Available online at www.sciencedirect.com
ScienceDirect
Procedia Social and Behavioral Sciences 5 (2010) 1124–1128
Procedia
Social and Behavioral Sciences

WCPCG-2010

Involved brain areas in processing of Persian classical music: an fMRI study

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Received January 9, 2010; revised February 16, 2010; accepted March 11, 2010

Abstract

The purpose of this study is to investigate the neurological process of the rhythm in Persian classical music by using fMRI. The test consists of two groups of no rhythmic and rhythmic pieces that has examined on 12 right-handed musicians. The result showed that no rhythmic Persian pieces activated right middle frontal gyrus, right middle temporal gyrus, left planum temporal and right superior temporal gyrus, and rhythmic pieces activated left frontal pole, left inferior frontal gyrus and left suramarginal. These results are based on the laterality and hierarchical models.

Keywords: Persian classical music, rhythm, no rhythm, brain, fMRI.

1. Introduction

Neurological studies have showed that music is a valuable tool for evaluating the brain system (Peretz & Zatorre, 2005). Music is included in elements such as weight, rhythm, melody, resonance, etc and among of these elements; rhythm and melody are the most important to music components (Krumhansl, 2000).

Studies emphasized on the function and importance of laterality model. According to this model, right hemisphere involves in the processing of melody and left hemisphere does in the processing of rhythm.

In addition to allocating of lateralized activity, studies have showed areas of brain especially to be active during rhythmic and melody pieces, this means that brain regions is differently processed for rhythm and melody (Sakai et al., 1999). Also studies have showed that motional areas such as Supplementary Motor, Premotor Cortex and Parietal Cortex activate during hearing and perception of rhythmic pieces (Halsband, 1993).

Perpetuated through an oral tradition, the classical repertoire encompasses a foundation of ancient pieces collectively known as the “radif” in Persian music. These pieces are organized into twelve groups, seven of them are known as basic modal structures called “dastgah” (system) that are included in Shur, Homayoun, Segah, Chahargah, Mahour, Rast-Panjgah, and Nava.

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1877-0428
doi:10.1016/j.sbspro.2010.07.247

The remaining five of them are commonly accepted as secondary or derivative Dastgahs. Four of them are Abou-ata, Dashti, Bayat-e-Turk and Afshari that are considered as derivatives of Shur, and Bayat-e-Esfahan is regarded as a sub-Dastgah of Homayun. The individual pieces in each of the twelve Dastgahs are generally called "gushe". Rhythmically, the majorities of "gushes" are flexible and free and cannot be assigned to a stable metric order. However, in every Dastgah, there are a number of metrically regulated gushes which are played among of the free pieces in order to provide periodic variety in rhythmic effects and one of the most important properties of Persian classical music is to have no rhythmic pieces.

So, we are going to investigate activity of areas in relationship with the rhythm and investigate the laterality model in Persian classical music.

2. Method

2.1. Participants

12 volunteers (9 men, 3 women) with a mean age of 28 years old (range 20-30) participated in the study. All subjects were right-handed and healthy. They were screened to ensure that they did not meet any exclusion criteria such as ocular problem affecting the visual acuity at the time of scan, medications, cochlear implants, any other metal objects in the body, and any psychological diseases such as depression. The imaging protocols received prior approval from our institutional review board, and all subjects were asked to sign consent for all procedures. All subjects were completely familiar with Persian classical music, and they had at least eight years experience in playing Persian musical instruments.

2.2. Materials

Eight pieces from Homayoun Dastgah were played in two parts rhythmic and no rhythmic. All the pieces have the same intervals. Their intervals include: G, AP, B, C, D, Eb, F, G. The no rhythmic pieces have free beat while rhythmic pieces have a beat that its tempo is 45bpm[1].

2.3. Procedure

All the pieces had 30 or 35 second length (Fig.1). The stimulus was presented in block design with random choosing of pieces in activity part to the subjects. They listened to the pieces in active blocks and to the white noise during the rest sections. Subjects lying in the MRI scanner in complete darkness with the head carefully fixed in place while closing their eyes. They were wanted to listen carefully to short musical excerpts presented through Non-magnet headphones for 7.10 minutes and in two distinct experiments.

