Homayoun as a Persian Music Scale on Non-Musician's Brain: an fMRI Study

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A B S T R A C T

Introduction: The aim of this study was to get to a neurological evaluation of one of the Persian music scales, Homayoun, on brain activation of non-musician subjects. We selected this scale because Homayoun is one of the main scales in Persian classical music which is similar to minor mode in western scales.

Methods: This study was performed on 19 right handed subjects, Aging 22-31. Here some pieces from Homayoun Dastgah are used in both rhythmic and non-rhythmic.

Result: The results of this study revealed the brain activities for each of rhythmic and non-rhythmic versions of Homayoun Dastgah. The activated regions for non-rhythmic Homayoun contained: right and left Subcallosal Cortex, left Medial Frontal cortex, left anterior Cingulate Gyrus, left Frontal Pole and for rhythmic Homayoun contained: left Precentral Gyrus, left Precuneous Cortex, left anterior Supramarginal, left Superior Parietal Lobule, left Postcentral Gyrus. Also, we acquired amygdala area in both pieces of music.

Discussion: Based on arousal effects of rhythm and Damasio's somatic marker hypothesis, non-rhythmic Homayoun activates regions related to emotion and thinking while activity of rhythmic Homayoun is related to areas of movement and motion.

1. Introduction

Neurological studies reveal that music is a valuable tool for the evaluation of brain (Peretz & Zatorre, 2005). Music is often a way to motivate people to accomplish particular tasks, and a means of mood regulation (Levitin, 2007). Music is closely related to emotions and arousal. Evidence proposed that music modulates emotional arousal as indexed by alteration in electrodermal, cardiovascular and respiratory activity (Bernardi et al., 2006; Gomez and Danuser, 2007).

There are many elements of music, but rhythm (or tempo) and melody (or mode) are two primary and important dimensions of music (Krumhansl, 2000; Khalfa et al, 2005). Rhythm refers to temporal variations; melody refers to pitch variations (Pietro et al, 2004). Although melody and rhythm are principal in creation of emotion, some researchers believe that rhythm plays a more important role in inducing of emotion (Bernardi et al., 2006). Studies show that presence of rhythm is associated with greater activity in the putamen and the supplementary motor area (SMA), the premotor cortex (PMC) and auditory cortex (Grahn & Rowe, 2009; Popescu et al., 2004).

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Together with the neurological effect of rhythm on brain, some studies showed that simple altering of initial musical components can make different emotional responses (Kallinen, 2003). The investigation of music shows some changes in the emotional valence along with alternation of rhythm with various tempos has some effects on the arousal intensity and valence. So, along with increasing of rhythm, music will induce more emotion and pleasure (Gomez & Danuser, 2007). In a study using fMRI with the aim of investigating the neural effects of west classic music, it was shown increase of BOLD signal in the ventral and dorsal striatum, anterior cingulate, parahippocampal gyrus, and auditory association areas during presentation of happy music as music with strong emotion. With sad music, increase of BOLD signal responses were noted in the hippocampus/amygdala and auditory association areas (Mitterschiffthaler, 2007).

One of the most known theories of emotional perceptions is Damasio's "somatic marker hypothesis" (Damasio, 1994). This model claims that comprehension of changes in body states form feelings. So, Somatic states can be induced from primary inducers, and secondary inducers (Damasio, 1995). Primary inducers are inborn or learned stimuli that cause enjoyable or repulsive states. Once present in the immediate environment, they automatically elicit a somatic response. Secondary inducers are generated by the recall of a personal emotional event such as thoughts and memories of the primary inducer, which when brought to working memory elicit a somatic state (Bechara & Damasio, 2005). According to this model, at first the stimulus is comprehended by related cortex, then amygdala and Ventromedial prefrontal (VMPF) analyze perceived stimulus. The relation of these two areas and the total emotional inducements cause some body changes via automatic neural system, motor system, peptide and endocrine systems and extra activity of neurotransmitters (Bechara & Damasio, 2005). Music could act as a primary inducer; that means the elements of music _such as rhythm _make an initial emotional reaction. On the other hand, if music recalls previous memories, it could affect as a secondary inducer (Jonsen, 2004).

