The Neural Representation of Rhythm, Non-Rhythm and Melody Aspects in Persian Classical Music: An fMRI Study

Farzaneh Pouladi[1], Habib Ganjgahi[2], Ali Zadehmohammadi[3], Haady Ahmadzadeh[2], Mohammad Ali Oghabian[2*]

1. Advanced Diagnostic and Interventional Radiology Research Center (ADIR), Tehran University of Medical Sciences, Tehran, Iran.
2. Neuro Imaging and Analysis Group, Research Center for Molecular and Cellular Imaging, Tehran University of Medical Sciences, Tehran, Iran.
3. Family Research Institute, University of Shahid Beheshti, Tehran, Iran.

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ABSTRACT

Purpose: The perception of music relies on many culture-specific factors; nevertheless this is processed by physiological and functional attributes of the brain system. The aim of this study is to evaluate the functional activity of brain during the perception of rhythm and melody in Persian classical music using fMRI.

Methods: The test consists of two groups of Persian Modal music scales, frequently called Dastgāh. Mahour and Homayoun, in two parts of non-rhythmic and rhythmic pieces presented on 19 right-handed non-musicians.

Results: The results of this study revealed the brain activities for each of rhythmic and non-rhythmic versions of Mahour and Homayoun Dastgah. For non-rhythmic Mahour, the activation was found in right lingual gyrus, right precuneous cortex, left Inferior frontal gyrus, and left temporal lobe; whereas for rhythmic Mahour, the areas contain left supplementary motor cortex, left superior frontal gyrus, right and left precentral and postcentral gyrus, left supramarginal gyrus, and right temporal pole.

The activated regions for non-rhythmic Homayoun include right and left subcallosal cortex, left medial frontal cortex, left anterior cingulate gyrus, and left frontal pole. In contrast, for rhythmic Homayoun, alternative areas including left precentral gyrus, left precuneous cortex, left anterior supramarginal, and left postcentral gyrus were revealed.

Conclusion: rhythmic pieces were shown to activate the areas mostly involved in movement while non-rhythmic pieces related to emotional and memory regions. Although, these results are not consistent totally with the previous findings on western music, they are similar to the outcomes performed on eastern cultural subjects.

Keywords:

Persian Music,
Functional Neuroimaging,
fMRI,
Rhythm,
Non-Rhythm,
Melody.

1. Introduction

Music is an important part of human's lives and most people notice that they are spending a large part of their time listening to music [1]. Neurological studies reveal that music is a valuable tool for the evaluation of brain [2]. Music is often described as the language of emotion. Research indicates that people value music because of the type and amount of emotion that it arouses [3]. Although music has many different elements, rhythm and melody [4] are two primary and important dimensions of music [5, 6]. Some studies showed that simple altering of them can make different neural and emotional responses [7]. Basic psychological research on rhythm is directed at describing human capacities to processing temporal information [5]. Synchronized movement to music, such as clapping, tapping, dancing, singing, and ensemble performance, has been observed across all known cultures

Corresponding Author:
Mohammad Ali Oghabian, PhD
Neuro Imaging and Analysis Group, Research Center for Molecular and Cellular Imaging, Tehran University of Medical Sciences.
Tel: +98 912 1962851
E-mail: oghabian@sina.tums.ac.ir

and historical periods, which implies the universality of this aspect of human behavior [8]. Such behavior is thought to depend on the ability to infer an underlying musical "beat" or meter and to integrate rhythmic information into that metrical framework [9].

Perception and production of main features of rhythm, such as perception of duration, beat or temporal aspects, involve an allocated system of brain. Rhythm is determined solely by the relationship between the time intervals of a series of events [10]. It has been shown that the presence of a beat is associated with a greater activity in the putamen and the supplementary motor area (SMA), the premotor cortex (PMC) and auditory cortex [11]. Other studies have begun to examine the neuropsychology of timing in the production of movements [12]. For example, Halsband et al. [13] showed that lesions in the left supplementary motor cortex lead to an impairment in the reproduction of manual rhythms. One role of the motor cortex serving speech may be analogous: to coordinate oral movements with the temporal resolution needed for normal speech production [14].

