Increased Hippocampal Volumes and Enhanced Visual Memory in Musicians

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It is well documented that behavioural training and skill acquisition can result in structural differences in the human brain[1-3]. Performing music at a professional level is among the most complex of human accomplishments, involving both physical skill acquisition and cognitive operations such assight-reading, improvisation and memorization of long musical passages. The development of musical memory commences in the earliest stages of training and advanced student musicians will memorise complete musical scores such as concerti for their solo instrument of training. Sight reading, or the rapid transformation of written musical notation into appropriate motor sequences of musical performance, is a visuospatial analysis task and behavioural studies have indicated that musicians perform significantly better on tasks outside of the musical domain which rely on visuo-spatial analytical ability. Maguire et al[2] demonstrated that that the right hippocampus, known from animal studies to be involved in spatial memory and navigation, is enlarged in taxi drivers relative to a control population. Furthermore, they reported that the hippocampal volume was directly proportional to with the amount of time spent as a taxi driver. Based on the previously reported associations between relevant brain structures and specific musical skills together with the importance of the hippocampus for memory and spatial abilities we hypothesized that acquisition and maintenance of musical performance skills by musicians would be associated with enhanced visuospatial memory in musicians and increased hippocampal volume. We applied two independent brain image analysis techniques to high-resolution MR brain images from a group of healthy adult musicians and a group of healthy age-, sex-, IQ- and handedness-matched non-musicians to investigate whether there exists a structural relationship between hippocampal volume and visuospatial memory.

Subjects and Methods

Thirty-eight musicians from Royal Liverpool Philharmonic Orchestra (26 male and 12 female) and thirty-eight non-musicians (26 male and 12 female) participated in this study (which had local research ethics committee approval). High-resolution T1-weighted images were acquired on a 1.5 T SIGNA MR imaging system (General Electric, Milwaukee, USA) with a 3D SPGR pulse sequence (TR/TE 34/9 msec, flip angle 30°, slice thickness 1.6 mm). All subjects underwent a battery of standard neuropsychology tests. The investigation reported here focuses on analysis of the visuospatial memory as measured by Wechsler Memory Scale. IQ was assessed using Cattell's Culture Fair test of fluid intelligence. Optimized voxel-based morphometry [4] was carried out using Statistical Parametric Mapping (SPM 99, http://www.fil.ion.ucl.ac.uk/spm). Additionally, voxel-by-voxel regression analysis of grey matter concentration was performed taking total brain grey matter as a confound and visual memory index as covariate of interest, within the framework of the general linear model in SPM99. The Cavalieri method of modern design stereology was applied in conjunction with point counting to estimate hippocampal, cerebral hemisphere and intracranial volumes[5].

Results

VBM: Within the contrast male musician>non-musician ($p < 0.05$ corrected for the multiple comparisons), there was a significant cluster (volume 387 mm³, p=0.045) of increased grey matter density within the right posterior hippocampus. The voxel of peak difference was at x=24, y=-29, z=-9, t=4.03 and the volume of peak difference extended from –21 to –39 in the y-axis. There were no significant findings in either male musician<non-musician or in female musicians vs female controls.

Stereology: There were no differences in ICV in either the male groups (musicians/controls) or female groups. Repeated measures ANOVA, covarying for ICV, identified a significant interaction between musicianship and sex ($F_{1,72}$=10.42, p<0.001). Post hoc t-tests were performed within gender and with musicianship as a factor:

Males – musicians' left (t=5.18, df=50, p<0.0001) and right hippocampi (t=4.69, df=50, p<0.0001) were significantly larger than controls – both for raw and ICV-corrected volumes. Bilaterally, significant age-related volume reduction in hippocampi of controls only (Rt r=-0.51, p<0.05; Lt r=-0.52, p<0.01). In under 50-year old male musicians, there was a weak positive correlation with years of orchestral playing (r=0.37, p<0.05).

Females - no significant differences in hippocampal volumes bilaterally (left: t=0.28, df=22, p>0.05; right: t=0.07, df=22, p>0.05). Significantly less variability in hippocampal volumes in female musicians than in female controls: Left: Musicians– SD=0.35; range=1.13; Controls – SD=0.63; range=2.30; Right: Musicians – SD=0.26; range=0.84; Controls – SD=0.60; range=2.61.

Wechsler Memory Scale: Musicians of both sexes scored significantly higher on visual memory score (males: t=5.12, p<0.001; females: t=2.69, p<0.01) but not on verbal memory score.

Structure-Function Relationships: Within males musicians only, there was a significant positive correlation between right hippocampal volume corrected for ICV and visual memory index (r=0.45, p<0.05) from the stereological data, which was supported by the voxel-by-voxel regression analysis – voxel of peak correlation in right hippocampus – x=29, y=-28, z=-17, t=2.49 (Figure 1). There were no significant correlations in female musicians or non-musicians of either sex.

Discussion

This study found a significant gender by musicianship interaction in the hippocampal volumes. Male musicians had larger hippocampal volumes bilaterally and increased grey matter density in the right posterior hippocampus compared to male non-musicians. In addition, hippocampal volume correlated positively with number of years of orchestral playing in male musicians under 50 years of age. Male musicians performed significantly better on visual memory tasks than non-musicians, and their performance was significantly positively correlated with the right hippocampal volume, which is known to have a critical role in processing visual memory. Based on anatomical and developmental research together with inferences from animal studies, we propose that the hippocampal structural differences found in male musicians reflect an overall internal reorganization of hippocampal circuitry in response to increasingly demanding tasks and skills required (e.g. sight-reading and memory) to perform music at professional level. Furthermore, the larger hippocampal volumes reported in male musicians may have contributed to the difference in visual memory scores between male musicians and controls. Details of the gender by musicianship interaction and the possibility of sexual dimorphism in hippocampal volume need to be further explored with a larger female sample.

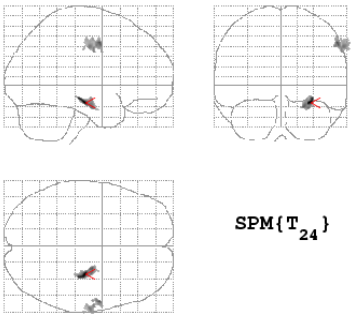

Figure 1. Statistical parametric maps showing a positive correlation between grey matter concentration and visual memory index in male musicians.

References

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