Gray Matter Differences between Musicians and Nonmusicians

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ABSTRACT: Musicians learn complex motor and auditory skills at an early age and practice these specialized skills extensively from childhood through their entire careers. Using a voxel-by-voxel morphometric technique, we found gray matter volume differences in motor as well as auditory and visuospatial brain regions comparing professional musicians (keyboard players) with matched amateur musicians and nonmusicians. These multiregional differences might represent structural adaptations in response to long-term skill learning and repetitive rehearsal of these skills. This is supported by finding a strong association between structural differences, musician status, and practice intensity as well as by a wealth of supporting animal data showing structural changes in response to long-term motor training.

KEYWORDS: morphometry; plasticity; skill acquisition; keyboard players

INTRODUCTION

Musicians are skilled in performing complex physical and mental operations such as translating visually presented musical symbols into complicated movements of fingers and hands and memorizing long musical phrases. Playing a musical instrument typically requires the integration of multimodal sensory and motor information and multimodal sensory feedback mechanisms to monitor the performance. The neural correlates of most of these musical operations are not fully understood, and no firm associations between specialized musical skills and particular brain regions or a characteristic brain anatomy are established. Although several functional and a few structural imaging studies have reported regional brain differences between musicians and nonmusicians,[1–6] no study has yet searched across the whole brain space for structural brain differences between these two groups that could be linked to the exceptional and specialized skills of musicians as well as to the long-term and extensive rehearsal of these skills.

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MATERIAL AND METHODS

Material. We compared 20 male professional musicians and 20 male amateur musicians (all keyboard players) to a group of 40 male nonmusicians (all matched with regard to age, handedness, and verbal skills). A professional musician was defined as someone whose main profession was to be a musician (either a performing artist, music teacher, or music student at a conservatory) with an average practice time of at least 1 hour per day. An amateur musician was defined as someone who plays a musical instrument regularly but has a profession other than that as a professional musician. The amateur musicians had an average daily practice time that was half that of professional musicians (1.15 vs 2.23 h/d). Nonmusicians were defined as those who never played a musical instrument.

Magnetic Resonance (MR) Data Acquisition and Image Analysis. Isotropic (1 mm^3) T_1-weighted MR data sets were acquired from each subject. Voxel-by-voxel *t* tests using the general linear model[7] were used to search for gray matter differences between professional musicians, amateur musicians, and nonmusicians. We assessed the correlation between musician status and gray matter differences by modeling the musician status as a 3-level gradation, in which professional musicians were highest and were assigned a value of 1, amateur musicians were intermediate and were assigned a value of 0.5, and nonmusicians were the lowest and were assigned a value of 0.

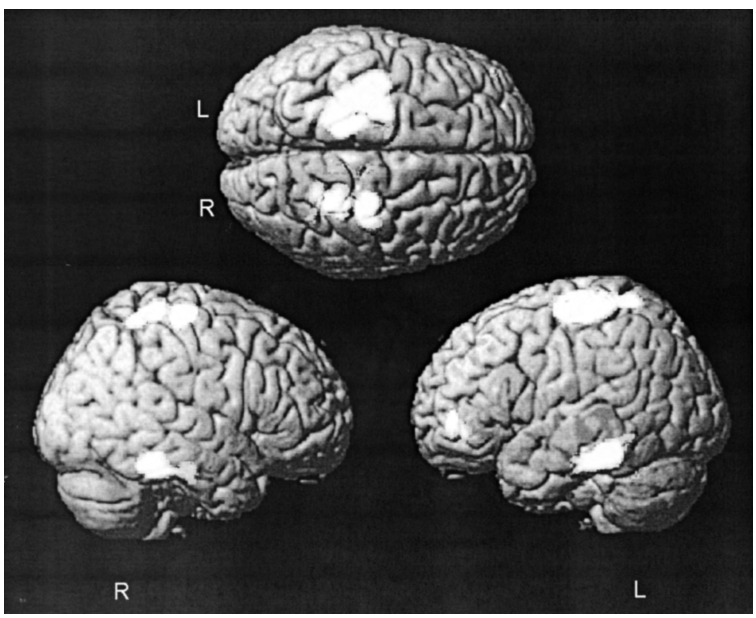

FIGURE 1. Brain regions with gray matter differences between professional musicians, amateur musicians, and nonmusicians ($P < 0.05$, corrected for multiple comparisons; only clusters of voxels consisting of at least 225 voxels are displayed corresponding to a spatial extent threshold of $P < 0.1$).

RESULTS

Areas of significantly increased gray matter volume comparing professional musicians (keyboard players) with amateur musicians (keyboard players) and nonmusicians were found in peri-rolandic regions including primary motor and somatosensory areas, premotor regions, superior parietal regions, and the inferior temporal gyrus bilaterally (FIG. 1). Additional significant differences were seen in the left cerebellum, left Heschl's gyrus, and left inferior frontal gyrus. No areas showed a significant decrease in gray matter volume comparing professional with amateur musicians and amateur musicians with nonmusicians, respectively.

CONCLUSIONS

Differences in the distribution of gray matter were mainly seen in brain regions that are of critical importance for a performing musician. These brain regions (e.g, primary sensorimotor region, premotor region, and cerebellum) are either part of a motor learning and skill acquisition network or they are part of a network that may play a crucial role in translating musical notation into complicated motor commands (e.g., superior parietal, inferior temporal lobe). There are two possible explanations for our findings: either individuals with a particular brain anatomy are drawn to becoming musicians or structural differences are due to use-dependent brain growth during a critical period of brain maturation. This second explanation is supported by a wealth of animal experiments[8] showing increases in glial, capillary, and synapse densities after long-term motor learning and by additional results of our study showing more gray matter differences depending on practice intensity. Overall, the results of our study and other studies[5–6,9–11] provide strong links between specialized skills and certain brain structures.

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