The difference between rhythm and melody was found in the medial occipital lobe, the superior temporal lobe, the rostral cingulate cortex, the putamen and the cerebellum process the melodic information; whereas the lateral occipital and the inferior temporal cortex, the left supra-marginal gyrus, the left inferior and ventral frontal gyri, the caudate nucleus, and the cerebellum process the rhythmic information [15].

Mood-arousal hypothesis describes that the fundamentals of music affect the brain differently [16]. The investigation of melody shows some changes in the emotional valence along with alternation of rhythm with various tempos has some effects on the arousal intensity and valence [17]. Therefore, it is expected that performing a melody in open intervals incorporating with high tempo induces happier emotions, and vice versa a melody with high tempo but in closed intervals induces unhappier emotions. In a study using fMRI to investigate the neural effects of western classic music, it was shown an increase of BOLD signal in the ventral and dorsal striatum, anterior cingulate, parahippocampal gyrus, and auditory association areas during presentation of happy music. In contrast, sad music showed an increase of BOLD signal in hippocampus, amygdale, and similarly in auditory association areas [18]. In another study, examining two groups of musician and non-musician, the neural effects of both minor and major modes were investigated. The results revealed that in both groups the minor mode did activate some parts of brain such as amygdale, retrosplenial cortex in brain stem, and cerebellum more strongly than the major mode [19].

According to the laterality model, there is an emotional asymmetry between the two hemispheres [20-22]. More specifically, it was found that positive emotions are primarily processed in the left, whereas the negative emotions are manipulated in the right hemisphere. The impression of human, in this asymmetric feeling, depends on the musical features; Tempo and melody [23]; so that fast and major excerpts elicit a sense of happiness while slow and minor excerpts elicit a sense of sadness [24]. Rhythm processing might be linked to left hemisphere language mechanisms in the musically trained. In a neuroimaging study of six subjects attempting to reproduce auditory rhythms, the authors found left-sided hemispheric lateralization in non-musicians for integer-based rhythms. Taken together, our findings support the notion that integer-based rhythms (which were also quantized and easier to reproduce) lead to relatively a greater activity within the left hemisphere [25]. A number of studies have shown that the left cerebral hemisphere is involved in rhythm processing [26-30], but others indicated that the processing of rhythm is not clearly lateralized [31, 32].

Persian traditional music embodies two distinct types: the rural folk music and the urban art Music, known as Persian classical music [33]. Current study attempted to investigate rhythmical aspects of Persian classical music. Persian classical music is organized into twelve 12 principal modal systems; seven of which are known as basic modal structures, called the seven "Dastgah". They are: Shur, Mahour, Segah, Chahargah, Homayoun, Nava, and Rast-Panjgah. The remaining five are commonly known as secondary Dastgahs or Avaz. Four of them: Abouata, Dashti, Bayat-e Turk and Afshari are considered to be derivatives of Shur. Persian musicians commonly consider Bayat-e Esfahan to be a derivative of dastgah-e Homayoun. [33]. The individual pieces in each of the twelve principal modal systems are called "Goucheh". Within certain modal restraints, the music is fluid, subjective and highly improvisatory. It is rhythmically, also generally, free and flexible, and much of the music and Guochehes are unmeasured and cannot assigned to a stable metric order. The wealth of this music, therefore, is not in complex rhythmic patterns, nor in polyphony, which it does not employ, but in the many modal possibilities and the cultivation of highly embellished melodies. However, in every Dastgah, there are a number of metrically regulated Gouchehs which are played among the free meter pieces in order to provide a periodic variety in rhythmic effects.

