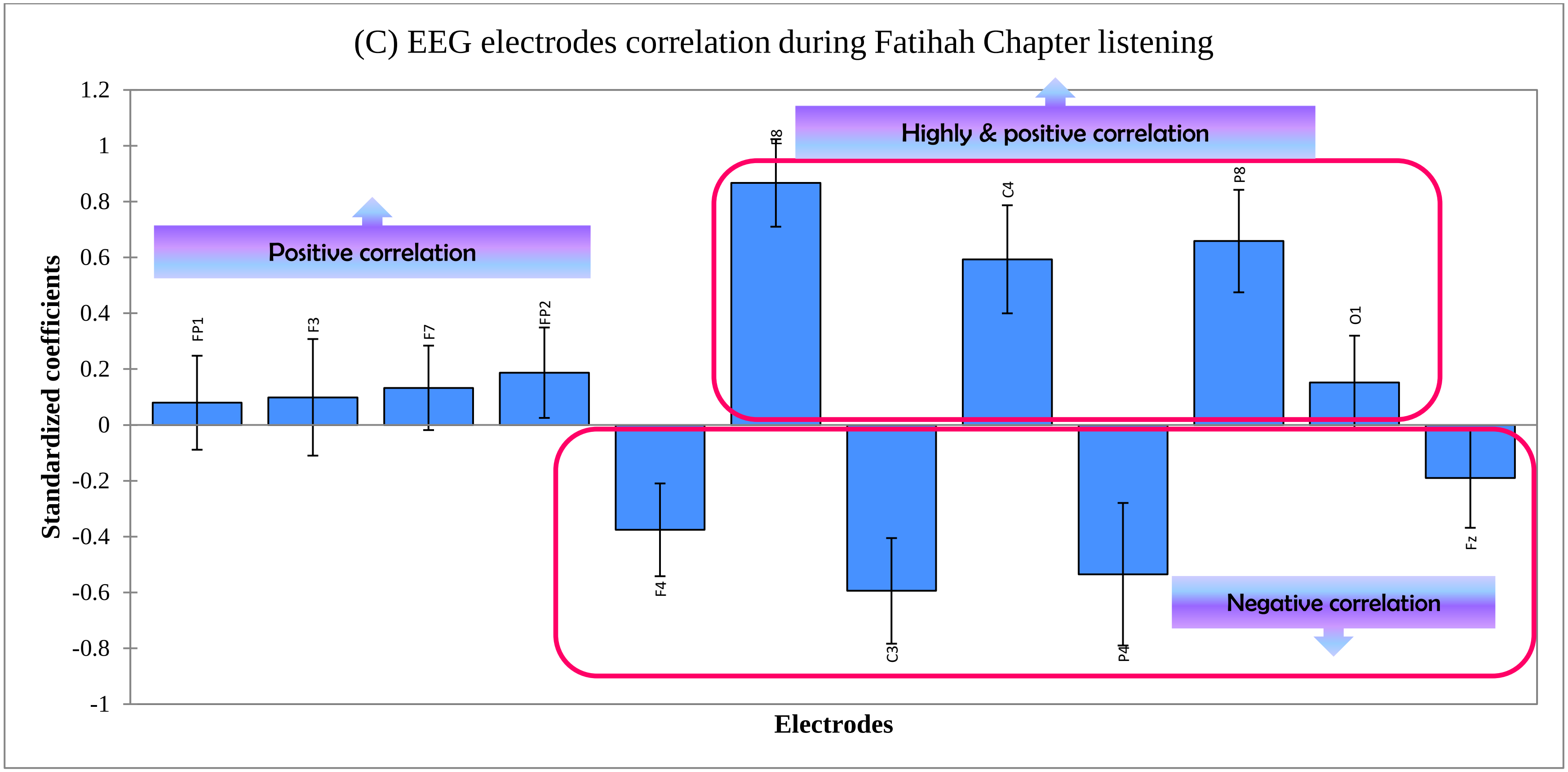


Correlation model:
[T8 = 0.28971+0.33498*FP1-0.62239*F3+0.48467*F7-0.24556*FP2+0.07074*C3+0.53961*C4-0.21704*P4+0.41633*P8-0.04078*F

