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RESEARCH ARTICLE

Rhythms Synchronization Effects on Cognition during Listening to Quranic Recitation

Ismail Samhani[a,*], Mohammed Faruque Reza[b], Mohd Hanifah Jusoh[c], and Hafizan Juahir[d]

[a] Faculty of Medicine, Universiti Sultan Zainal Abidin (UniSZA) Medical Campus, 20400 Kuala Terengganu, Terengganu, Malaysia; [b] Department of Neurosciences, School of Medical Sciences, Universiti Sains Malaysia, 16150 Kota Bharu, Kelantan, Malaysia; [c] Department of Orthopaedics, School of Medical Sciences, Universiti Sains Malaysia, 16150 Kota Bharu, Kelantan, Malaysia;[d] East Coast Environmental Research Institute (ESERI), Universiti Sultan Zainal Abidin (UniSZA) Gong Badak Campus, 21300 Kuala Nerus, Terengganu, Malaysia

Abstract Sound has rhythms that can interact with human brain rhythms. The interaction may improve human cognition through neuronal synchronization. However, research on the synchronization effects of listening to the Holy Quran remains elusive. This study aimed to learn the potential synchronous effects of Quranic listening in beta frequency through electroencephalographic oscillatory dataset. Subjects were listening to Fatihah Chapter, Arabic News and Rest in random sequence. Data were pre-processed followed by neuroimaging analysis using BESA Research 6.1. Repeated Measures ANOVA and Agglomerative Hierarchical Clustering (AHC) algorithm were applied to elucidate the significantly different EEG electrode channels compared to Rest and their clusters. Results showed that Beta rhythms synchronization with the Fatihah Chapter is associated with verbal fluency, academic performance, social interaction, inhibitory function, movement planning, self-motivation, self-management and reactivation of sensory features of memory trace as highly activated cluster, followed by working memory, language processing and decision making as medially activated cluster; and tune recognition and visual mental imagery as low activated neural circuits cluster during listening to the Fatihah Chapter.

Keywords: Acoustic stimulation, Al-Quran, Brain oscillations, Cognitive neuroscience, Multivariate analysis, Signal analysis.

***For correspondence:**
samhanismail@gmail.com

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Introduction

Having approximately 100 billion neurons, the brain is incredibly powerful organ occupying on the top of spinal chord. The brain areas assigned specifically to their functions, interconnecting with each other to support the mind with thought and emotion. Listening to Quranic recitation was proved to mold and shape the brain and there is link between listening to Quranic recitation and cognitive enhancement (Hashim *et al*., 2018; Ishak *et al*., 2021; Samhani *et al*., 2018; Samhani *et al*., 2019a; Samhani *et al*., 2019b). Listening to Fatihah Chapter recitation might provide a sounding environment which likely to drive brain plasticity whether it is microstructural or macrostructural level of adaptation. The macrostructural adaptation involves changes in

volume, morphology, density and connectivity of brain structures while the microstructural level changes occurs at the neurons and synapses level such as neurogenesis (giving birth to new neurons) and glial cells by the formation and remodelling of new connections by the outgrowth of dendrites, axonal sprouting and increasing synaptic connection strength (Reybrouck *et al*., 2018).

Rhythms are fundamental to music and speech, as well as to Quranic sound. Rhythmic sound is a potent catalyst to elicit positive effects such as cooperation, mediates bonding and social connection and understanding of speech. Rhythms enable babies to understand their mother's voice, not through comprehension but through perceived rhythms. To comprehend a spoken language, listeners must perceive temporal organization of phonemes, syllables, words and phrases from an ongoing speech stream. fMRI studies have shown that the processing of sound envelopes in acoustic signals associated with activities in the brainstem's inferior colliculus, the thalamus's geniculate body, the superior temporal gyrus, Hescl's gyrus and superior temporal sulcus (Giraud & Poeppel, 2015).

Rhythmic acoustic stimulation can alter brain activity, predominantly beta rhythms. For instance, music has been found to stimulate beta rhythms. More prominent activation was detected when listening to a preferred tempo, while faster-paced music elicited greater physiological activation than slower-paced music. Beta rhythms (14-30Hz) are distributed in limited topography with high frequency and can be considered elementary brain signals functionally related to diverse cognitive processes. Beta rhythms decrease associated with decision making, motor planning and language processing. Furthermore, beta rhythms are associated with working memory and beta spectral power decrease, as recorded during the memory retrieval process, suggesting memory reactivation. Parietal beta, however, is related to the coordination of inputs from multiple modalities, while activation of beta rhythms in basal ganglia and motor cortex is also associated with motor control.

Quran brings a rhythmic sound that has significant effects on human brain oscillations.
Fatihah Chapter is the first chapter in the Quran renowned for its beautiful audible and poetic rhythmicity. Although it was a fascinating experience for one to hear its recitation, little is known about the neural association of its recitations' psychoacoustic and cognitive effects. The synchronous effects of the brain rhythms due to its linguistic rhythms also remain unclear. Fatihah Chapter sound brings the rhythms and energy which entrain human brain rhythms, subsequently elicits intense affection experiences associated with language, memory, attention and behavioral control. The rhythmic sound from Quranic Fatihah Chapter originated from the verses structure comprised of coupled syllable forming rhymes, selected words and letters that produce fluctuating intensity, repetitive and periodic pitching, stress system, elongation, nasalization and utilisation of twisted sound those governed by Tajweed system.

Electroencephalographic neuroimaging technique has been used to enrich our understanding of the neural basis of a wide variety of cognitive abilities, including attention, language and memory. Electroencephalography measurement is non-invasive tool that is widely used for its highly precise temporal resolution that allows the investigation of neural activity at milisecond level. It measures the currents that flow during synaptic excitations of the dendrites of pyramidal neurons in the cerebral cortex. This is the principal source of EEG potentials that coming from the pyramidal cells that paralleling lined perpendicular to brain surface. Often, they cross several cortical layers and bring summated voltage of inhibitory and excitatory postsynaptic potentials to be recorded by EEG device. Currently, the large EEG dataset and advance data analytics had led to the deployment of advanced analysis of EEG signals in understanding the information it may contain for brain functionality related to health and behaviour (Craik et al., 2019).

