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Differences in Brain Structures between Female Musicians and Non-Musicians

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Abstract. This study examines the differences in brain structures between female musicians and their non-musian counterparts by using a voxel-by-voxel morphometric method. We found gray matter volume differences in right and left cerebellum regions, right and left middle temporal gyrus and superior occipital gyrus. These differences are consistant with those of male musicians and non-musicians on the whole. This study showed that the above special regions may have a close relation to long-term skill exercises and the repetitive rehearsal of those skills.

Keywords: musician; brain structure; VBM; gray matter

1. Introduction

Various factors have an impact on the structure of human brain, including disease, handedness, age, gender, and profession. [Seitz et al., 1994; Wright et al., 1995; Schneider et al., 2002]. We have been interested in studying whether the brain structure of female musicians differs from that of non-musicians. There were several reports showing the brain structure differences between musicians and non-musicians in the auditory cortex [Schneider et al., 2002; Bermudez and Zatorre, 2005], cerebellum [Hutchinson et al., 2003; Gaser et al., 2003], primary motor, somatosensory areas, premotor areas and anterior superior parietal areas [Gaser et al., 2003]. Schneider et al. compared the difference in the auditory cortex between two groups; Hutchinson et al. focus on cerebellar volume on both the male and the female subjects; and Gaser et al. examined whole brain structural differences only in the male subjects. However, no study has examined the whole brain structural differences between female musicians and non-musicians.

We applied the method of voxel-based morphometry (VBM) using the VBM-toolbox [Ashburner and Friston, 2000; Good et al., 2001a, b; Ashburner and Friston, 2005] to explore the structural differences between the two groups of subjects.

2. Material and Methods

Subjects groups were made up of 15 female musicians (about 6-20 years of musical experience) and 15 age-matched non-musicians. The age range of all subjects was 20-27 years. All of the participants were right-handed. Subjects were recruited through advertisements in the SouthWest University of China. Informed consent was obtained from all subjects.

For this study, high-resolution T1-3D anatomical images of the whole brain were acquired on a 3T Siemens Vision whole-body scanner. Voxel size is 1 mm^3. Images were then analyzed using VBM5, a tool-box of SPM5 package (Wellcome Department of Cognitive Neurology, University College-London). The method of VBM was performed in several stages: first, all images were normalize to a standardized anatomical space (remove differences in global shape, position and overall size); second, every image was divided into gray matter (GM), white matter (WM) and cerebrospinal fluid (CSF) segments; third, the resulting gray and white matter images were smoothed with a Gaussian kernel of 8 mm FWHM; finally, the differences in local gray and white volume were analyzed across the whole brain. Statistical analyses were made use of SPM5 package using general linear model, contrast was then used voxel-by-voxel in a random effect analysis (t-test) for the contrast of interest. Results are reported with $p<0.001$, uncorrected (cluster size > 38 voxels).

3. Results

The difference of cerebellum is especially significant. Our research comparing the brain structure of female musicians and non-musicians, we found a greater gray matter concentration in musicians as compared to non-musicians in the cingular cortex, right middle temporal gyrus, left cerebellum, left middle temporal gyrus and the right cerebellum (Fig. 1, 2; Tab. 1), superior occipital gyrus and hypothalamus. On the result of the prevenient study that the musicians' and non-musicians' brain structure, which showed differences in a marker of temporal gyrus, left and right cerebellum volume between the two groups [Gaser et al., 2003; Hutchinson et al., 2003; Bermudez and Zatorre, 2005]. Both male and female musicians have greater gray matter concentration in the cerebellum and the temporal gyrus, long-term exercise and perform musical instruments and listen to the music and sing etc. may conduce to the growth of the cerebellum and the temporal lobe. There was no significant difference in white matter volume using the similar statistical cutoffs of those used in the gray matter analysis.