10. 11113/mjfas.v19n4.2969



Correlation model:
[T8 = 0.03174+0.08554*FP1+0.10956*F3+0.11834*F7+0.18636*FP2-0.47082*F4+0.80941*F8-0.51215*C3+0.55267*C4-0.62934*P4+0.63530*P8+0.16344*O1-0.25853*Fz]

Figure 6. EEG electrodes correlation during (A) Rest, listening to (B) Arabic News and (C) Fatihah Chapter depicted from MLR computing. Correlation models were also given to the respective graphs

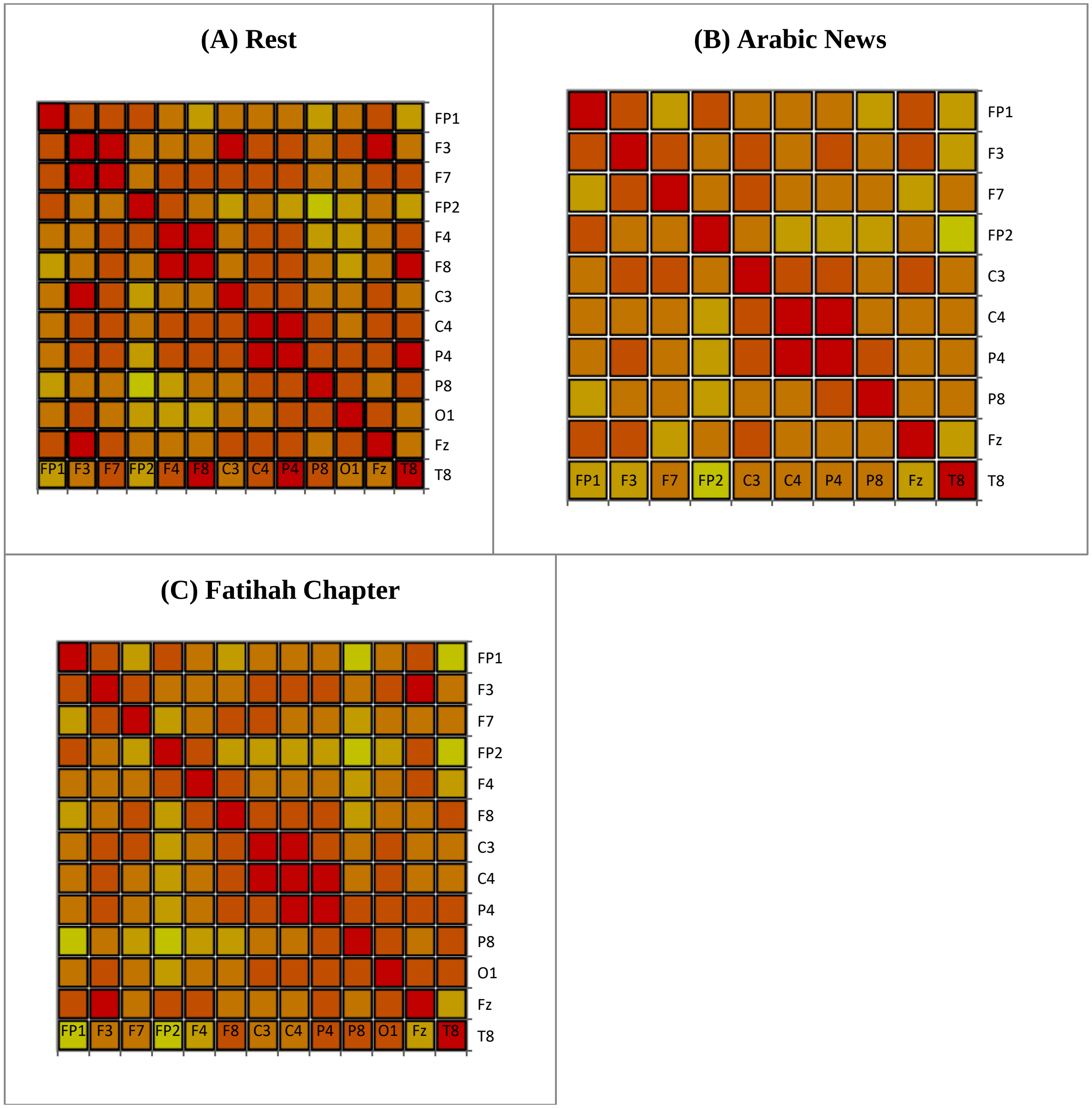


Figure 7. Correlation matrix for (A) Rest, listening to (B) Arabic News and (C) Fatihah Chapter

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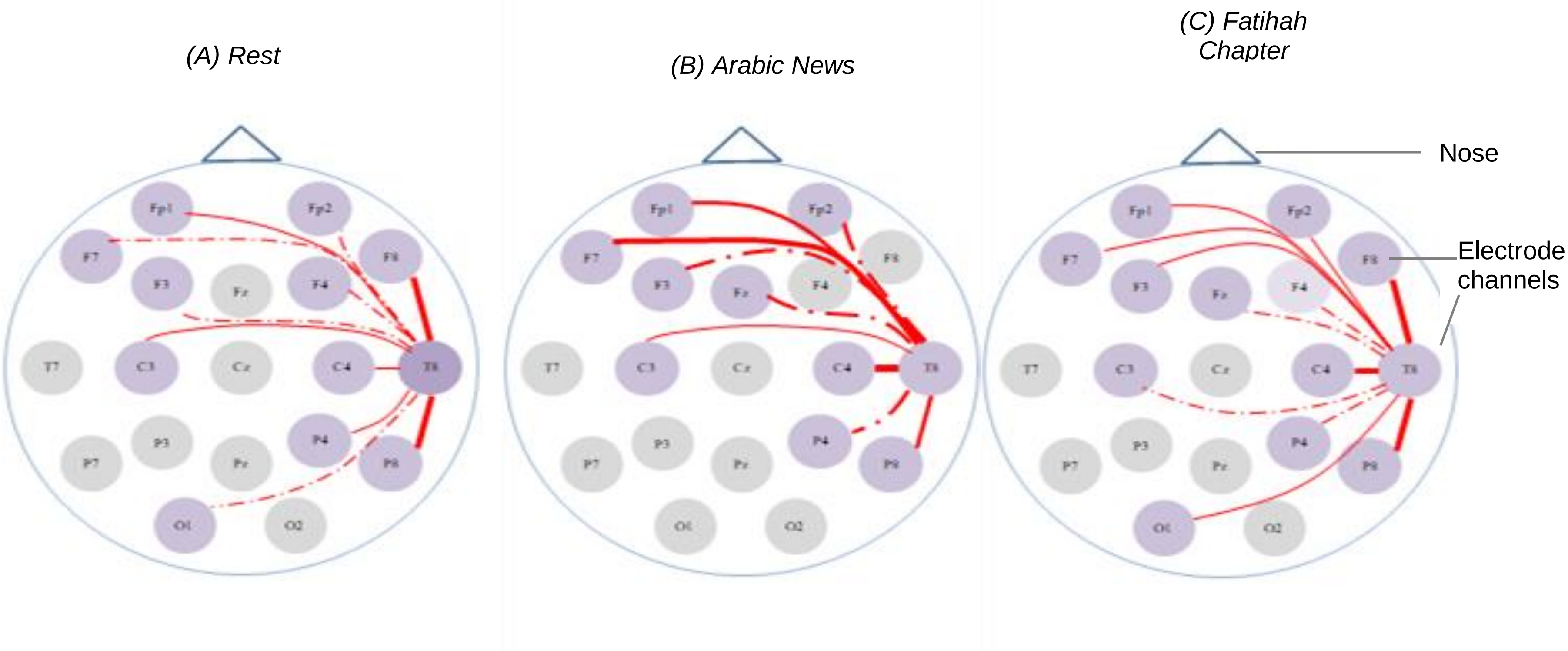