To date, the knowledge regarding auditory stimulation from Quranic Fatihah Chapter raised interest from researchers from various disciplines, whether from religious study, scientific, or medical backgrounds. Its contribution to the medical application was promising since the intervention shows positive impacts without implications on cost and thread. However, the scientific explanation regarding its neural mechanism and synchronous effects on cognition and

emotion is a dearth. Hence, we aim to investigate the synchronous beta effects of listening to the acoustic stimulation from the Quranic Fatihah Chapter on human cognition and its neuroscientific explanation. EEG was used as a biomarker in various activities (Zainuddin *et al*., 2017), and this study was performed by conducting neuroimaging techniques using electroencephalogram (EEG) combined with multivariate analysis to see the potential of EEG as a biomarker for Quranic sound perception and its synchronous effects towards cognitive processes in the brain.

Materials and Methods

Participants

Brain electrical patterns from 28 healthy regular non-Arabic speakers, with the inclusion criteria of habitual daily Quran-listening Malay Muslims, were recorded (14 female: 14 males, mean age was 31.12 years). All participants consented before participation. The study was approved by the Human Ethical Committee at HUSM (Human Ethical Committee of University Sains Malaysia (USMKK/PP/JEPeM[234.3.(09)].

Task

Experiment was performed in sound treated chamber in the ERP/MEG Laboratory, Hospital Universiti Sains Malaysia. Participants were asked to sit in the sound-treated chamber and refrain from movement to reduce artifacts. During this experiment, participants wore headphones that connected to a computer and closed their eyes. The task required participants to listen to the sound stimulus from Fatihah Chapter, Arabic News and Rest in a random sequence but with the same specific lengths of 5, 8, 6, 6, 10, 8 and 20 seconds each at 65 dB. The Fatihah Chapter was recited by Egyptian Qari, Sheikh Abdul Basit bin Abdul Samad, recited with tajweed without tarannum while the Arabic News was taken from open source.

EEG Recording

EEG data were continuously recorded using a 128-channel Geodesic EEG System (GES) (Electrical Geodesics, Inc.), placed over the frontal, parietal, occipital and temporal lobes, following the extended version of the International 10-20 system (Klem *et al*., 1999). The local currents produced when listening to auditory stimulus were measured at a sampling rate of 250 Hz. Cz was assigned as the reference electrode. EEG signals were filtered in the bandpass range of 0.3 Hz to 50 Hz. Next, they underwent pre-processing steps of artifact detection for bad channel, eye blink and eye movement, bad channel replacement and montage operation with a Hydrocel GSN (128.1.0). The raw waveforms were then transferred into Fast Fourier Transform (FFT) to get the exported spectral power of each respondent in Delta (0.5-3Hz), Theta (4-7Hz), Alpha (8-13Hz), Beta (14-30Hz) and Gamma (31-50Hz) bands. Finally, the data were transferred to Microsoft Excel for statistical analysis.

Statistical Analysis

Pre-processing steps for the EEG data were performed to remove artifacts or outliers. Outliers or artifacts can be generated from electrical devices in the laboratory, movement of the electrodes or respondents. After the outliers were checked and removed during the pre-processing steps, the data were normalized by SPSS 21.0. Then, descriptive statistics were performed using XLSTAT statistical packages to give preliminary ideas, followed by Repeated Measures ANOVA.

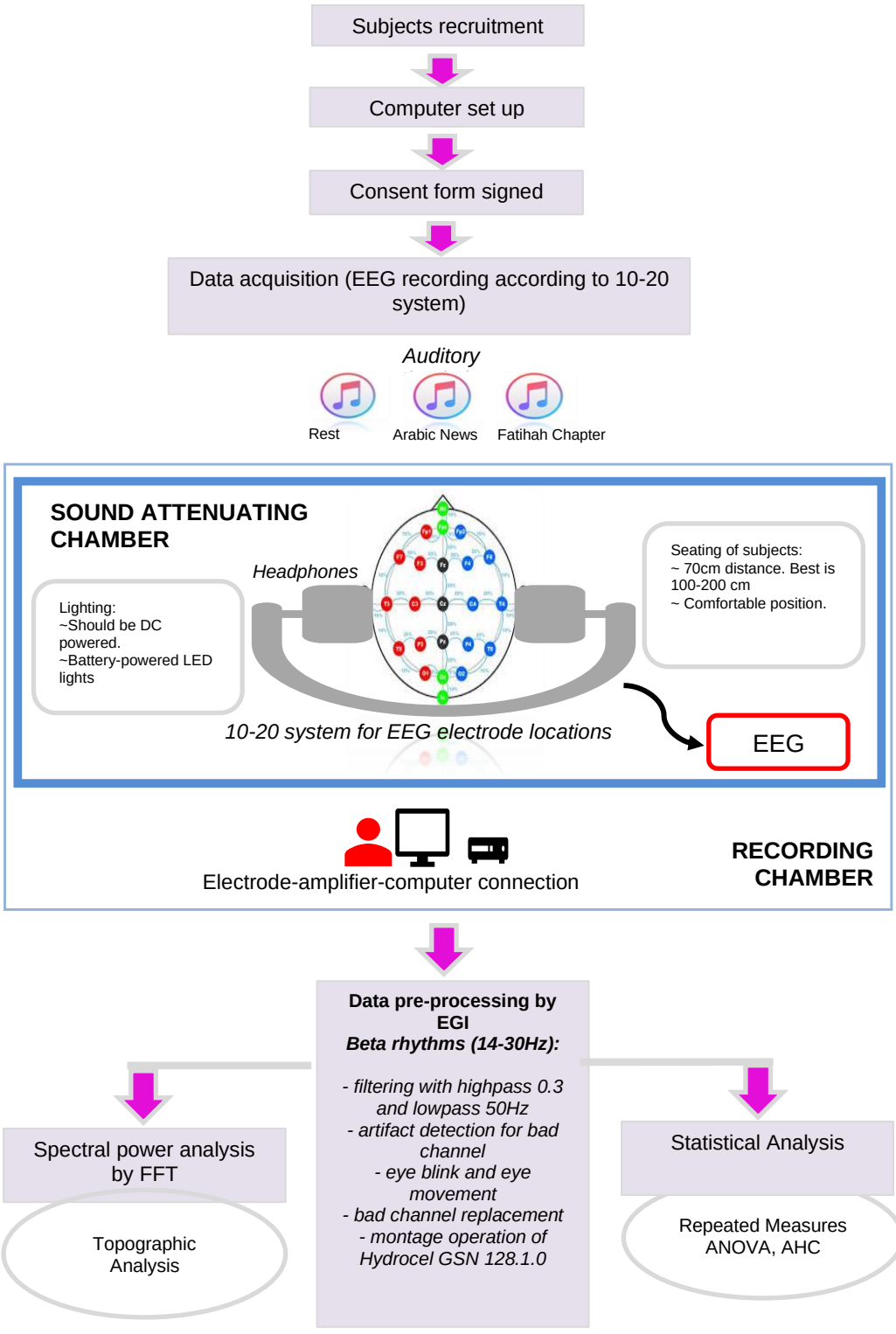

Figure 1. Flow chart of this study which involves EEG acquisition, signal processing and statistical analysis