Persian classic music is the traditional and indigenous music of Iran. Iranian classic music relies on improvisation and composition and is based on a series of modal scales and tunes which must be memorized. The classic repertoire encompasses a body of ancient pieces collectively known as the "Radif" of Persian music. These pieces are organized into twelve groupings, seven of which are known as basic modal structures and are called the seven "Dastgah" (system). The individual pieces in each of the twelve groupings are generally called "Gushe". Rhythmically, the majority of Gushe is flexible and free and cannot be assigned to a stable metric order that is called "Avaz". However, in every Dastgah, there are a number of metrically regulated gushes which are played among the free meter pieces in order to provide periodic variety in rhythmic effects. Indeed, except for several brief pieces in each Dastgah that have definite rhythms, its majority consist of pieces that no weight that have non common definition from rhythm The most important thing that distinguishes Persian music from western music is in their intervals; especially there is quarter tone that forms the twelve groupings in Persian music.

Homayoun is one of the most fundamental Dastgah in Persian music that is similar to minor scale in west music.

The present study is aimed to evaluate neurological effects Homayoun on brain. So, firstly, we want to know what the neurological effect of rhythm on brain is.

Secondly, according to the studies which showed the arousal effect of rhythm on brain, the question is, whether rhythm in Persian intervals causes pleasure and emotion reaction as the west music does.

And finally, Under Damasio' model, it is our hypotheses that Homayoun with rhythmic element increases activity in the areas which is related to perception of emotion and primary inducer and Homayoun with free rhythm impacts the memories and thoughts relations.

2. Methods

2.1. Subjects

Nineteen right-handed healthy participants (ten males: mean age 24.80, SD 2.09; nine females: mean age 27.44, SD 2.78; group: mean age 26.05, SD 2.73) were recruited among students at the University of Tehran who were not familiar with the kind of music.

All participants were screened for neurological disorder, head injuries, and current or past psychiatric disorders by using clinical interview and General Health Questionnaire. Handedness was assessed using the Edinburgh inventory. Before scanning, participants completed the BDI (Beck Depression inventory).

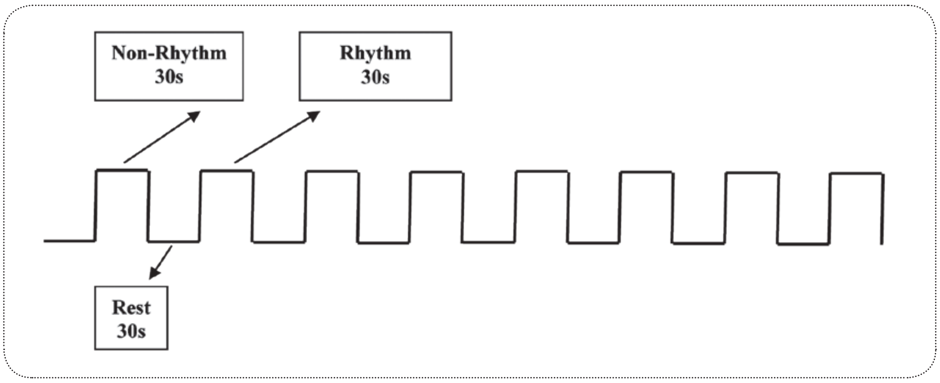

Figure 1. The design of stimulus NEUROSCIENCE

Participants gave informed consent to the proceedings during the experiment, which were approved by the ethics committee of the Tehran University of Medical Sciences.

2.2. Stimuli

Due to more differences between others Dastgah and West music, we couldn't choose them from Persian music. So, eight pieces of Homayoun were selected in two parts of non-rhythm and rhythm. All the pieces had the same intervals with this scale: G AP B C D Eb F G. Non-rhythmic Homayoun was free beat while rhythm Homayoun had beat with 45bpm[1] . The pieces were arranged during 30 second by Goldwave software, and then were set in block design with random choosing of pieces in activity part to the subjects. In this way, there were 8 blocks with 30s pieces of non-rhythm and rhythm that were alternatively presented. They listened to the pieces in activated blocks during 30 seconds. After that, they didn't listen to anything in further sections during 30 second and were asked to rest quietly and wait for the music to begin again (Fig 1).

