

An Investigation of the Effect of Hearing Ability on underlying Neural Processes, Cortical Structural integrity and Auditory Resting State Networks



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Abstract

Introduction: The aim of this study was to investigate the impact of hearing acuity on brain structure and function alterations. **Methods and materials:** 20 participants with normal hearing and 20 participants with mild to moderate hearing loss have been recruited in this study. Four different MRI techniques were applied: structure MRI, diffusion MRI, task-based fMRI and resting state fMRI. **Results:** Different auditory and non-auditory brain regions in the right hemisphere showed abnormalities in mild to moderate hearing loss group compared to normal hearing group. **Conclusion:** These results suggest neuronal reorganisation as a consequences of mild to moderate hearing loss.

Background

Hearing loss (HL) is one of the commonest sensory losses in ageing, and is related to functional loss of both sensory and neural elements (Roth, Hanebuth et al. 2011). HL is associated with some symptoms of cognitive decline such as reduced working memory capacity, slowed processing and speech problems (Lin 2011, Lin, Ferrucci et al. 2011, Lin, Yaffe et al. 2013). We investigate the effect of wide range of hearing variations on brain cortical structural, neural processes, cortical structural integrity and auditory resting state networks.

Methods and Materials

Population

This study was approved by the Research Ethics Committee at the University of Liverpool (United Kingdom). The sample consisted of 40 adults who underwent routine clinical audiometry and magnetic resonance imaging: 20 normal hearers (age 30-63 years, mean 41, SD 9 years) and 20 subjects with mild to moderate hearing loss (age 30-65 years, mean 49, SD 10 years).

Auditory examination

Routine hearing examination was performed using calibrated pure tone audiometry, including 7 frequencies (0.5-8.0) kHz used for clinical hearing evaluation: normal hearing was defined as pure tone hearing thresholds of 20 dB or better at these frequencies, and mild to moderate hearing loss was defined as a hearing threshold between 25 dB and 60 dB at any frequency.

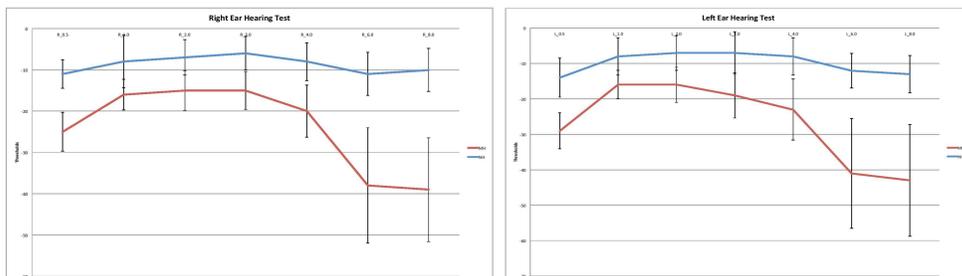


Figure 1: Audiogram graphs for each group's ear.

Data Acquisition

MRI data were acquired using 3T MRI scanner (Siemens Trio). Four different techniques were applied in this study:

- Structural MRI,
- Resting state functional MRI,
- Task based functional MRI
- Diffusion MRI.

Data analysis

All methods applied in this study are based on Unbiased Whole Brain Analysis. Structural MRI data were processed using FSL-VBM toolbox as part of FMRIB Software Library (FSL), Oxford, UK (Good et al 2001).

Resting state functional MRI data were processed using MELODIC toolbox as part of FMRIB Software Library (FSL), Oxford, UK (Beckmann, DeLuca et al. 2005).

Task (auditory)-based functional MRI data were processed using FEAT toolbox as part of FMRIB Software Library (FSL), Oxford, UK (Smith, S. M., et al. (2004).

Diffusion MRI data were processed using TBSS toolbox as part of FMRIB Software Library (FSL), Oxford, UK (Smith, S. M., et al. 2006)

Different types of analysis tests were applied to identify the effect of hearing acuity on brain structure and function: sample t-test (one and two tails) and multiple regressions.