Agglomerative Hierarchical Clustering

Cognitive processes involve oscillations between neurons in a hierarchically structure from the upper and lower level of neurons. For instance, mental imagery activity involves structures from the hippocampus, posterior cingulate cortex, dorsolateral and ventrolateral prefrontal cortex, angular gyrus, dorsal and ventral precuneus, anterior and mid-cingulate cortex, and supramarginal gyrus (Brodziak, 2013). Mathematical models are variedly used as a significant tool in understanding natural phenomena (Hussain, Madi, Iqbal, *et al*., 2021). Namely, the stochastic epidemic model was utilized to predict the COVID-19 spread (Hussain, Madi, Khan, *et al*., 2021).

This study used Agglomerative Hierarchical Clustering (AHC) analysis to stratify the EEG electrode data. AHC is an unsupervised learning classification technique that is commonly used (Massart & Kaufman, 1983)**,** which sequentially joins nodes of data with the shortest distance (Komaru *et al*., 2020), where the data were then stratified into clusters or groups with high homogeneity level within the classes and high heterogeneity level between classes concerning a predetermined selection criterion (McKenna, 2003). AHC used Ward's methods with Euclidean distances as a similarity measure (Otto 1998; Usman *et al*. 2014; Azhar *et al*. 2015). This method, also called a minimum variance method, is agglomerative and successively merges the pair of clusters that causes the smallest increase in terms of the total sum-of-squared-error (SSE). The error is defined as the Euclidean distance of a data point to its cluster mean. The rise in square-error obtained by merging two clusters, *Di* and *Dj*, as given by:

$$d\ (Di, Dj) = \sqrt{\frac{ninj}{ni + nj}}\ \{mi - mj\}$$

where the *ni* and *nj* is the number of point in each cluster, while mi and mj are the means of the points in each cluster. Hierarchical feature extraction allows for the compact representation and classification of datasets.

The results are presented by a dendograms that align the leaf nodes along the horizontal axis and connect them by lines to the higher-level nodes along the vertical axis. The position of the nodes along the vertical axis could correspond linearly to the hierarchy level *k*. However, this would reveal almost nothing of the structure of the data. Most of the structural information is contained in the dissimilarity values. One, therefore usually positions the node at level k vertically concerning the dissimilarity value of its two corresponding child clusters, Di and Dj, as follows:

$$\delta(k) = d(Di, Dj).$$

For k = n, there are no child clusters and therefore δ (n) = 0 (Jain & Dubes, 1988).
The function can be regarded as within-cluster dissimilarity. Using δ as the vertical scale in a dendrogram, a large gap between two levels, for example, k and k + 1, means that two very dissimilar clusters have been merged at level k, exposing the clusters and their proximity (Forina *et al*., 2002).

Results and Discussion

Listening to the Quranic recitation produces profound effects on human psychology and cognition as it is termed as psychoacoutic effect. However, we lack scientific data and explanations. Hence, our objective is to identify the synchronous effects of listening to the Fatihah Chapter and Arabic News on human cognition through statistical mapping. Several methods such as continuous EEG data recording, pre-processing, ANOVA and AHC were performed upon auditory stimulation to measure the spectral power changes and the synchronous effects on cognition in beta oscillations of 28 healthy normal Malay adults. This study suggested a beta power reduction in global brain areas when listening to the acoustic stimulation of Fatihah Chapter and Arabic News, indicating cortical brain activation and cognition enhancement. Beta power reduction has gained a reputation in motor and gait measurement, indicating an active cortical area. Decreased beta spectral power in sensorimotor and the parietal regions has been observed during active walking relative to standing or passive walking (when participants' legs were moved via robot) (Wagner *et al*., 2012), during step adaptation to interactive visual feedback in a virtual environment (Wagner *et al*., 2014). Beta power also decreased during the preparation and execution of movements (Pfurtscheller & Berghold, 1989; Stenner *et al*., 2016), whereas beta power increase was associated to movement suppression (Pfurtscheller & Berghold, 1989; Pfurtscheller & Lopes, 1999; Stenner *et al*., 2016). In terms of cognitive function, beta rhythm has been proposed to play a crucial role in several cognitive activities includes working memory (Simon Hanslmayr *et al*., 2016) and attention (Zimmermann *et al*., 2016).

Waveform Analysis

Table 1 shows spectral power changes due to Fatihah Chapter and Arabic News acoustic stimulations. Spectral power analysis is a well-established method for quantitative EEG signal analysis. Repeated Measures ANOVA was conducted for each participant according to the electrode channels. Results from the mean value of the Arabic News show that ten electrode channels from the frontal and parietal lobes significantly reduced its beta spectral power compared to Rest. In contrast, 13 electrode channels from the frontal, temporal, parietal and occipital lobes were significantly reduced its beta spectral power compared to Rest, indicating that desynchronization occured while listening to Fatihah Chapter and Arabic News.

Results showed that spectral power was reduced due to listening to Fatihah Chapter and Arabic News. Ten electrode channels from the frontal and parietal were decreased significantly ($P<0.05$) due to listening to Arabic News; while 13 electrodes from the frontal, temporal, parietal and occipital were significantly reduced ($p<0.05$) due to listening to Fatihah Chapter. This indicates that listening to Fatihah Chapter activated greater neural ensemble rather than Arabic News.

Table 1. Beta spectral power changes due to acoustic stimulation. The results were expressed as the mean ± S.D. The significant difference was determined by Repeated Measures ANOVA with $p < 0.05$, indicates statistically significant difference. *$p < 0.05$ versus Rest.