Figure 8. This figure depicts the correlation of the electrode channels across the global brain derived from MLR analysis from top view. Bold line shows positive correlation with high magnitude, normal line shows the the positive correlation and interrupted line shows negative correlation for (A) Rest, listening to (B) Arabic News and (C) Fatihah Chapter

10. 11113/mjfas.v19n4.2969

This EEG electrodes correlation suggested underlying neural mechanisms related to the acoustic perception of the rhythmic stimuli from Fatihah Chapter recitation listening. Firstly, upon receiving the sound vibration, the impulse signals to the brain and activates T8, an area in which the s system is located. The temporal cortex participates in the perceptual analysis of melodies and pitch processing affected via a neural network that includes the right prefrontal cortex (Zatorre, Evans, and Meyer 1994).

The superior temporal lobes have long been responsible for sound stimulation in animals and humans. Perceiving a melody or sequence of pitches requires relatively complex perceptual analysis, demanding a corresponding set of neural computations. Although current knowledge does not provide us with the exact neural pathway according to Quranic stimulation, we suggested the possible neurophysiological mechanism according to neuroanatomy and neurophysiology principles that affect the human auditory system and cognition.

Discussions

This study aimed to evaluate a linguistic feature from Fatihah Chapter that contributes to high rhythmicity to the Fatihah Chapter sound. We also aimed to compare the spectral power from EEG's electrode correlation during listening to Fatihah Chapter and listening to Arabic News as a predictive measure for neural connectivity.

Results showed that more energy concentrated when people reciting Fatihah Chapter as showed by dark areas dominating the spectrograms from the Fatihah Chapter. Compared to speech of Arabic News, the energy was lower and inconsistent, where much white areas or low grey shaded appeared along the time axis in all Arabic News verses. Indeed, the dark areas marked when the tajweed or pronunciation rules appear, for example at the lLa of the word Allah, a Lafzul Jallalah in verse 1. Noted that the syllable contains Lam Tafkhim which must be recited by heavy sound to glorify Allah, hence the energy is high. The same also visible in the syllable Ma: from Rahman in verse 1, also the Lafzul Jallalah which must be read by stressing the syllable for the same purpose. Tajweed appears many times in the Fatihah Chapter but not present in the Arabic News. As tajweed contains some regulation in stressing phonemes or syllables, thus it produces variation in the vowel's duration, whether one, two, four or six measures of harakat. It makes the verses recitation more intoned according to the tajweed rules.

In the Verse 1 of Fatihah Chapter the verse *Bismillahirrahmanirrahim* contains a few rules of pronunciation which are Mad Tabie, Mad Aridh lissukun, Idgham Syamsiah, Shaddah and Lam Tafkhim. In the Verse 2 of the Fatihah Chapter, Hamzah Wasal, Izhar Qamariah, Izhar Syafawi, Lam Tafkhim, Ra Tafkhim, Shaddah, Mad Aridh Lissukun and Mad Tabie appeared. While in the Verse 3 of Fatihah Chapter, Hamzah Wasal, Shaddah, Idgham Syamsiah or Sun Letter, Ra Tafkhim, Shaddah, Mad Aridh Lissukun and Mad Tabie present, and in the verse 4, Mad Tabie, Wau Leen, Shaddah and Mad Aridh Lissukun appeared as tabulated in Appendix A. These rules are arranged so well that the recitation produces a melodic sound, not because of the external musical enriched here.

First thing, we can clearly see the repetition of the same rule of tajweed in the verses. Mad Tabie which is read by prolonging the syllable to two measures of harakat was applied in all the verses, whether in the beginning of verses or in the middle. Mad Aridh Lissukun also presents in every verse, located in the end of the verse to be read in two, four or six measures of harakat make up a rhyming sound. In the Fatihah Chapter, there are a lot of Lafzul Jallalah which is the name of Allah, and it was ruled to pronounce the words or syllables with heavy and strong sound in order to glorify Allah (Al-Qaradhawi, 1999).