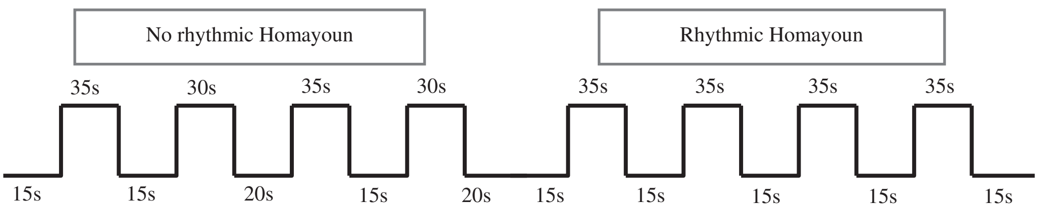

Fig1.presentation of music task in during photography by fMRI

2.4. Image acquisition and analyses

Image acquisition and analyses

T2*-weighted Echo Planar images (EPI) were acquired by a 1.5T standard clinical scanner (GE® Signa) with TR=1800 ms, TE=90 ms, Flip Angle=90, voxel-size=4.06×4.06×6mm3, matrix=64×64, and Slice- thickness=6mm. Fifteen contiguous axial slices were obtained, relatively parallel to the 'anterior commissure-posterior commissure' line according to Talairach atlas beginning from vertex.

[1] Beat per minute

Data preprocessing and analysis were performed using FMRIB Software Library (FSL). The first two volumes of each imaging run were discarded to eliminate spin saturation effects. Head motion correction was performed using FMRIB's Linear Image Registration Tool (MCFLIRT) (Jenkinson et al., 2001). Brain Extraction Tool (BET), Version 1.1 (Smith, 2002), was used to remove non-brain structures.

At first slice-timing correction was performed using Fourier-space time-series phase-shifting. Subsequently, the data sets were smoothed with an 8-mm (FWHM) isotropic Gaussian kernel to compensate for inter-subject variability and to attenuate high-frequency noise, thus increasing the signal-to noise ratio. High-pass temporal filtering (Gaussian-weighted least-squares straight line fitting, with sigma=100s) was implemented to remove some low frequency variability and artifacts of each voxel signal. Slice timing – smoothing Statistical analysis was carried out using group GLM algorithm in FEAT part of FSL using mix effect mode. Generally the reason that is used mix effect mode, FEAT offers both fixed effects (FE) and mixed effects (ME) higher-level modelling. FE modelling is more "sensitive" to activation than ME, but is restricted in the inferences that can be made from its results; because FE ignores cross-session/subject variance, reported activation is with respect to the group of sessions or subjects present, and not representative of the wider population. ME does model the session/subject variability, and it therefore allows inference to be made about the wider population from which the sessions/subjects were drawn. "Mixed-effects" (ME) variance is the sum of "fixed-effects" (FE) variance (the within-session across-time variances estimated in the first-level analyses) and "random-effects" (RE) variance (the "true" cross-session variances of first-level parameter estimates). So, we use mix effect mode because of its more exactness than fixed effects.

The results were expressed as statistical parametric maps. Only clusters with Z-Stat > and cluster p-value threshold less than 0.05 were assumed to be significant.

3. Results

The highest activity was observed in temporal lobe areas that it has been observed the difference between no rhythmic and rhythmic Homayoun after removing the effect of rhythm in no rhythmic test of Homayoun (fig.1). And also the most importance of activated areas are consist of superior temporale gyrus by analysis the difference between rhythmic and no rhythmic Homayoun so that high level of this activity were found in anterior and inferior parts of frontal area (fig.2).

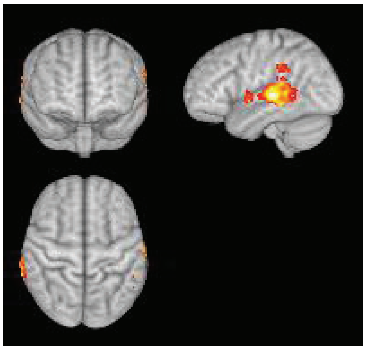

Figure 2. Especial areas related to melody (no rhythm) in contrast between no rhythmic and rhythmic pieces. Images are sagittal (right), coronal (left), axial (low) sections. These activities are shown in the right hemisphere especially in parts of temporal.