Lobes	Electrode sites	Stimulus (n=28)		
		Rest	Arabic News	Fatihah Chapter
		Mean ± S.D	*Mean ± S.D*	*Mean ± S.D*
Frontal	Fp1	1.243 ± 0.407	1.143 ± 0.273*	1.153 ± 3.23*
	F3	1.165 ± 0.473	0.998 ± 0.320*	0.956 ± 0.314*
	F7	1.193 ± 0.508	1.035 ± 0.402*	1.005 ± 0.390*
	Fp2	1.258 ± 0.370	1.167 ± 0.330*	1.177 ± 0.349*
	F4	1.161 ± 0.379	1.058 ± 0.254*	1.079 ± 0.277*
	F8	1.172 ± 0.455	1.102 ± 0.371	1.031 ± 0.372*
	Fz	1.052 ± 0.339	0.918 ± 0.203*	0.941 ± 0.254*
Central	C3	1.082 ± 0.384	0.971 ± 0.311*	0.936 ± 0.403*
	C4	1.076 ± 0.423	0.971 ± 0.351*	0.959 ± 0.373*
	Cz	0.981 ± 0.322	0.934 ± 0.336	0.879 ± 0.290
Temporal	T7	1.110 ± 0.421	1.084 ± 0.381	1.055 ± 0.396
	T8	1.111 ± 0.408	1.048 ± 0.344	0.976 ± 0.347*
Parietal	P3	1.015 ± 0.369	0.991 ± 0.337	0.982 ± 0.347
	P7	1.174 ± 0.329	1.144 ± 0.321	1.114 ± 0.326
	P4	1.001 ± 0.330	0.932 ± 0.298*	0.898 ± 0.295*
	P8	1.113 ± 0.357	1.031 ± 0.309*	1.031 ± 0.360*
	Pz	0.959 ± 0.360	0.940 ± 0.303	0.902 ± 0.243
Occipital	O1	1.178 ± 0.346	1.190 ± 0.389	1.098 ± 0.322*
	O2	1.136 ± 0.314	1.112 ± 0.311	1.096 ± 0.283

Topographic mapping

The oscillatory neural activity during three auditory stimulations is shown in Figure 1. These topographic maps generally showed the voltage amplitude reduction during the rhythmic acoustic stimulations compared to Rest.

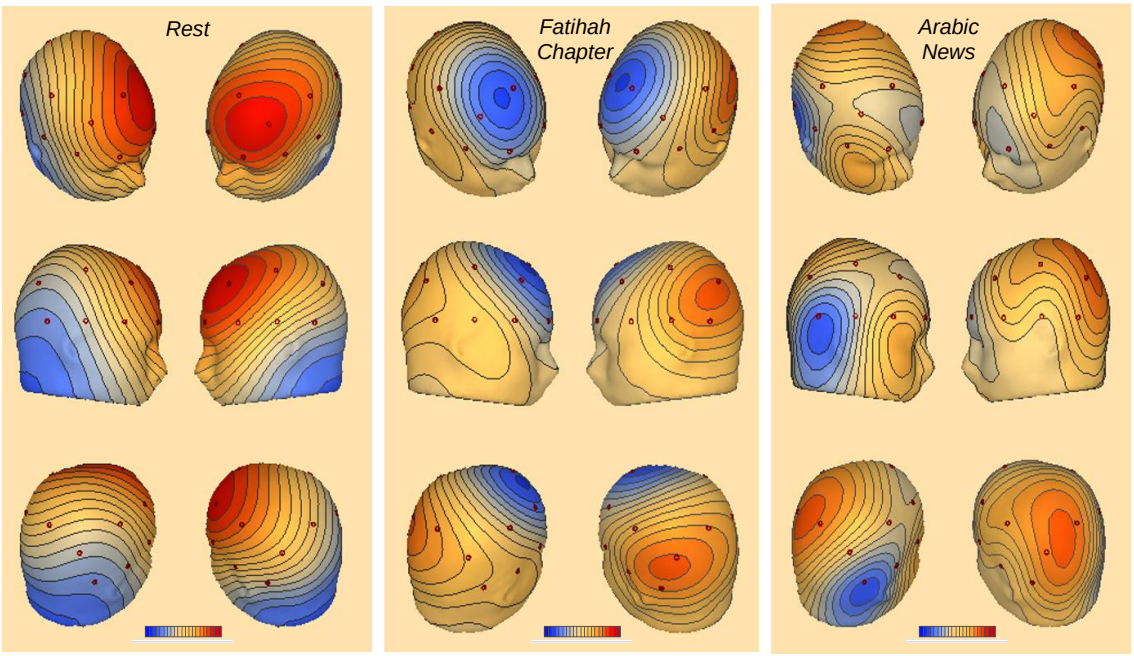

Figure 1. Whole-head voltage topographic maps. The EEG voltage maps are plotted by using BESA 6.1. after performing auditory stimulation in three conditions of Rest (left), Fatihah Chapter (middle) and Arabic News (right). Auditory stimuli were delivered by speakers. Topographic maps depict the beta power spectrum distribution over the scalp indicating the related density changes during listening to the auditory stimulation. Red buttons represent the electrode locations from 128-Hydrocel GSN (Geodesic Inc.). The voltage distributions are plotted on a color shade minimum-maximum scale from blue to red (negative polarity to positive polarity). A darker tint indicates a higher voltage value.

Clustering analysis

In machine learning and advanced data analytics, ranking is an attempt to rank things according to the relevance which is very helpful for decision making (Rosdan *et al*., 2022). The spectral power mean values were classified and ranked into three clusters using a non-supervised classification method, Agglomerative Hierarchical Clustering (AHC). During Rest, Cluster High comprised Fp1 and Fp2, Cluster Low comprised P8, O2, Pz, O1, Fz, Cz, C3, T7, P3, P7, P3 and F7, while Cluster Middle included F8, T8, F4, C4 and P4. While during Arabic News acoustic stimulation, the spectral power for those electrodes were changed. The High Cluster with average spectral power of 1.06713 was comprised of F7, F8, T7 and T8; Middle Cluster with average spectral power of 1.057061 was comprised of Fp1, F3, Fp2, F4 and Fz; and Low Cluster with average spectral power of 1.021704 was comprised of C3, C4, P3, P7, P4, P8, O1, O2, Pz and Cz. These changes showed that different neuronal activation levels occur in the different stimulations. In contrast, when listening to the rhythmic Fatihah Chapter acoustic stimulation, spectral levels were categorized into three clusters: High Cluster with average spectral power of 1.036224 was comprised of T8, P7, P8, O1, O2 and Pz; Middle Cluster with average spectral power of 1.030867 was comprised of Fp1, F3, Fp2, F4, Fz and Cz; and Low Cluster with average spectral power of 0.980962 contained F7, F8, C3, C4, T7, P3 and P4.

