Lateralized fMRI activation and connectivity in the central auditory system of normal hearing and unilaterally deaf humans.

D. Langers[1], P. van Dijk[2], W. Backes[1]

[1]dept. of radiology, Maastricht University Hospital, Maastricht, Limburg, Netherlands, [2]dept. of otorhinolaryngology, University Hospital Groningen, Groningen, Groningen, Netherlands

Introduction

Because binaural information is indispensable for the localization of sound sources, information streams in the central auditory system cross at many locations. At the low-level cochlear nucleus, input is available only from the ipsilateral ear, whereas at the high-level auditory cortex the strongest responses are evoked by stimulation of the contralateral ear. In unilaterally deaf patients cortical activation patterns are more symmetrical, suggesting plastic reorganizations in the auditory processing chain. However, little is known about whether similar changes exist in the subcortical nuclei, and at which levels changes in connection strengths occur. In this study, functional MRI was used to measure the lateralization of hemodynamic responses in various nuclei of the human central auditory system, and to quantify their mutual connectivity levels.

Materials and Methods

16 subjects (8 with normal hearing, 8 with left ear hearing loss or deafness) were presented with noise and ripple stimuli of which the intensity to the left and right ear was varied independently (0, 40 or 70 dB). T_2*-weighted EPI scans were sparsely conducted in an oblique coronal plane (1.5 T, TR 11 s, TE 50 ms, voxel size 1.0×1.0×2.5 mm). Ten regions of interest (ROIs) corresponding with the left and right cochlear nuclei (CN), superior olivary nuclei (SO), inferior colliculi (IC), medial geniculate nuclei (MG) and auditory cortices (AC) were defined, and per ROI the signals from the 10 % most active voxels according to *F*-test statistics were averaged. Activation levels were determined using multiple linear regression, and effective connectivity levels between ROIs were calculated using path analysis on a hierarchical connectivity model (see Fig. 3).

Results

Activation could be detected in the ICs, MGs and ACs of almost all normal hearing subjects, and was predominantly contralateral in nature (Fig. 1). For the CNs and SOs, activation was found in only approximately half of the subjects. For the unilaterally deaf subjects, activation in response to stimulation of the unaffected ear was again mostly contralateral for the ICs and MGs, but more symmetrical for the ACs (Fig. 2); responses to the deaf left ear were hardly significant. The effective connectivity analysis revealed that pathways predominantly crossed to the contralateral side below the IC, and continued ipsilaterally from there on in normal hearing subjects (Fig. 3). In the unilaterally impaired subjects, the unaffected right ear pathway remained strong. However, the left ear pathway was hardly active, although the right AC did receive relatively strong input from the left MG.

Conclusion

Activation was detected reliably in the ICs, MGs and ACs (predominantly contralaterally), and occasionally in the CNs and SOs. Evidence for plastic reorganization in unilaterally deaf subjects was limited to the MGs and ACs and their connectivity.

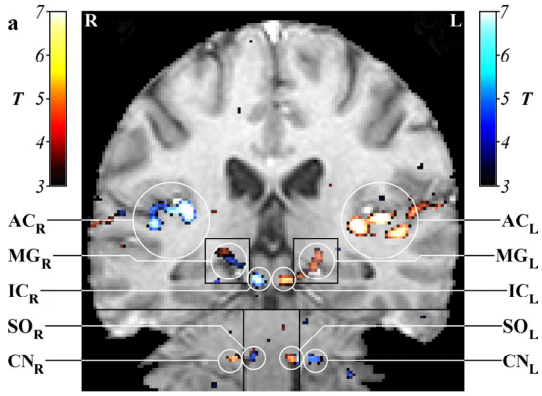

Fig 1: Composite image showing the activation in the various auditory nuclei in response to right (red) and left (blue) ear stimulation in one illustrative subject.

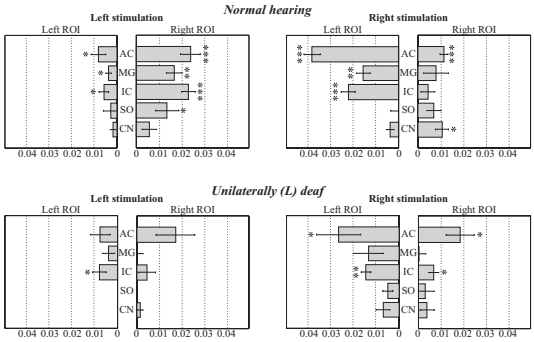

Fig 2: Average activation levels [%/dB]. In normal hearing subjects (upper panels), activation is highly significant in the contralateral ICs, MGs and ACs, while in unilaterally deaf subjects (lower panels) activation is significant to stimulation of the unaffected right ear and more symmetrical in the ACs.

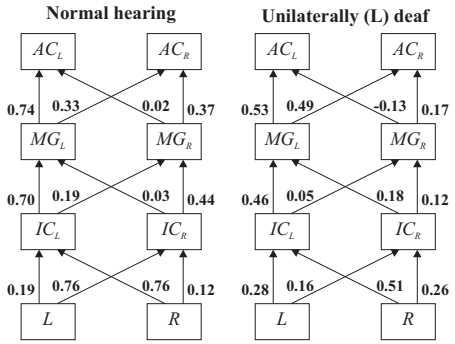

Fig 3: Structural equation model, involving the left and right stimulus intensities (*L* and *R*), ICs, MGs and ACs, and containing ipsi- and contralateral connections between nuclei at successive levels. The CNs and SOs were left out because their activation was less consistent. The effective connectivity strengths were quantified by standardized regression coefficients using path analysis . In normal hearing subjects (left), signals cross below the level of the IC and remain dominantly ipsilateral hereafter. In the unilaterally deaf subjects (right), the pathway associated with the affected left ear is hardly active; only the deprived right AC seems to reorganize to receive stronger input from the left MG.