Z-max	Z	Y	X	No rhythmic Homayoun
3.75	52	2	42	R. Middle frontal Gyrus
3.63	4	-40	68	R. Middle Temporal Gyrus
3.73	6	-26	-62	L. Planum Temporal
4.49	2	-30	66	R. Superior Temporal Gyrus
3.67	-2	-26	54	R. Superior Temporal Gyrus
3.59	2	-22	54	R. Superior Temporal Gyrus

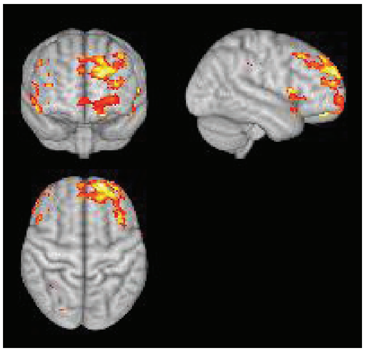

Fig3. Especial areas related to rhythm in contrast between no rhythmic and rhythmic pieces. Images are sagittal (right), coronal (left), axial (low) sections. The related activities are demonstrated in the left hemisphere especially in parts of frontal.

Z-max	Z	Y	X	Rhythmic Homayoun
3.75	52	2	42	L. frontal pole
3.63	4	-40	68	L. Inferior frontal Gyrus
4.49	2	-30	66	L. Supramarginal

4. Conclusion

On the basis of laterality model, allocation of melody's processing is in right hemisphere and rhythmic pieces in left hemisphere. During investigation of difference about tow pieces of rhythmic and no rhythmic Homayoun, laterality model is justifiable. Because rhythmic pieces of Homayoun are able for more allocation of activity in left hemisphere and no rhythmic pieces indicated this activity in right hemisphere and this is coherent with much of studies.

In justification of second hypothesis on the basis of activity of rhythmic pieces in frontal areas and areas related to motion, we can attribute to hierarchical model. Anatomic studies which are performed on monkeys show that hearing cortex is composed of 3 sections. 1. Central Core, 2. Surrounding Belt, 3. Lateral Parabelt (Hackett et al., 1998) we believe that this cortex system is related to each other hierarchically (Kaas & Hackett, 2000).

In studying which its purpose is investigation of difference between melody and rhythm with using of fMRI, we tried to consider major steps of melody's processing in hearing paths. In this study on the basis of hierarchical model the most importance of areas for pitch understands is activity of Heschls gyrus (HG) of first level of hierarchical model while in higher hierarchy of melodies processing including activity of two areas of superior temporal gyrus (STG) and Planum Polar (PP) in higher levels of this model. In more justification of this model when a sound is produced just in shape of pitch, in primary step causes that two areas of HG and planum temporal PT become active and when this pitch forms a more complex shape than melody, superior level including two areas such as STG and PP (Patterson et al., 2002) especially founction of STG area in right hemisphere and its anterior sections in melody's processing has been emphasized more (Zatorre, 1998).

Justification of hierarchical model of rhythmic and no rhythmic Homayoun pieces is also dependent on existence of weighty rhythms. Rhythmic pieces of Homayoun in comparison with no rhythmic pieces in higher level causes the activity in frontal pole areas and inferior areas of frontal while special areas of processing in no rhythmic Homayoun is activated in lower level and planum temporal area and posterior section of superior temporal gyrus. According to this model if melody is within more complexity, higher levels of processing will be involved.

Middle frontal gyrus and middle frontal gyrus are areas that activated during no rhythm Homayoun. Studies show importance of these regions for memory's processing. As it is seen activity of anterior middle temporal gyrus during semantic memory of music (Platel et al., 2003) and retrieval of music (Watanabe, 2008) also other studies emphasized activity of Middle frontal gyrus and inferior frontal gyrus in working memory (Braver et al., 1997). Certainly these areas have a role in processing of music but we could not discuss about this issue because we don't designed music task for appraisal of memory. Anyway according to present findings can discover new findings about relation of type of music and memory's type.

Anyway, report of present conclusion is when no study has been done in the field of neurological processing of Persian music and presentation of such conclusions creates another opportunity to draw a conclusion in continuation of these series of studies more findings from music effects.

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