The significantly decreased Beta spectral levels when listening to Fatihah Chapter were in the frontal lobes for both hemispheres, the motor area, the right middle temporal, the right parietal area and the left occipital area. Those significantly attenuated brain areas were classified into three clusters of Low Cluster, Middle Cluster and High Cluster, using AHC to identify their clustering patterns or levels of activation indicated of highly activated, medially activated and moderately activated, respectively (Joundi *et al*., 2012).

Previous studies have indicated that oscillatory neural activities obtained by decomposing EEG signals into frequency-specific bands reveal communication processes between neural ensembles (Boly *et al*., 2012; O'Reilly *et al*., 2015). Low Cluster which was the most attenuated spectral power consisted of F7,

F8, T8, C3 and C4 shows that listening to the rhythmical piece of Fatihah Chapter activate brain regions related to movement control while Middle Cluster consisted of Fp1, Fp2, F3, F4 and Fz; and High Cluster consisted of P8 and O1. The hierarchical clustering technique was used in EEG signals data which involves an iteration process through which the two most similar clusters of the previous steps are merged into a new cluster. Using statistical criteria, it is possible to delimit the number of classes so that the distance between their centroids does not fall below a certain value (Ismail *et al*., 2022).

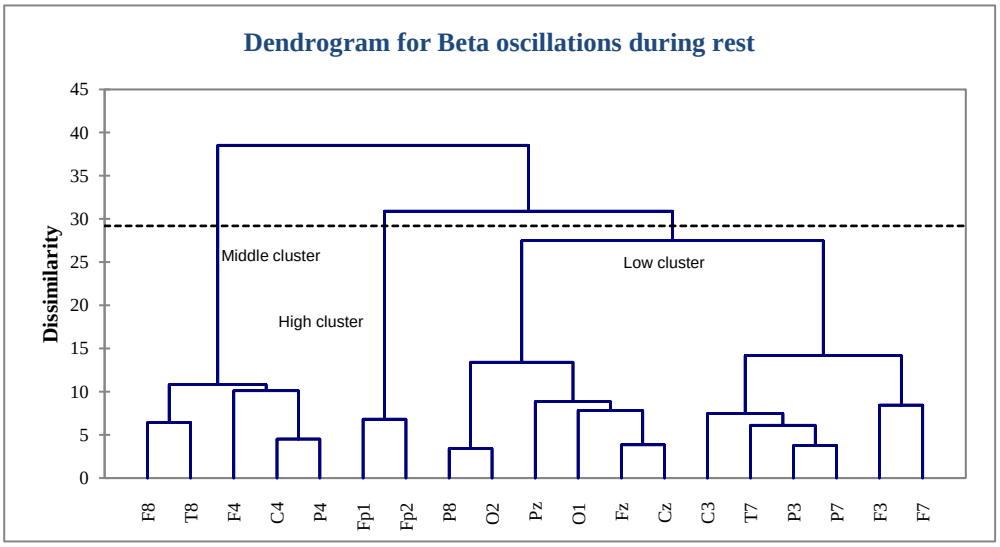

Figure 2a. Dendogram of the cluster analysis for beta oscillations during Rest using Agglomerative Hierarchical Clustering. Noted here that P8, 02, Pz, O1, Fz, Cz, C3, T7, P3, P7, F3 and F7 were in Low Cluster indicated of highly activated while F8, T8, F4, C4 and P4 were in Middle Cluster indicated of medially activated; and Fp1 and Fp2 was in High Cluster indicated of fairly activated.

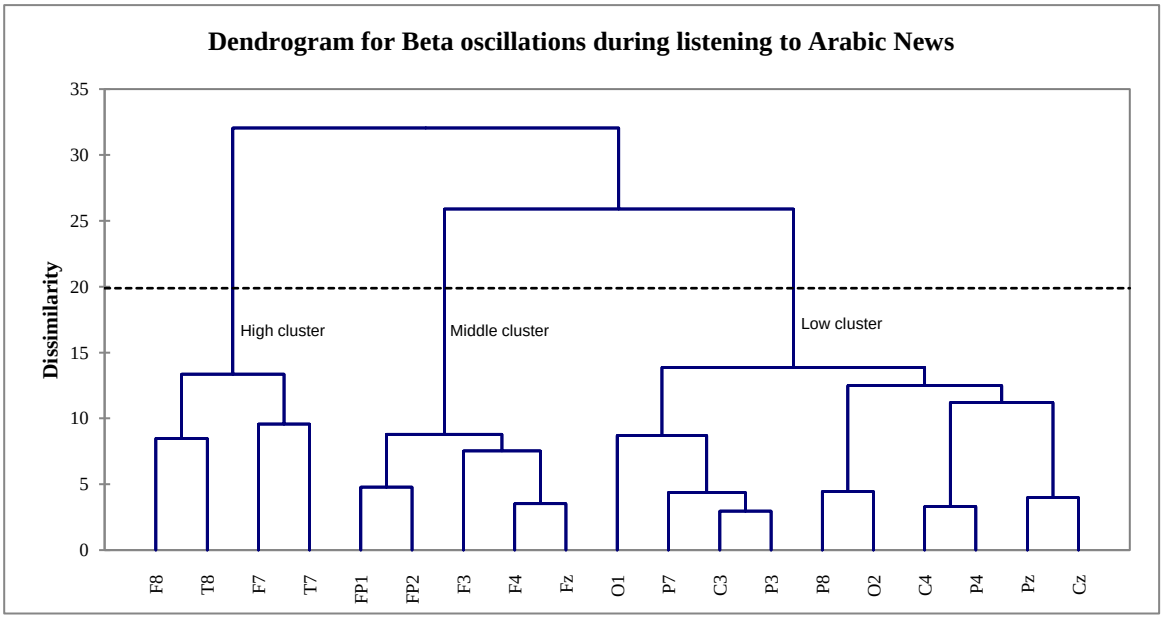

Figure 2b. Dendogram of Beta oscillations during listening to the Arabic News. Noted here that O1, P7, C3, P3, P8, O2, C4, P4, Pz and Cz were in Low Cluster indicated of highly activated while Fp1, Fp2, F3, F4 and Fz were in Middle Cluster indicated of medially activated; and F8, T8, F7 and T7 were in High Cluster indicated of fairly activated.