The most important thing that distinguishes Persian music from western music is the difference in their intervals; especially the existence of quarter tones which cause formation of 7 different Dastgah and 5 sub-classes in Persian music. Each of the twelve system has its own scale, its own special degree of the scale where the melodies center and where they stop, and its own group of traditional melody pattern. Much of the Persian pieces are unmeasured, have no beat, but proceed with systems of rhythmic cycles akin to that of speech. This music is well suited to the basic philosophical nature of the Persian people. It is important to know that the base of this music is on a free rhythm. The use of micro-intervals plus the free floating unmeasured rhythm and the particular tone of the instruments and voice create a quality of sadness for the western listeners. Similar to most seven main Dastgahs, both Mahour and Homayoun may be rhythmic or non-rhythmic while comprising melody sense. Since the rhythm itself changes the sensational effect of a melodic based music, we evaluate the On/Off effects of rhythm on two such main dasigahs, i.e.; Mahour and Homayoun. Moreover, since Mahour is known as a happy music and Homayoun as a sad and mysterious music, we are able to assess the effect of rhythm in two behavioral states.

2. Objectives

As expected, the perception of music relies on many culture-specific factors; nevertheless this is processed by physiological and functional attributes of the brain system. The present study aims to distinguish between brain activities involved in melodic and rhythmic processing using functional magnetic resonance imaging (fMRI). It is important to achieve further insights into brain mechanisms during processing of emotions induced by listening to a well-known Persian classical music, and to check whether the neural and emotional effects of this music is similar to that of well-defined western classic music.

3. Methods

3.1. Subject

Nineteen right-handed healthy participants (10 males: mean age 24.80, SD 2.09; 9 females: mean age 27.44, SD 2.78; group: mean age 26.05, SD 2.73) were recruited among students who had no previous training in musical instruments.Before scanning, all participants were screened for neurological disorder, head injuries, depression and current or past psychiatric disorders by using clinical interview, General Health Questionnaire (GHQ) and Beck Depression Inventory (BDI).The instrumental and control handedness was assessed using the Edinburgh inventory.Participants gave informed consent to the proceedings during the experiment, which were approved by the ethics committee of the Tehran University of Medical Sciences.

3.2. Music Stimuli

Eight pieces from Homayoun and Mahour were presented in two parts of rhythmic and non-rhythmic. Although Mahour scale is somehow similar to the western major scale, additional chromatic tones are added for the principal Gouchehs. We have selected Homayoun because of its historically usage in requiems and lamentations. So, there are two tasks Homayoun and Mahour and each task has two parts, rhythmic and non-rhythmic, that is performed as every other. The stimulus was presented in block design with random choosing of pieces in activity parts to the subjects. They listened to the pieces in active blocks during 30 second. After that, they did not listen to anything in rest sections during 30 second (diagram.1). According to the task, it has been used repeated measure design. In a repeated measures design, each subject participates in every condition of the experiment.

In order to avoid novelty effects, participants were familiarized with the musical stimuli one week prior to the fMRI scan. During the activation period, partici-

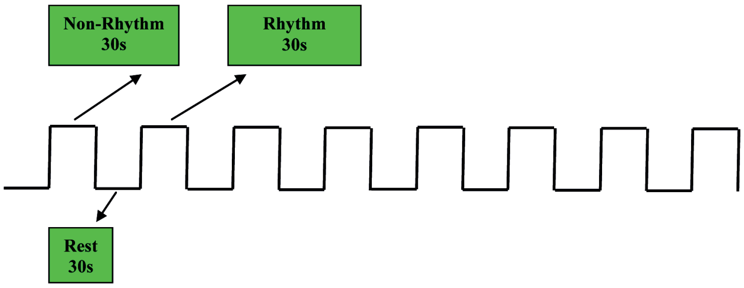


Diagram 1. The task of music with active and rest blocks.