In order to avoid novelty effects, participants were familiarized with the musical stimuli 1 week prior to the fMRI scan.

2.3. Imaging

Functional 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, voxel size 3×3×4 , 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, band width= 61 KHZ and flip angle=30).

1. Beat Per Minute

2.4. Functional Data Analysis

2.4.1. Preprocessing

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). Z (Gaussianised T/F) statistic images were thresholded using clusters determined by Z>1.8 and a (corrected) cluster significance threshold of P=0.05 in Mixed effects mode.

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).

2.4.2. Single Data Analysis

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 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 account for higher level analysis.

2.4.3. Group Level Data 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).

3. Results

3.1. fMRI Experiment

The brain activity obtained by the non-rhythmic Homayoun (non-rhythm>rhythm contrast) showed that high level of activity presents in regions of frontal and limbic lobe. As the figure 2 shows, the left hemisphere has been mainly activated by non-rhythmic Homayoun (table 2). Significant BOLD responses were observed in frontal lobe obtained from the difference between

Table 1. 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

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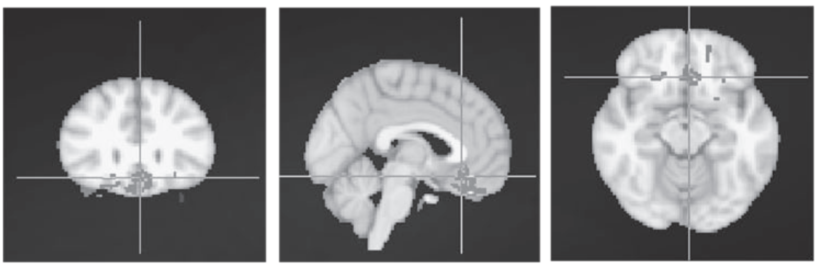

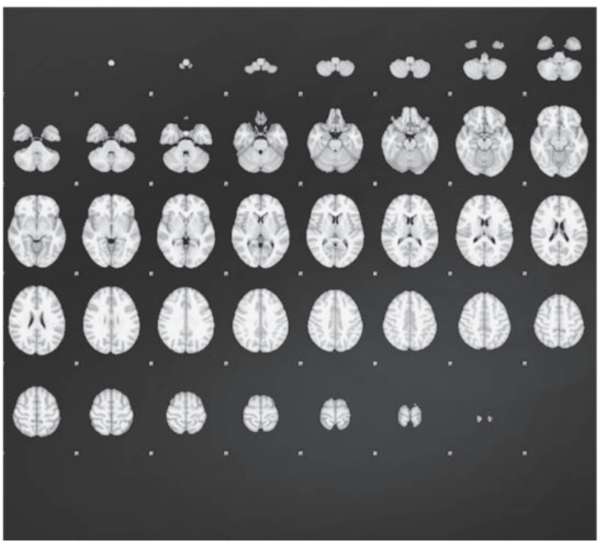

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Figure 2. Statistical activation maps for the rhythmic Homayoun. Image shows activities in the left hemisphere in parietal lobe. (Colors appear in electronic version)

rhythmic and non-rhythmic Homayoun (rhythm>non-rhythm). Considering figure 3, Parietal lobe can mainly be activated in the rhythmic Homayoun. The Processing of rhythmic Homayoun has also occurred in left hemisphere (table 3).