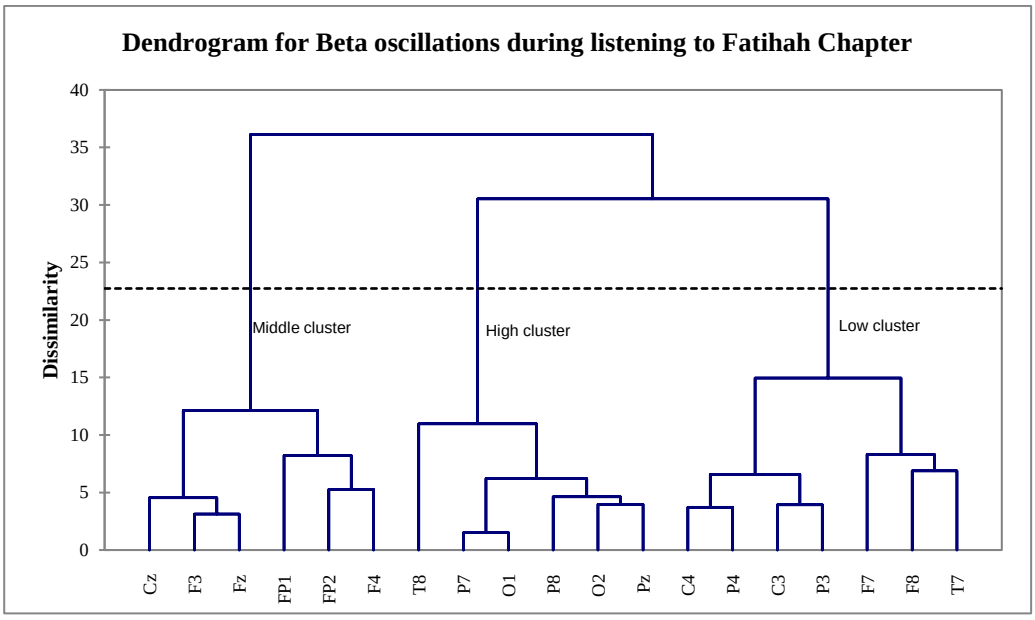

Figure 2c. Dendogram for beta oscillations during listening to the Fatihah Chapter. Noted here that C4, P4, C3, P3, F7, F8 and T7 were in Low Clusters indicated of highly activated while Cz, F3, Fz, Fp1, Fp2 and F4 were in Middle Cluster; and T8, P7, O1, P8, O2 and Pz were in High Cluster indicated of fairly activated.

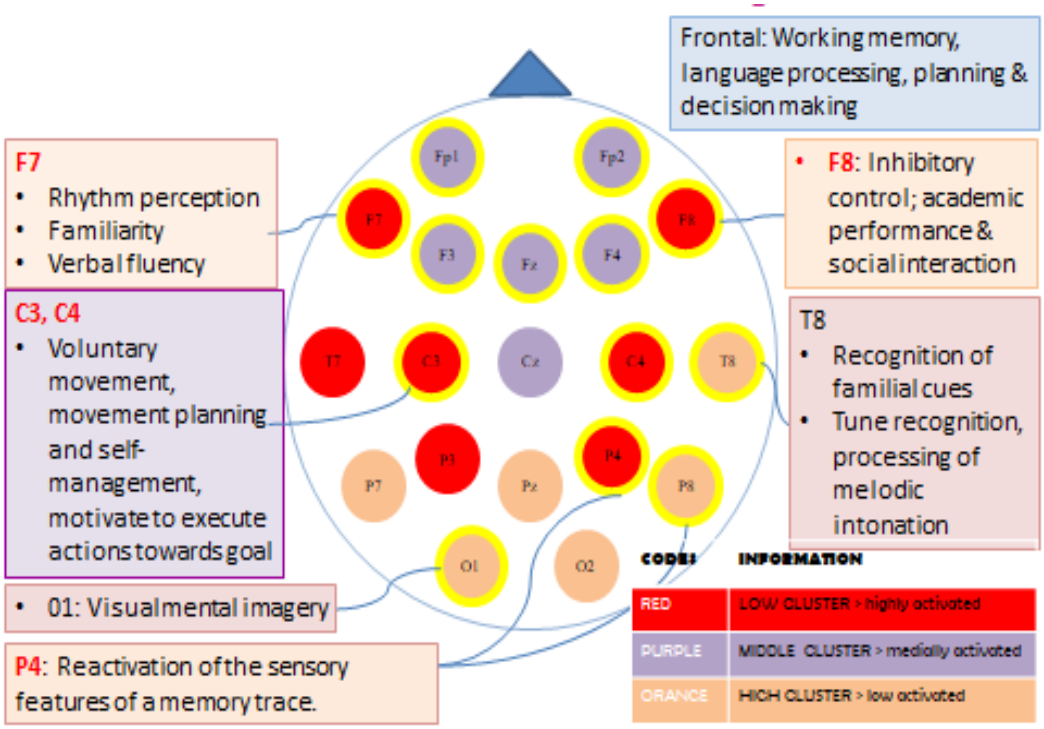

Figure 3a. Proposed model of Fatihah Chapter fronto-temporo-parieto-occipital beta network and its synchronous effects using Agglomerative Hierarchical Clustering using the 10-20 system framing. Channels surrounded with yellow colour are significantly different compared to Rest.