References

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Results

Cortical Volume Analysis



Figure 2: Grey matter volume reduction in mild to moderate hearing loss group comparing with normal hearers. Maximum intensity projection with a threshold of $P < 0.001$ (corrected)

Cortical Structure Integrity

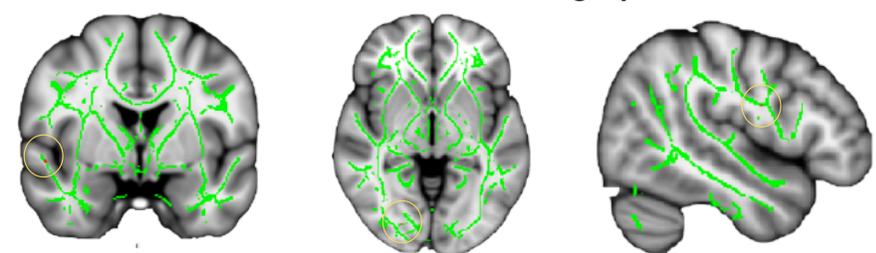


Figure 2: Whole-brain group comparison (NH>HL) of DTI data obtained from TBSS analysis (Uncorrected at $P < 0.05$). The statistically significant clusters are shown in red color over a FA skeleton map in green color

Auditory Perception

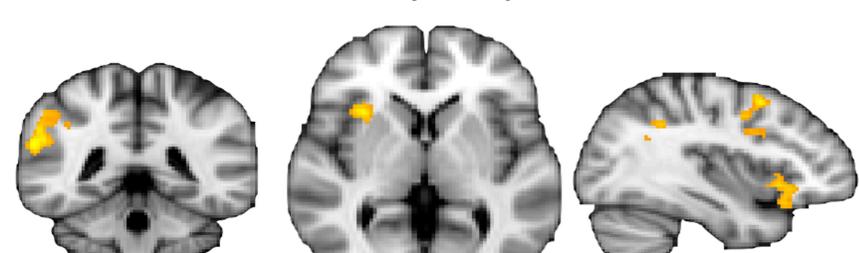


Figure 4: Two sample t-test map of fMRI activity showed a reduction activity in mild to moderate hearing loss (MH) compared to normal hearing (NH) groups (SMG: Supramarginal gyrus, IFG: Inferior frontal gyrus, MFG: Middle frontal gyrus)

Functional Connectivity

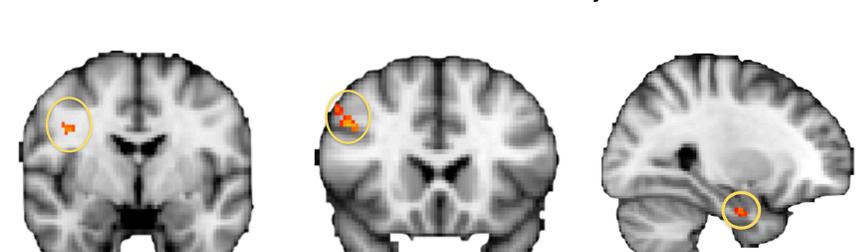


Figure 5: Two sample t-test map of fMRI activity showed increased functional connectivity in auditory and attention networks in mild to moderate hearing loss group compared to normal hearing group. Limbic network showed positive correlation between functional connectivity and hearing loss thresholds.

Discussion / Conclusion

We investigate the influence of wide range of hearing acuity on brain cortical structural volume, underlying neural processes, cortical structural integrity and functional connectivity.

These results demonstrated the involvement of auditory and non-auditory brain regions in the pathophysiology of hearing loss even at an early stage.

No significant difference was identified in the left hemisphere which may reflect the role of language network to protect the brain from structural and functional alterations in the left hemisphere.

Future work

We are currently recruiting participants with tinnitus symptoms. These preliminary results are going to be compared with tinnitus results in order to identify the pathophysiological mechanism differences between hearing loss and tinnitus.

Acknowledgment

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