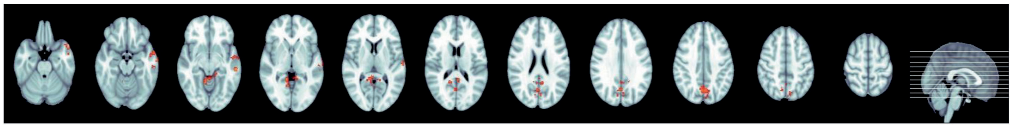
pants were instructed to lie in the scanner and listen consciously to the music. In the rest period, they were asked to rest quietly and wait for the music to begin again.

3.3. Imaging Protocol

Functional MR images were acquired on a 1.5 T standard clinical scanner (SIEMENS AVENTO) using echo-planar imaging (EPI) with a T2*-weighted gradient-echo multi-slice sequence (TR=1800 ms, TE=60 ms, Flip Angle=90, Pixel size=3×3 mm, matrix= 64 × 64, Slice thickness=4mm, and Bandwidth = 15.62 KHZ). T1 3D weighted images were obtained for registration of fMRI data to the brain's structural map (TE = 4200 ms, TR = 9850 ms, slice thickness = 1 mm, bandwidth= 61 KHZ and flip angle=30).

3.4. Data Preprocessing

Before data analysis, some preprocessing steps were performed: 1) head motion correction using MCFLIRT (Motion Correction using FMRIB's Linear Image Registration Tool), 2) slice-timing correction using Fourier-space time-series phase-shifting, 3) mean intensity normalization of the entire 4D dataset by a single multiplicative factor, 4) spatial smoothing using a Gaussian kernel of FWHM of 5 mm, 5) brain extraction to remove non brain tissues using Brain Extraction Tool (BET, Version 1.1), 6) high-pass temporal filtering (Gaussian-weighted least-squares straight line fitting, with sigma = 100 s).



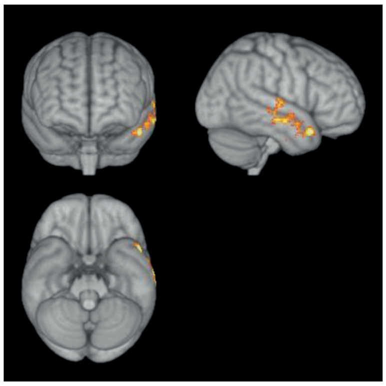
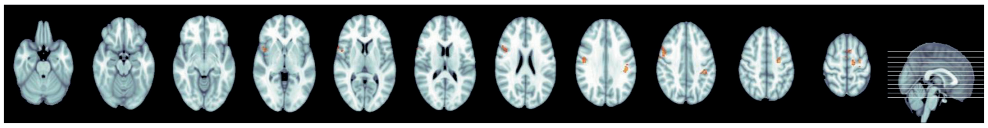


Figure 1. Statistical activation maps for the non-rhythmic Mahour. Images are coronal (left), sagittal (right), axial (low) sections. The activities are seen into both hemispheres especially in temporal lobes.

Table 1. Talairach coordinates and Zscores for the brain regions in subtraction analyses in non-rhythmic versus rhythmic Mahour. .

	Areas	Side	Lob	Z score	x	y	Z
Non-rhythmic Mahour	Lingual Gyrus	R	Occipital	3.12	12	-48	0
	Precuneous Cortex	R	Parietal	3.01	2	-66	42
	Lingual Gyrus	R	Occipital	2.97	8	-54	-8
	Precuneous Cortex	R	Parietal	2.92	14	-52	16
	Lingual Gyrus	R	Occipital	2.9	10	-50	-10
	Inferior Frontal Gyrus	L	Frontal	3.84	-52	14	-28
	Middle Temporal Gyrus, posterior	L	Temporal	3.32	-68	-12	-16
	Superior Temporal Gyrus, posterior	L	Temporal	3.09	-58	-30	-10
	Middle Temporal Gyrus, anterior	L	Temporal	3.02	-50	-2	-30
	Middle Temporal Gyrus, posterior	L	Temporal	3	-68	-22	-14
	Middle Temporal Gyrus, anterior	L	Temporal	2.81	-64	2	-24