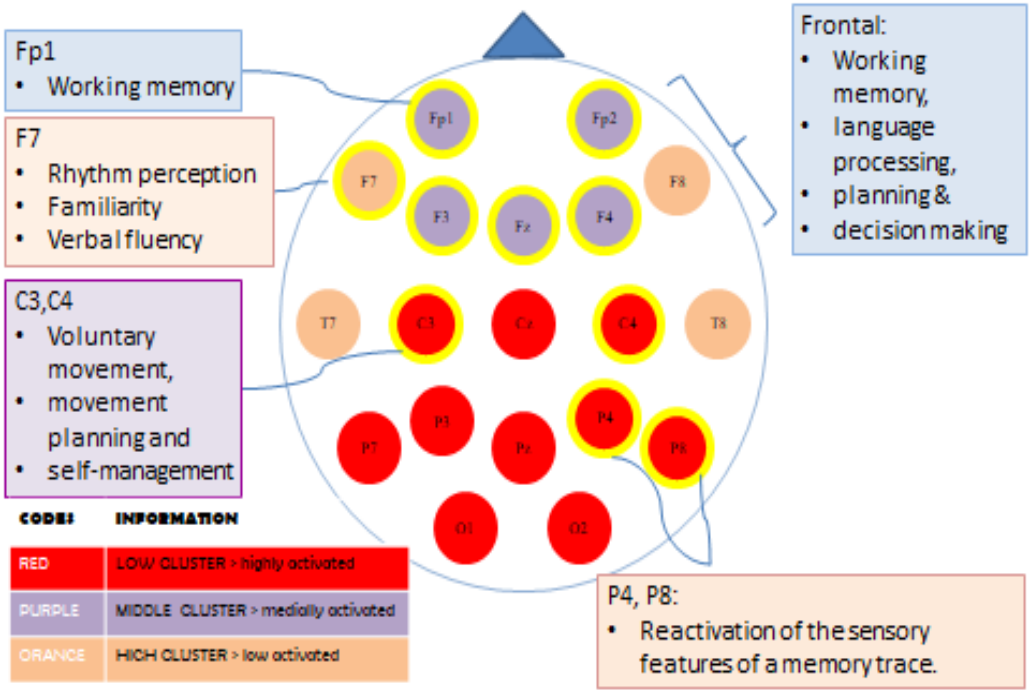

Figure 3b. Proposed model of Arabic News fronto-parietal beta network and its synchronous effects using Agglomerative Hierarchical Clustering using the 10-20 system framing. Channels surrounded with yellow colour are significantly different compared to Rest.

Generally, the whole frontal region was activated. The statistical analysis shows that the bilateral inferior frontal was significantly decreased and clustered in the Low Cluster. For Arabic News, only the left inferior frontal was significant and clustered in the Middle Cluster. The right inferior frontal was not significantly decreased. Activation of the left inferior frontal in both the Fatihah Chapter and Arabic News is believed to be related to the perceiving process of the rhythmical, temporal and sequential components of the Listening to Fatihah Chapter and also a rhythmical pattern of Arabic news. Due to the rhythm, a study using fMRI suggested that reduced activation of the inferior frontal was due to familiarity, which would decrease the recognition process. Familiarity activates an extensive network, including the inferior frontal, posterior inferior and middle temporal, medial superior frontal gyri, and the right superior temporal pole (Platel, 1997). Motor synchronization to rhythm is more active when engaging with familiar music, reflecting top-down feedback in the auditory pathway from the cortex to lower nuclei, such that familiarity leads to greater response due to anticipation of familiar sounds (Groussard *et al*., 2009).

Due to Broca's areas located nearby improved verbal fluency and increased language skills were predicted. On the other hand, the decrease in beta power also relates to successful memory formation predicting for subsequent recall (Sikka *et al*., 2015). One fMRI study also identified the inferior frontal cortex as key for successful encoding with higher BOLD activity prediction later recall (Hanslmayr *et al*., 2011). The decreased synchrony in the left inferior frontal also correlates with memory processing. Fatihah Chapter is a compulsory Chapter of the Holy Quran that is memorized and repetitively recited by Muslims daily while performing prayer. Activation indicates memory retrieval processing when listening to this recitation. Numerous studies have demonstrated that beta power decreases can be robustly observed during long-term memory tasks. Although no theoretical framework exists, its mechanisms could serve memory encoding and retrieval processes (Simon Hanslmayr *et al*., 2012). The beta decrease is also a prerequisite for information encoding; thus, this phenomenon suggests that listening to Fatihah Chapter or other rhythmic Holy Quran verses could induce long-term potentiation in neural assemblies and the retrieving process.

Activation of the right inferior frontal, which was significantly decreased and grouped in the Low Cluster, suggests that this activity helps in inhibitory control functions. The right inferior frontal has been reported to be critically involved in inhibitory control (Aron *et al*., 4 C.E.) to implement a brake over response tendencies which is important in academic performance and social interaction. Inhibition of irrelevant processing is an important function of selective attention. In contrast, disinhibition and impulsivity may relate to hyperactivity, hyperorality, loss of empathy, apathy, and executive dysfunction, including cognitive inflexibility (Aron *et al*., 4 C.E.; Hampshire *et al*., 2010). In addition, people with enhanced inhibitory control

are more successful in romantic relationships, particularly in the ability to persevere in goal-directed action despite negative emotional contexts such as sadness (Hughes *et al*., 2015). This result indicates that the inhibitory function was activated when listening to the Fatihah Chapter. Although no psychological details confirm the inhibitory role in the precise brain location, functional magnetic resonance imaging has provided spatial and temporal images with shaded light in at least four frontal regions involved in inhibitory functions: the dorsolateral, ventrolateral, rostral part of the frontal lobe and the pre-supplementary motor area (preSMA) (Song *et al*., 2016). However, when listening to Arabic News, all frontal lobe areas were activated except the right inferior frontal lobe.

The right middle temporal region was also activated when listening to Fatihah Chapter. This region is grouped in the Low Cluster, indicating that the right auditory cortex was entrained to Fatihah Chapter acoustic stimuli, which then evoke subsequent activation to several brain areas. This spectral power decrement shows a Beta modulation during encoding the predicted time following entraining periodic rhythmic stimulation of the Fatihah Chapter. Beta power decreased rapidly was in line with (Fujioka *et al*., 2012) who observed a dropped Beta signal after each stimulus tone and an increased signal before the next tone that, shows for periodicity of Beta modulation when listening to rhythmic auditory stimuli (Konishi, 2011). Such rhythmic Beta modulation also carries a predictive value of the Beta band regarding sensory entrainment (Sameiro-barbosa & Geiser, 2016). In addition, attenuation at the right temporal area indicates of recognition of familiar acoustic cues compared to unfamiliar one of the Arabic News. This is because recognition is correlated with grey matter volume at the right side of the inferior frontal and temporal area. The right temporal has been frequently reported to be involved in tune recognition. Since Fatihah Chapter has a kind of melodious intonation, we suggest that the activation at this area was due to the processing of melodic sound, including pitch contours (Sikka *et al*., 2015). Our results show that activation at the right temporal of the Fatihah Chapter strongly relates to its rhythmic and melodic intonation perceived by listeners. The right auditory hemisphere shows its dominancy in coding the Fatihah Chapter syllable envelope. The right auditory cortex is more accurate in following Quranic scripture or speech envelope contours and had larger response magnitude while following the envelope compared to the left hemisphere auditory cortex. Asymmetry was observed where the right pole was significantly different, but not the left one. Our results provide evidence that the right hemisphere auditory cortex plays an important role in Fatihah Chapter acoustic processing which is in agreement with (Patterson *et al*., 2002). This study also in agreement with (Edagawa & Kawasaki, 2017) which reported on beta oscillations network containing temporal, cerebellar and frontal areas synchronized during rhythm learning.