The importance of the Fatihah Chapter as The Mother of Quran are reflected in shaddah which appeared in many verses. Shaddah is a repetition of letter to strengthen the sound. Besides, it also strengthens the majesty of Allah. Although the letters used are among those having light sound, then with the shaddah, their sounds and energy become more intense.

In the verse 4, the syllable Yau produced bands of energy that run roughly horizontally across the spectrogram, but tilting slightly upward to reflect the changing formants frequencies over time (Kent, 1997). The changing formants clearly showed in spectrogram when the consonant-vowels changes appeared. In the AN, the spectrograms are running short-term spectrum or in other words, shows a continuously changing spectral pattern. This is due to many words are uttered in the time length thus the signal changes rapidly and nearly continuously, even for simple. The waveforms captured the dynamicity of the speech and not easily being interpreted. For instance, it is hard to determine the vowel identity by looking the spectrogram or waveform.

Moreover, there are many silent segments due to absence of any tajweed rule which makes the speech uttered shortly. The voiced sounds are clearly shown by the dark shades while the silent segments follow the sound which represents the period when the articulation is completely closed and the air is imprisoned inside it (Altalmas *et al*., 2015).

In the Lafzul Jallalah the rhythmic movement of energy along the time was shown. Utterance of Ar, Ra and Ma: produce high energy level as marked by dark shades which are alternately followed by lower energy those comes from trilling sound of R or Ra letter, vibration of H or Ha letter and murmur precedes the M or Mim letter. These energy level changing pattern producing a rhythmicity in the amplitude of sound as well as the energy intensity, that marked by yellow line of Intensity Contour. Fundamental Frequency is clearly shown with the steady pitch along the time axis. Noted here the presence of tajweed rules of Idgham Syamsiah, Ra Tafkhim, and Mad Aridh Lissukun which makes the length of duration rhythmically changed.

The cognition processing ultimately depends on a large-scale brain network or organisation and communication. Although cognitive functions have long been assumed to be attributable to single brain areas' remote operations, the weight of evidence currently shows that cognition results from the dynamic interactions of distributed brain areas operating in large-scale networks (Bressler and Menon 2010). Hence this study was conducted using statistical analysis to map the relationship between the EEG electrodes during listening to the Fatihah Chapter compared with Rest and Arabic New listening.

We also postulated that listening to the Fatihah Chapter acoustic stimulation may induce neuronal reorganisation in the global brain regions. The frontal, temporal, parietal, motor, and occipital lobes were all involved in perceiving the sound cues from the Fatihah Chapter. Using right temporal areas as the independent variable for their significantly activated during listening to Fatihah Chapter and its association with auditory stimuli processing, we found that several regions were positively correlated with the temporal region in our extended analysis using Multiple Linear Regression. The right superior frontal, inferior bilateral frontal, right motor cortex, right inferior parietal, and left occipital cortex were all involved. The right superior frontal left motor cortex, and right superior parietal cortex were inversely linked with the right temporal area. This regression depicts the creation of a cohesive cognitive function because of the integration of a distributed mosaic of functionally specialised brain regions while processing auditory stimuli. Although the mechanism is unknown, we believe that the formation of dynamic linkages mediated by phase synchronisation is the most likely choice. The relationship between the temporal structures of brain signals is known as phase synchronisation, and the signals are considered to be synchronous if their rhythms coincide (Eilam 2019). During listening to Fatihah Chapter, a great scale of integration from distant neuronal assemblies was detected in the temporo-fronto-motor-parieto-occipital brain areas, according to the findings. However, because the T8 was not statistically different during this activity, less phase synchronisation was expected in Rest and Arabic News when they perceived the acoustic stimulus. During rest, EEG electrodes correlations were generally low in magnitude.