3.2. Region of Interest Analysis

Although comparison between different stimuli did not demonstrate any activation in amygdala, according to Damasio's somatic marker hypothesis we expected to see activation in this region. So, Region of interest (ROI) analysis was applied to the amygdala for non-rhythmic Homayoun (fig 4) and rhythmic Homayoun (fig 5). The ROIs were defined based on a conjunction of functional and anatomical criteria: 1) only voxels activated by a contrast of non-rhythmic Homayoun versus rhythmic Homayoun in a multisubject GLM (n = 19, $P < 0.005$, fixed effects model, uncorrected) were included. 2) Anatomical boundaries were defined in Talairach space for each ROI. The amygdala was marked using the Talairach atlas (Talairach & Tournoux 1988). Mean

Table 2. 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	Precentral Gyrus	Frontal	L	3.35	-20	-20	72
	Precuneous Cortex	Parietal	L	3.18	-14	-42	56
	Supramarginal, anterior	Parietal	L	2.89	-20	-38	68
	Cingulate Gyrus, anterior	Parietal	L	2.88	-34	-36	54
	Postcentral Gyrus	Parietal	L	2.8	-30	-34	70
	Precentral Gyrus	Frontal	L	2.78	-32	-24	68

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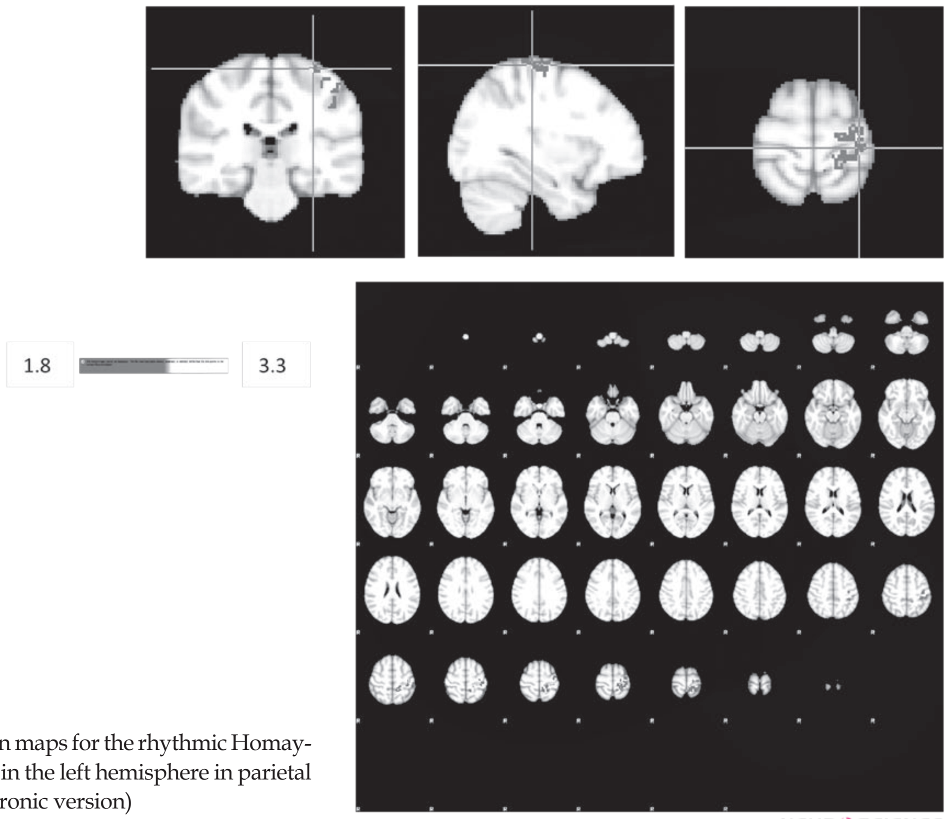

Figure 3. Statistical activation maps for the rhythmic Homayoun. Image shows activities in the left hemisphere in parietal lobe. (Colors appear in electronic version)