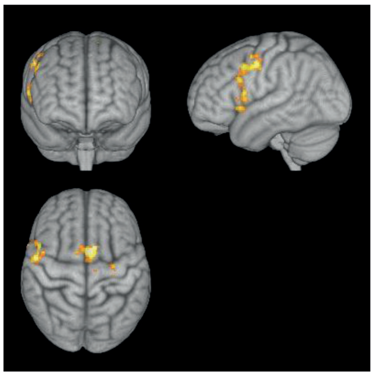


Figure 2. Statistical activation maps for the rhythmic Mahour. Images are coronal (left), sagittal (right), axial (low) sections. The activities are seen in both hemispheres especially in parietal lobes.

Table 2. Talairach coordinates and Z scores for the brain regions in subtraction analyses in rhythmic versus non-rhythmic Mhour.

	Areas	Side	Lob	Z score	x	y	Z
Rhythmic Mahour	Supplementary Motor Cortex	L	Frontal	3.4	-4	2	62
	Superior Frontal Gyrus	L	Frontal	3.24	-8	6	66
	PrecentralGyrus	L	Frontal	3.2	-28	-14	50
	PostcentralGyrus	L	Parietal	3.01	-40	-34	40
	SupramarginalGyrus, anterior	L	Parietal	3.01	-46	-28	28
	PrecentralGyrus	R	Frontal	3.11	54	-4	42
	PrecentralGyrus	R	Frontal	2.86	50	12	26
	PostcentralGyrus	R	Parietal	2.8	48	-16	34
	Temporal Pole	R	Temporal	2.7	52	14	-4

3.5. Single Data Analysis

FMRI data processing was carried out using FEAT (FMRI Expert Analysis Tool) Version 5.98, part of FSL (FMRIB's Software Library, www.fmrib.ox.ac.uk/fsl).

Time series statistical analysis was carried out using FMRIB's Improved Linear Model (FILM) with local autocorrelation correction. Regressors were modeled for conditions of interest (non-rhythmic stimuli and rhythmic stimuli) using a canonical hemodynamic response function with a temporal derivative. Contrasts at this level examined whether the parameter estimate (PE) of the hemodynamic response to non-rhythmic pieces was greater than the PE for the hemodynamic response to rhythmic pieces and vice versa. These contrasts were used in a higher level analysis.

3.6. Group Analysis

Higher level analyses were carried out using FMRIB's Local Analysis of Mixed Effects (FLAME). Mean activity of each contrast were computed. Z (Gaussianized T/F) statistic images were thresholded using cluster detection statistics, with a height threshold of $z>1.8$ and a cluster probability of $p=0.05$, corrected for whole-brain multiple comparisons based on the Gaussian Random Field Theory (GRFT). Paired sample t test was used to explore differences between rhythmic and non-rhythmic contrasts in each task.

4. Results

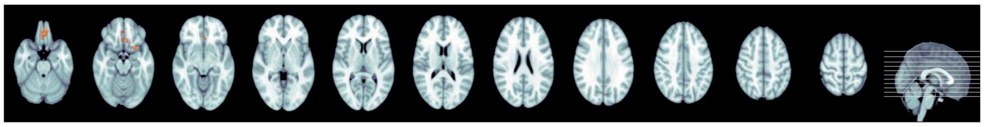
4.1. Activation Regions

The main effect contrast for non-rhythmic Mahour processing (non-rhythm>rhythm) revealed a brain activity in occipital and parietal lobes (see table1). The most statistically significant local maximum of activation was in left inferior frontal gyrus; also both of hemispheres were activated by non-rhythmic Mahour. Other significantly activated regions included right lingual gyrus, right precuneous cortex, left Inferior frontal gyrus, left middle temporal gyrus, and left superior temporal gyrus. The locations and Z-scores of peak activation in these are shown in table 1.