We also observed that the right superior parietal P4 was greatly decreased and was clustered in Low Cluster. When listening to Arabic News, this electrode also significantly reduced and clustered in Low Cluster. We learned that this area was activated greatly when listening to Fatihah Chapter and Arabic News. This result suggested that beta power decrease might reflect the reactivation of the sensory features of a memory trace. The reactivation of sensory memory may prevent interference from competing memories. Such activation in the parietal area after listening to verses describing action was observed previously by (Waldhauser *et al*., 2012). In their study, participants listened to sentences describing actions performed with the mouth and legs. Results showed that listening to action-related sentences synchronized the frontoparietal-temporal circuits relating the engagement with the visuomotor network, which underlies action execution and observation. In comparison, the inferior parietal electrode was decreased and clustered in Middle Cluster. These results suggested neuronal activation responsible for arithmetic operations and may suggest social cognition underpinning empathy and other meta-cognitive capacities (Chochon *et al*., 1999).

Many classical observations have linked rhythmic auditory stimulation to motor function activities. It was found to pronounce during steady state contractions, attenuated by voluntary movements, inhibited by mental imagery and greatest during following movements. During the preparation and execution of movements, it was replaced by the gamma band (Chochon *et al*., 1999). In our study, activation of Beta at the bilateral motor areas showed that the brain was associated with voluntary movement when listening to Fatihah Chapter, indicating that the neurons synchronize their firing activity. The rhythmical patterns of the Fatihah Chapter and Arabic News are believed to help in movement planning and execution. Fatihah Chapter shows greater activation than Arabic News. This result indicated that listening to Fatihah Chapter helps an individual in self-management, planning of action and motivation to execute the action towards the goal. It has been suggested that Beta activity in motor areas is related to both the maintenance of the current state of the network and the expectancy of forthcoming events (Engel & Fries, 2010). By activating this area, it is proposed that, concerning cognition, such desynchronization in this area was related to divergent thinking, which relates to creative potential (Engel & Fries, 2010). Activation of motor areas was higher in Fatihah Chapter than in Arabic News. Both the right and left motor areas were clustered in Low Cluster, indicating that Fatihah Chapter highly evoked motor-related functions such as motor imagery, which benefitted learning and creativity (Reedijk *et al*., 2013). The predictive role of beta activity in the

motor system was observed during Fatihah Chapter rhythms perception, where participants must extract regularities from the rhythmic acoustic stimulus of Quranic recitation. The tajweed and other rules of its unique linguistic systems predict when the next will occur (Fink & Benedek, 2014).

The Middle Cluster of beta rhythms consists of frontopolar, superior frontal and midline frontal, which shows that all the frontal lobe areas were activated due to its synchronization with the entraining Fatihah Chapter. Beta attenuation in frontal brain areas predicts speech and language processing and executive functions enhancement, including working memory, planning and decision making as the effects of its evoked potential (Bartolo & Merchant, 2015). The activation of the left occipital area, which was clustered in High Cluster along with the superior bilateral frontal, bring a prediction of activation in the visual imagery process (Ismail *et al*., 2022). Previously, de (Plakke *et al*., 2014) proposed that the superior frontal gyrus appears to have principle integrative role in visual imagery task. The frontal region integrates the information of 'what' and 'where' into a visually imagined scene. Reduced spectral power in beta frontal midline also suggests increased alertness in listeners due to attentional arousal in neuronal activity. Kamiński *et al*., (2012) suggested an engagement of the brain alert system in the Beta band to attentional arousal and increased alertness during auditory attention where they found a faster response accompanied higher EEG activation in beta band (de Borst *et al*., 2012). Activation in the bilateral prefrontal cortex suggests the superior ability of Fatihah Chapter listeners to deconstruct and organize the rhythm's temporal structure during attention and mediating working memory (Kamiński *et al*., 2012). The left occipital region (O1) was significantly decreased and was clustered in High Cluster, indicating the phenomena of 'seeing' occurred when listening to Fatihah Chapter recitation. However, no activation was observed during Arabic News.

In terms of Beta power, the decrement of spectral power supports attentional processing and generation of images. Although images were not present, this visual imagery exhibited the same mechanism of visual working memory by manipulating existing visual information (Chen *et al*., 2008) which would also suggest that mental imagery responsible for activation of autonomic nervous system and amygdala in a similar way to perception, leading to physiological changes as stated in the Quran, *"Allah has revealed the most beautiful Message in the form of a book, consistent with itself, yet repeating. The skins of those who fear their Lord tremble thereat; then their skins and their hearts do soften to the celebration of Allah. Such is the guidance of Allah. He guides therewith whom he pleases, but such as Allah leaves to stray, can have none to guide" (Chapter Az-Zumar 39:23)*. The synchronous effects of Fatihah Chapter and Arabic News listening on psychoacoustic and cognitive functions were proposed in beta network model in Figure 3a and Figure 3b, respectively.

Conclusions

As a conclusion, listening to the Fatihah Chapter could serve as an enriched environment for cognition, emotion and inhibitory control in humans. Beta rhythms synchronization with the Fatihah Chapter as associated with verbal fluency, academic performance, social interaction, inhibitory function, movement planning, self-motivation, self-management and reactivation of sensory features of a memory trace were evident as a highly activated cluster, followed by working memory, language processing and decision making as medially activated cluster; and tune recognition and visual mental imagery as low activated neural circuits cluster during listening to the Fatihah Chapter. Whilst, voluntary movement, movement planning, self-management and reactivation of sensory feature of memory trace were highly activated neural circuit, followed by working memory, language processing, planning and decision making in a medially activated cluster, and rhythm perception, familiarity and verbal fluency in the low activated cluster in Arabic News. Listening to the Fatihah Chapter activates more expansive neural ensemble involving the frontal, temporal, parietal and occipital. Further works are necessary to establish the neuromechanism underlying this phenomenon.

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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