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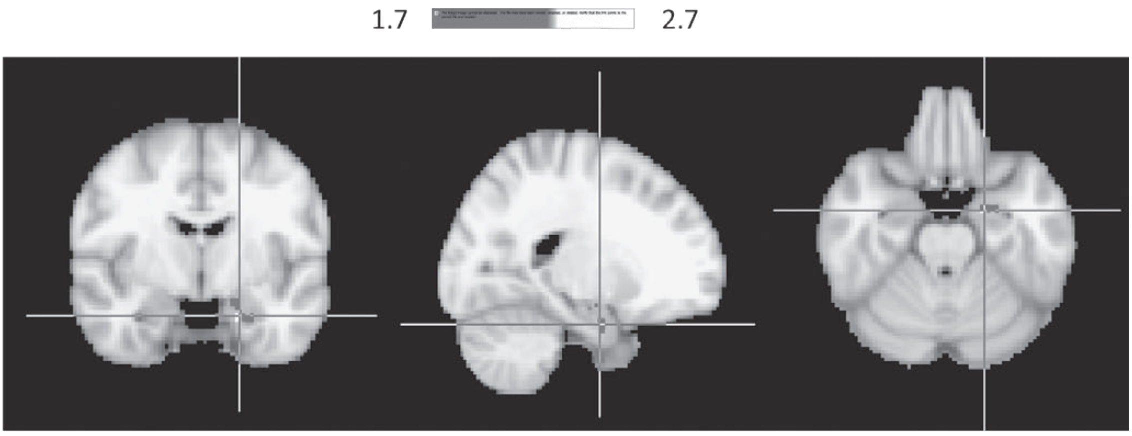

Figure 4. Statistical activation maps for non-rhythmic Homayoun in comparison with rhythmic Homayoun. Images are coronal (left), sagittal (right), axial (low) sections. The activity is related to the left amygdala.

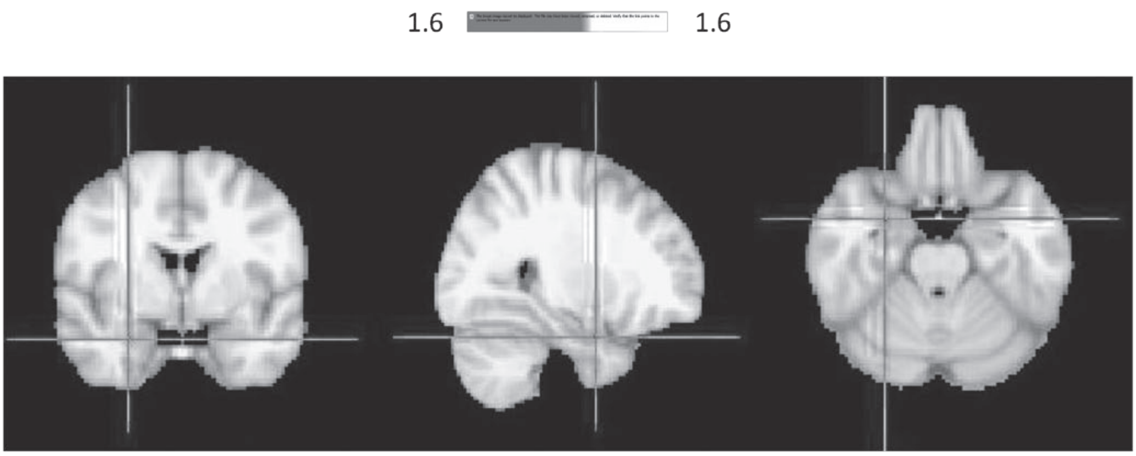

Figure 5. Statistical activation maps for rhythmic Homayoun in comparison with non-rhythmic Homayoun. Images are coronal (left), sagittal (right), axial (low) sections. The activity is related to the right amygdala.

signal change's percent was extracted for each subject and compared between Rhythmic and Non-rhythmic pieces (Left Amygdala mean difference: 0.05± .1± p-value<0.05± Right Amygdala mean difference: 0.05± 0.2± p-value>0.05±).

4. Discussion

This study showed the neural regions that are responsible for rhythm and affective processing involved in listening to rhythmic and non-rhythmic Persian music. The present experiment mainly converges with some previous studies such as Damasio' hypothesis and Suzuki who investigated in east music and others studies about rhythm effects, but it couldn't be in line with researches which investigated the arousal effects of music on brain.