Brain activations revealed in the main effects for rhythmic Mahour (rhythm>non-rhythm) were shown in frontal and parietal areas (see table 2). The most statistically significant local maximum of activation was in left supplementary motor cortex. Other significantly activated regions included left supplementary motor cortex, left superior frontal gyrus, right and left precentral gyrus, right and left postcentral gyrus, left supramarginal gyrus, and right temporal pole. The rhythm contrast was found generally to be bilateral in both hemispheres. The locations and Z-scores of the peak activation are shown in table 2.

The brain contrast activity obtained by the non-rhythmic Homayoun (non-rhythm>rhythm) showed a high level of activity in regions of frontal and limbic lobes. As shown in table 3, the left hemisphere has been mainly activated by a non-rhythmic contrast in Homayoun. The most statistically significant local maximum of activation was in left subcallosal cortex. Other significantly activated regions included right and left subcallosal cortex, left medial frontal cortex, left anterior cingulate gyrus, left frontal pole. The locations and Z-scores of the peak activation are shown in table 3.

For a contrast of rhythmic Homayoun (rhythm>non-rhythm), significant BOLD responses were observed in frontaland parietal lobes. As shown in table 4, a contrast activation of rhythmic Homayoun has lateralized mainly in left hemisphere. The most statistically significant local maximum of activation was observed in left precentralgyrus. Other significantly activated regions included left precentral gyrus, left precuneous-cortex, left anterior supramarginal, left superior parietal lobe, and left postcentral gyrus. The locations and Z-scores of peak activation in these regions are shown in table 4.



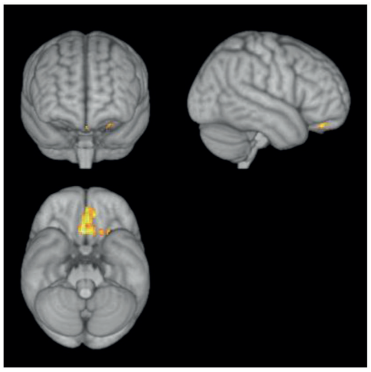
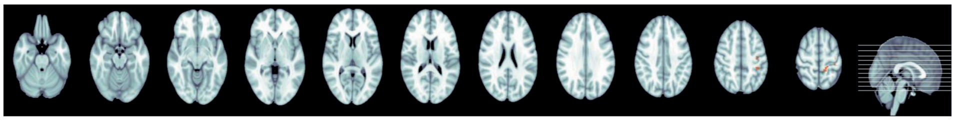


Figure 3. Statistical activation maps for the non-rhythmic Homayoun. Images are coronal (left), sagittal (right), axial (low) sections. The activities are seen both hemispheres in left side of frontal and limbic lobes.

Table 3. Talairach coordinates and Z scores for the brain regions in subtraction analyses in non-rhythmic versus rhythmic Homayoun.

	Areas	Lob	Side	Z score	x	y	Z
Non-rhythmic Homayoun	Subcallosal Cortex	Frontal	R	3.46	4	22	-22
	Medial Frontal cortex	Frontal	L	3.15	-2	36	-26
	Subcallosal Cortex	Frontal	L	2.88	-2	26	-14
	Cingulate Gyrus, anterior	Limbic	L	2.83	-6	26	-14
	Frontal Pole	Frontal	L	2.78	-8	40	-26



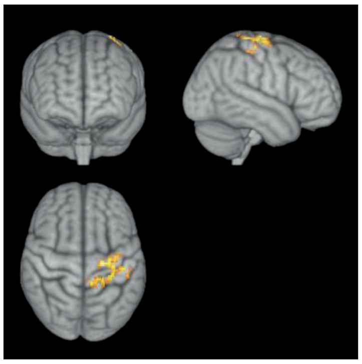


Figure 4. Statistical activation maps for the rhythmic Homayoun. Images are coronal (left), sagittal (right), axial (low) sections. The activities are only seen into the left hemisphere in parietal lobe

Table 4. Talairach coordinates and Z scores for the brain regions in subtraction analyses in rhythmic versus non-rhythmic Homayoun.