The correlation can be divided into three categories: short-distance, long-distance, and negatively correlated regions. The right inferior frontal, right inferior parietal, and right motor cortex (F8, P8, and C4, respectively) were the short-distance channels, while the bilateral prefrontal and the left superior, inferior frontal, and left occipital lobe (FP1, FP2, F3, F7, and O1) were the long-distance channels. Finally, the inversely related regions of the right superior frontal, left motor frontal, and right superior parietal (F4, C3 and P4) reliable to the right temporal area (T8). In our research, the right temporo-fronto-motor-parieto region had a high association. This was believed that listening to the Fatihah Chapter may trigger an activation of a large network of brain connection. This strong association suggested that there was a lot of information flow around, which boosted the efficiency of local data processing. In Rest and Arabic News, on the other hand, fewer brain areas were activated.

The high magnitude positive association of fronto-motor-parieto-occipital suggested activation of the mirror-neuron system (Zhang *et al*. 2018), leading to Quranic verse reciting and improved Fatihah Chapter rhythm perception. Action comprehension is based on mirror neurons and the network's activation is linked to the action's execution (Hickok 2013; Zhang *et al*. 2018). Impaired mirror-neuron networks reflect the ability to perceive one's own and others' mental states, and they may be linked to antisocial and borderline personality disorders (Sosic-Vasic *et al*. 2019; Chan and Han 2020;). The human mirror-neuron system is made up of premotor-parietal circuits with a somatotopic organisation, according to imaging studies (Tettamanti *et al*. 2005). The perceiving motor system processes auditory regularity even when attention is not directed on the rhythmic stimuli, and probably plays a role in controlling time-based expectancies.

The opposite direction of beta activity between superior-inferior frontal, right-left motor cortices, and superior-inferior parietal brain areas during Fatihah Chapter hearing could be explained by synchronisation and desynchronisation dynamic balance during the chapter. Normal brain function depends on a dynamic equilibrium between synchronisation and desynchronisation, and abnormalities are frequently linked to pathological diseases like epilepsy, dementia, autism, and thalamo-cortical dysrhythmia (Thatcher 2012; Prokic *et al*. 2019). Many brain activities rely on neural synchronisation. The short-term (phasic) amplitude attenuation in beta oscillations is referred to as beta event-related desynchronisation (Pfurtscheller and Aranibar 1977). It's an awake brain phenomenon that occurs during, before, or after sensory and cognitive processing and motor behaviour. It is a feature of cortical areas preparing for information processing and motor command execution, and it represents the electrophysiology of cortical activation (Pfurtscheller, 1992). Synchronisation, on the other hand, is the opposite of desynchronisation in that it increases the spectral peak. Based on the cooperative behaviour of big neurons, this process produces amplitude enhancement (Gyorgy Buzsáki, 2006).

The opposite phase was also proposed as a way to transmit a top-down motor expectation signal of the rhythm structure to the auditory system (Bartolo and Merchant 2015; Merchant *et al*. 2015; Fujioka, Ross, and Trainor 2015). On the other hand, since activation in the temporal-parietal was linked to improved moral judgement, we would assume that such activation would aid in improving reasoning and moral judgement, allowing us to become morally correct and socially useful. Because beta-band activity is highly suggested for motor functions, this is the case. As a result, during the tracking of the Fatihah Chapter rhythmic pace, the right temporal brain revealed an extensive network of sensors. This is related to the activation of the motor system during the passive perception of the beats. Passive, rhythmic entrainment of the sound and motor systems can be explained as the cause of this scenario.