First, the current study has widely been revealed distributed neural networks involved in perception of rhythm and it was consistent with previous findings. postcentral gyrus, precentral gyrus, anterior supramarginal gyrus and also supplementary motor cortex are associated with processing of rhythm. Activations in areas of the supramarginal and postcentral gyrus have been reported to be involved in processing the fundamental physical properties of sound (Porro et al., 1996) and the rhythmic information (Bengtsson & Ulle´n, 2006). Lesion of the left supramarginal causes disrupted attention to motor acts and planning of consecutive movements (Harrington & Haaland, 1992; Rushworth et al., 2001). As a matter of fact, Harrington and Haaland (1992) found a shortage in the timing of motor programs of sequential movements activated the left SMG. Porro et al (1996) showed that functional activity levels in postcentral and precentral gyrus are increased during mental representation (motor imagery) of a simple sequence of finger movements, although the intensity of activation is lower than during real movements. The results of studies demonstrated that activity in supplementary motor areas correlated with measures of rhythm derived from the music (Ferrandez et al., 2003; Popescu et al., 2004). We often spontaneously coordinate our body movements to a rhythm's beat during listening to music (Chen et al., 2006; Grahn & McAuley, 2009). This response implies a universal beat-timing mechanism, potentially intervened by motor brain regions (Grahn & Brett, 2007). Although in this study the subjects listen to rhythmic music without moving and beating, rhythmic sounds activate areas of cortex involved in movement generation. So rhythm easily evoke in the imagination the movements required to produce them.

Second, in line with researches in case of arousal effects of rhythm model, we couldn't find results that confirm it. But it was corresponding to east studies_ similar to ours. Subcallosal, frontal pole, anterior cingulated regions have been activated in non-rhythm. These areas were implicated in emotional processing (Bush et al, 2000; Suzuki et al, 2008; Blood et al, 1999; Morris et al, 1999; Zald & Pardo, 1997). Blood and et al (1999) showed that activity in the subcallosal region decreased with sad, whereas it increased with happy stimuli. It has also been seen that lesions in subcallosal and other ventral medial prefrontal regions is along with damage of emotional expression (Hornak et al., 1996). Maddock et al (20003) 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 may have a particular role to positive emotional processes (Maddock et al., 2003). According to the others similar studies on west music, it was expected to enhance arousal in rhythmic Homayoun not in non-rhythmic. So, this result is not in line with this model. Although current results were not consistent with other findings, we have to notice the difference between western music and that of the East. In the current study, Persian classic music was considered as a part of Persian culture in which non-rhythm (free rhythm) constructs its principle sections, and most people in Iran are familiar with this music and have strong emotion and memories with it.

Third, Amygdala, anterior cingulated and VMPF are main regions of stimulus perception that have activated in non-rhythmic Homayoun and they are corresponding to Damasio's model. In agreement with Damasio's somatic marker hypothesis when a person listens to music, amygdala is triggered as a primary inducer and it can cause a physiological signs. Although this study had some limitations in evaluating of physical and physiological responses during of experiment, it is necessary to investigate effects of Persian music on physiological signs in future researches. For this stage, amyagdala is a region activated in both pieces of music. Accordingly, rhythm and non-rhythmic Homayoun are primary inducer to audience. On the other hand, non-rhythmic Homayoun can be considered a secondary inducer by activation of VMPF. Frontal pole is subdivision of wider ventromedial prefrontal VMPF area and it is activated as a secondary inducer. That means frontal pole helps to think about everything that is related to primary inducer. It seems that ventromedial cortex is important in the description of stimulus information such as thought and memories (Bechara et al., 2003). Studies show that damaging of this region is along with some problems in the emotional responses such as decision making (Damasio, 1994).

In conclusion, non-rhythmic Homayoun is important as a secondary inducer and activates areas of brain that are essential for thinking and decision making. We expect that non-rhythmic music can affect the regulation of emotion, mood and thinking more than rhythmic.

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