3.1. Figures

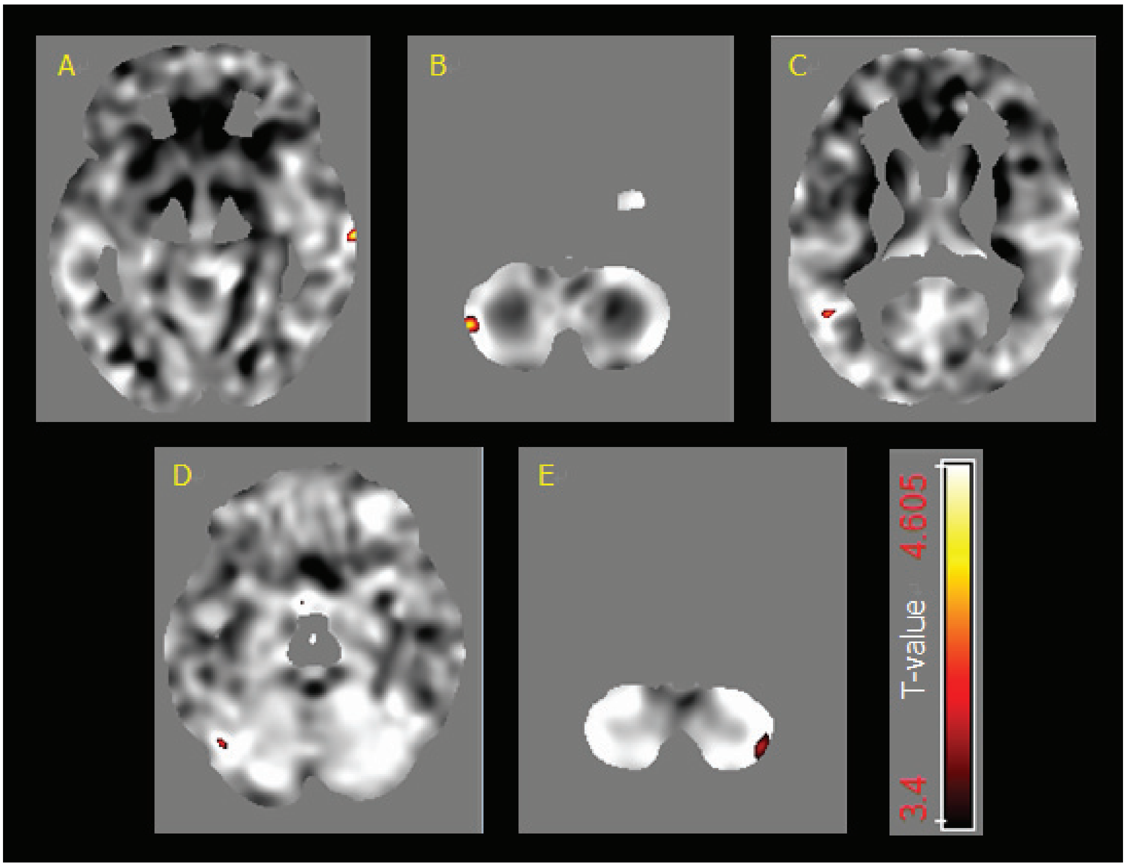

Figure 1. *Brain regions with gray matter differences between 15 female musicians and 15 matched non-musicians. Only those voxels with a significant greater volume that musicians compared to non-musicians in gray matter are shown (p<0.001, uncorrected). Mainly, regions include right middle temporal gyrus (A), left cerebellum (B and D), left middle temporal gyrus (C) and right cerebellum (E).*