	Areas	Lob	Side	Z score	x	y	Z
Rhythmic Homayoun	PrecentralGyrus	Frontal	L	3.35	-20	-20	72
	Precuneous Cortex	Frontal	L	3.18	-14	-42	56
	Supramarginal, anterior	Parietal	L	2.89	-20	-38	68
	Superior Parietal Lobule	Parietal	L	2.88	-34	-36	54
	PostcentralGyrus	Parietal	L	2.8	-30	-34	70
	PrecentralGyrus	Frontal	L	2.78	-32	-24	68

4.2. Results of ROI Analyses

In the second level analysis, we tested an interaction of rhythm and melody using both whole brain analyses and region of interests (ROIs) analyses. In the whole brain analysis, the hemodynamic responses of Mahour and Homayoun calculated for each subject were tested with a paired sample t-test to detect the difference between rhythmic Mahour and non-rhythmic Homayoun. According to the ROI analyses, both supplementary motor cortex and precentral gyrus showed a significant contrast between rhythmic Mahour and non-rhythmic Homayoun. In addition, they showed a significant activation in subcallosal cortex area during non-rhythmic Homayoun stimulus (Table 5).

Table 5. Regions of interest (ROI) that show interaction of rhythm and melody by differential activation between rhythmic Mahour and non-rhythmic Homayoun.

Pieces	Area	Side	Std. Deviation	Significant
Rhythmic Mahour> Non-rhytmicHomayoun	Supplementary Motor Cortex	0.1742914	0.11092125	0.002
		0.0163311	0.14069656	
	PrecentralGyrus	0.1436265	0.09648204	0.0004
		0.0092734	0.06931700	
Non-rhytmicHomayoun> Rhythmic Mahour	Subcallosal Cortex	0.4149684	0.46581838	0.053
		0.1227389	0.34104762	

5. Discussion

This study assessed the neural regions which are responsible for the emotional processing involved in listening to rhythmic and non-rhythmic Persian music. Based on our study, the results of the rhythmic versus non-rhythmic stimuli showed a larger activity contrast in left hemisphere for Homayoun and in both hemispheres for the Mahour.

According to the mood-arousal hypothesis, the rhythmic pieces in major mode should convey happiness and calmness, whereas non-beat pieces in minor mode are expected to convey sadness [6]. Moreover, based on the laterality model, positive emotions such as happiness would present a greater activity in left hemisphere; and negative emotions such as sadness would do relatively a greater activity in right hemisphere [34, 35].

We did not see a better activation of rhythmic pieces in the left hemisphere, nor in the right hemisphere, activation of non-rhythmic stimulus. In this respect, our results did not show an anticipated valence lateralization model. This disparity can be due to the nature of Persian music, especially regarding its emotional differences of the musical pieces. Moreover, we are concerned about the cultural differences between Persian music and the Western.

Further to a greater involvement of left side during Homayoun and Mahour stimuli, the activity of areas related to emotion and reward such as anterior cingulated gyrus, frontal pole, and subcallosal revealed that even sad music in Persian style reminding spiritual narration can be pleasurable in the same way of the happy music. According to the ROI analyses, it was shown that rhythmic pieces with an open interval effect on motional areas and non-rhythmic pieces with a close interval effect on the emotional are as correlated to the results as obtained from the whole brain.

Subcallosal, frontal pole, anterior cingulated, middle temporal gyrus regions have all been implicated in emotional processing [36-40]. Blood et al [38] showed that the activity in the subcallosal region decreased with sad, whereas it increased with happy stimuli. It has also been shown that those lesions in subcallosal and other ventral medial prefrontal regions are correlated with the damage of emotional expression [41]. Superior temporal gyrus is also activated by emotional music, but it is different between two hemispheres. In other context, Maddock et al. revealed that the left frontal pole was activated during the valence evaluation of pleasant words compared to neutral words. Activation in this region was not observed in the unpleasant words. This region is expected to have a particular role to positive emotional processes [42].