This study offers preliminary insights into how brain connectivity occurs during these activities. EEG signals provide information on the brain signals through multiple electrode channels. Correlation between those electrodes may represent intercommunication between different EEG signals (Cao, 2021), while brain connectivity explained statistical dependence and directed information flow between cortical regions, underlying the intrinsic brain network and its functional and mechanisms (Babiloni *et al*., 2005; Sakkalis, 2011; Cao, 2021). EEG was not directly revealed structural connections like Magnetic Resonance Imaging (MRI) did, and EEG is applied to estimate functional and effective connectivity. However, compared with MRI, EEG offers an excellent temporal resolution hence provides more precise information according to its time series (Burle, 2015). On the other hand, EEG offers early detection of brain anomalies or any pathophysiological processes at a lower cost before clinical symptoms emerge and aggravate, posing a good prognosis to the patients' management. However, this study does not provide other functional connectivity like coherence or effective connectivity. Hence, it is suggested to design a study using other brain connectivity methods from nonlinear methods like phase locking value (PLV), complex Pearson Correlation Coefficient (CPCC) (Šverko *et al*., 2022), synchronisation likelihood (Montez *et al*., 2022), or parametric methods like Dynamic Causal Modelling and Structural Equation Modelling to uncover more brain secrets responsible for human behaviour.

Conclusions

In conclusion, Quranic sound had its internal structure that makes its sound rhythmic and aesthetic. This rhythmic sound activated greater neural ensemble in listeners which was believed to bring high energy and contributed to cognition enhancement.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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Appendix A

Tajweed rule	Explanation
Mad tabie	If there is alif (ا) located after fathah or ya' sukun (ي) after kasrah (—ِ) or wau (و) after Dhommah (—ُ). Mad means long, tabie means: normal. The way to read it should be two words long. example: كِتَا بٌ - يَقُوْلُ - سمِيْعٌ
Mad aridh lissukun	If there is a waqaf or a place to stop reading while before the waqaf there is Mad Asli or Mad Layyin, then there are 3 ways to read it: a. Read long like Mad Wajib Muttasil (6 movements). b. Read four values. c. Read two values Example : بَصِيْرٌ خَالِدُوْنَ والنَّاسِ سَمِيْعٌ
Idgham Syamsiah	The word idgham linguistically means to insert or melt, while syamsiyah means like the sun. So, the meaning of the syamsiyah idgham is to insert or merge the lam ta'rif sound into the syamsiyah letters that are located on the letter after it. The Syamsiyah idgham letters themselves consist of 14 letters, namely: ن (nun), ل (lam), ظ (dho), ط (tha), ض (dhad), ص (shad), ش (syin), س (sin), ز (zai) , ر (ro') , ذ (dzal) , د (dal) , ث (tsa) ت (ta').
Syaddah	Syadddah is used to write two identical letters. To pronounce syaddah, the first letter will have sukoon and the second one will have the harakah that comes with the syaddah.
Lam Tafkhim	The letter lined up before the letter mad (alif) is from the 7 isti'la letters. Isti' la letters are kha' (خ), ṣad (ص), ḍad (ض), ghayn (غ), ṭa' (ط), qaf (ق), dan za' (ظ).
Hamzah Wasal	Hamzah wasal (حمزه وصل) is a hamzah in the form of an additional alif at the beginning of a word. This hamzah will be ignored if one chooses to continue reading from the previous verse. But this hamzah will be read in line if someone chooses to start reading from the word that has the wasal hamzah.
Izhar Qamariah	Izhar according to language is clear, while Qamariyah is derived from the word Qamar which means Moon. According to the term Izhar Qamariyah, reading sentences clearly is when the letters Alif and Lam (ا ل) meet with the letters Qamariyah.

Tajweed rule	Explanation
	The reading law is called Izhar Qamariyah if there are letters Alif and Lam (ا ل) that meet one of the letters Qamariyah, which is 14 letters in total including: ء ب غ ح ج ك و خ ف ع ف ي م ه
Izhar Syafawi	Idzhar means clear or bright, while syafawi comes from the word syafatun which means lips. So what is called izhar syafawi is sounding the pronunciation or recitation clearly without buzzing and by bringing the lips together. The law of recitation is called izhar syafawi is when there is mim sukun (مْ) meets one of the 26 hijaiyah letters other than the letters Mim (م) and Ba' (ب). The law of izhar syafawi is included in the legal category of reading Mim Sukun.
Ra Tafkhim	Tafkhim is the law of reading the letter Ra (ر) by saying it in bold until it fills the mouth when saying it.