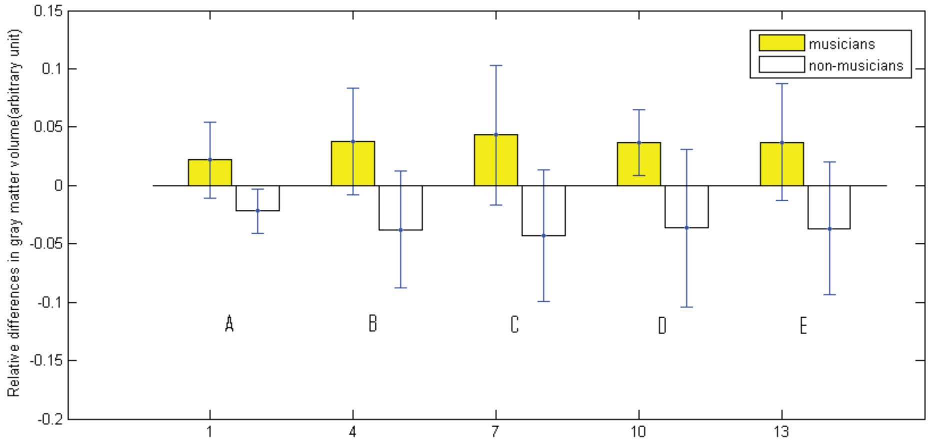

Figure 2. *Relative differences in gray matter volume (mean and SD) between female musicians and non-musicians in the five regions correspond to figure 1. Regions include right middle temporal gyrus (A), left cerebellum (B and D), left middle temporal gyrus (C) and right cerebellum (E).*

3.2. Table

Table 1. *Brain regions with gray matter differences between musicians and non-musicians (musicians>non-musicians)*

Region	*x*	*y*	*z*	*t value*	*number of voxels*
Part of cingular cortex	6	-56	6	4.60	346
Right middle temporal gyrus	73	-20	-7	4.48	91
Left cerebellum	-43	-65	-52	4.30	286
Superior occipital gyrus	-32	-73	25	4.17	79
Left middle temporal gyrus	-51	-60	13	4.06	75
Hypothalamus	-5	-1	-16	3.99	98
Left cerebellum	-43	-68	-19	3.86	38
Right cerebellum	40	-67	-57	3.76	413

4. Discussion

Our study showed that several areas of differences in the gray matter between female musicians and non-musicians. We only tested the female subjects for two reasons. First, many reports showed gender difference in brain structure using the traditional morphometric method [Kansaku et al., 2000; Nopoulos et al., 2000], VBM [Good et al., 2001b; Keller and Menon, 2009] or other tools. Second, previous studies focused on musicians' brain structure research into either the difference at certain area between two or more groups (every group include male and female) or the whole brain difference between groups of only male or others, but no study focus on the brain structure that female musicians differ from non-musicians as far as we know.

The statistical threshold of our study was chosen based on uncorrected p values. This may attribute to the small number of subjects. We only contrast the gray matters and we give the cluster size (number of voxels) of areas which had differences between the two groups. Therefore, the statistic was based on the small cardinal number (compare to the number of whole brain voxels) and the considerable numbers of different voxels (shown in Tab. 1). Accordingly, we believe that our results are credible.

The differences we found between the two groups involve motor, auditory and some of visual regions. Cerebellar cortex has been play a critical role in the balance, music processing [Parsons, 2001; Gaab et al., 2003], planning, preparation, execution, control of bimanual finger sequential movements and in cognitive skill learning; middle temporal gyrus, which mostly take charge human's auditory and speech, long-term musical stimulus and auditory exercises have influence on these regions; superior occipital gyrus, the occipital lobe related to our vision, language, sense of action and abstract conception, so the musical exercise and performance may help for the growth of this region; our study also showed strong greater in gray matter volume in the cingular cortex, a very complex area of human brain, we can't ensure why musicians' cingular cortex volume are larger than that of non-musicians, but we believe that it is reasonable because cingular cortex is associated with many important functions such as motor planning, error detection and so on [Gregory et al., 2008].

We also compute whether the differences exist between musicians and non-musicians in the white matter. But we found that no significant difference between the two groups, this may because of VBM technology is insensitive to white matter [Ashburner and Friston, 2000; Bookstein, 2001].

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