There are some music studies, performed in eastern cultural subjects [37, 43]. In a research carried out in Japan, Suzuki et al [37] have observed pleasure evoked by the minor key in music related to reward; provoking strong emotions in humans. All these studies show earliest experiences that believe eastern and western music may have different influences on the brain. However, additional investigation is required for examination of the correlation between the neural networks and culture during perceptions of rhythm and melody.

The current study has widely revealed a distributed neural network involved in rhythm perception. A number of regions including postcentral gyrus, precentral gyrus, anterior supramarginal gyrus, and supplementary motor cortex are associated with the temporal aspects of stimulus processing. Although in our study the subjects listened to rhythmic music without moving and beating, the rhythm activated areas of cortex involved in movement generation. So rhythm can easily evoke the imagination of movement required to produce it. Activations in areas of supra-marginal and post-central gyrus have been reported to be involved in processing the fundamental physical properties of sound [44] and rhythmic information [15]. Lesions of the left supramarginal area were shown to cause disrupted attention to motor acts and planning of consecutive movements [45, 46]. Porro et al (1996) showed that functional activity increased in post-central and pre-central gyrus during mental representation (motor imagery) of a simple sequence of finger movements[44]. The results of these studies demonstrated that activity in supplementary motor areas is correlated with the measure of rhythmic power derived from the music [47, 48]. Halsband et al [13] revealed that lesions in the left supplementary motor cortex lead to a deficit in the reproduction of manual rhythms. Besides, this area has been shown in musical imagery studies [49, 50] which demonstrates motor imagery [51]. When listening to music, we often spontaneously coordinate our body movements to a rhythm's beat [52, 53]. This so called cross-cultural response implies a universal beat-timing mechanism, potentially intervened by motor brain regions [54].

The areas related to memory were also activated in our studies. Inferior frontal gyrus, Precunous cortex, and medial frontal cortex are regions that deal with the memory. Neuroimaging studies found that left inferior frontal gyrus and precunous cortex are associated with episodic retrieval of music, memory retrieval, as well as mental imagery [55-58]. Other areas such as medial frontal cortex and middle temporal gyrus are related to semantic memory [56]. Listeners often use music to remind them of past events [3]. It is obvious why a piece of music is called pleasurable or unpleasurable, because of a happy or sad memory in the past [3]. Music seems to be a very effective cue in bringing emotional experiences from memory back into consciousness [59] and it can be related to the kind of music. There are studies that investigated the effects of musical mood induction on memory. These studies have mentioned that music often evokes memories [60, 61]. We know when the memories are evoked, it is related to emotions [61, 62] and the physiological reaction patterns are often made by reviewing some memories [63]. Researches show that positive affect could improve episodic memory [64]. It has been found that in spite of the impact of happy music on memory, sad music has no significant effect on recalling memory. It may reflect the fact that people typically organize materials for memory storage in terms of positive but not negative feelings. This does not mean that materials are never organized in a negative affective tone, but rather most people do not use negative feelings for memory organization and storage [65].

In the current study, Persian classical music was considered as a part of Persian culture in which Avaz (flexible and free rhythm) constructs its principle sections, and most our people are familiar with this music and have emotions and memories related to it. The increased activation of these areas in the non-rhythmic pieces shows that the type of the rhythm especially music in a free rhythm can be associated with memories while these pieces have involved left hemisphere, particularly in the regions that are related to emotions. This means non-rhythmic pieces produce emotions with a sense of pleasure and enjoyment, along with a review of memories related to emotions. However, the major limitation of this study was the lack of behavioral studies which was left for the future studies with a larger number of subjects.

Conclusion

Rhythmic pieces in Persian music were shown to activate the areas mostly involved in movement while non-rhythmic pieces were related to emotional and memory regions. The results found in our work are consistent to the outcomes obtained on east cultural subjects. Since non-rhythmic pieces have been involved mostly in emotional related regions in left hemisphere, it can be concluded that these pieces produce emotions with a sense of pleasure and enjoyment, along with a review of memories related to emotions.

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