Networks utilized for receptive speech in children with right and left unilateral sensorineural hearing loss

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Introduction

Children with severe-to-profound unilateral sensorineural hearing loss (USNHL) have shown deficits in higher-order auditory processing tasks, such as interpretation of speech-in-noise and sound localization [1]. These deficits may reflect in deficits in academic performance [2]. In addition, risk of academic failure is greater in children with deafness in the right ear [3]. Here we investigate the task of receptive speech using functional MRI (fMRI) in children with right and left USNHL, using acquisition and post-processing techniques specialized for hearing-impaired children.

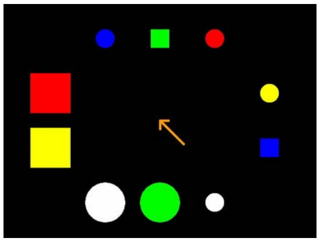

Figure 1. Illustration of the modified token task. The orange arrow will move to touch the small blue circle and the small blue square. The subject will hear "Touched the small blue circle and the small blue square" during the movement of the arrow.

Materials and Methods

Nine children with USNHL participated in the study. IRB approval and informed consent from one parent was obtained for all participants. All children had confirmed severe-to-profound USNHL via standard pure-tone audiometry, with normal hearing in the other ear (<= 20 dB HL for all frequencies between 250 Hz – 4 kHz). Data from one child was discarded due to excessive motion artifacts. Of the eight children remaining (6M, 2F, age = 9.2 ± 1.83 yrs, range = 7.2 – 11.8 yrs), 4 had right USNHL and 4 had left USNHL. MRI scans were performed using a Siemens 3T Trio system. Scan parameters were: TR/TE = 2000/38 ms, FOV = 24 X 24 cm, matrix = 64 X 64, slice thickness = 5 mm.

The paradigm consisted of a "modified token" task (Figure 1). Subjects viewed the arrow moving to point to two of the shapes on the screen. Simultaneously, a corresponding audio stimulus was presented such as "Touched the small yellow circle and the large green square". Subjects would respond via a pneumatic button if the speaker correctly described the motion of the arrow. There were 13 "simple" trials (using "and" for the conjunction), 13 "advanced" trials (using "before" or "after" for the conjunction), and 13 "control" trials, where the audio stimulus consisted of a beep, to control for sublexical auditory processing. Stimuli were presented using the PC program Presentation (Neurobehavioral Systems, Inc., Albany, CA) during completely silent scanner intervals, using a silent-gradient pulse sequence [4]. A specially constructed MR audio system with ER-30 headphones was used, with very low ambient noise of 10 dB. All stimuli were calibrated using a B & K audiometer to 80-85 dB SPL.

Data was processed using routines in IDL (Research Systems Inc., Boulder, CO). Data was retrospectively corrected for motion and time courses normalized (to percent change from the mean) separately for the first, second, and third scans after the silent gradient interval, to account for T1 relaxation effects. Data was transformed into stereotaxic space and group Independent Component Analysis (ICA) [5] was performed. Relevant components were obtained via analysis of the associated time courses. Frames were retained for further analysis if 1) the subject responded correctly and 2) the motion for the given frame was within acceptable limits, using a cost function and a visually determined threshold. Due to the varying number of frames available for each subject, an expectation-maximization restricted maximum-likelihood (EM-ReML) method previously used for a longitudinal analysis [6] was used to detect components with significant activation during "simple" trials vs. control trials, or "advanced" vs. "simple" trials; and components with differential activation between children with right and left USNHL, for both contrasts.

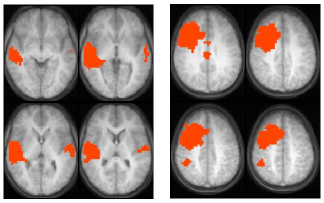

Figure 2. Group IC maps for the task of receptive speech in a population of children with USNHL. (Left image significant for group activation; right image significant for left USNHL > right USNHL). ($T > 3.5$, spatial extent threshold = 15 voxels. Images in radiologic orientation.)

Results

For the contrast of "simple" receptive speech vs. "control" trials, a bilateral, though right-lateralized component, was seen in Wernicke's area and its RH homolog (Figure 2, left). A right-lateralized component (Figure 2, right), with activation in the parietal lobe and the RH homolog of Broca's area was also seen, with activation in children with left USNHL > activation in children with right USNHL; this network was activated for children with left USNHL ($p < 0.05$) but de-activated for children with right USNHL.

For the contrast of "advanced" vs. "simple" receptive speech, activation was seen in occipito-temporal and posterior temporal areas in the left hemisphere (Figure 3, left two images), likely associated with auditory-visual integration and higher-order integrative processes, respectively. A component with activation in the left inferior frontal gyrus (BA 45/47) was also seen (Figure 3, right), with activation in children with right USNHL > activation in children with left USNHL.

Discussion

The bilateral activation in Wernicke's area and its RH homolog (Figure 2, left) and posterior temporal areas (Figure 3) agrees with previous results for narrative processing [7]; however, the right and left lateralization, respectively, was unexpected. A future comparison with normal controls will elucidate whether this result is specific to children with USNHL.

Our results also indicate the preferential development of pathways *ipsilateral* to the hearing ear. This may represent differential compensation strategies in children with right and left USNHL, and corroborates a preliminary fMRI study using tone presentation [8] hypothesizing formation of sound processing pathways ipsilateral to the hearing ear, as children with left USNHL preferentially activated the right superior temporal gyrus (Heschl's gyrus) while children with right USNHL preferentially activated the left inferior frontal gyrus.

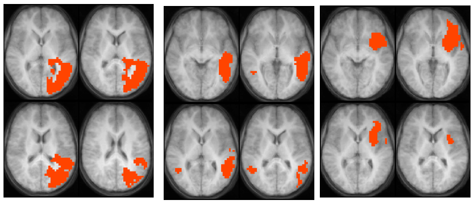

Figure 3. Group IC maps for the task of receptive speech, comparing "advanced" trials with "simple" trials, in a population of children with USNHL. (Left two images significant for group activation; right image significant for right USNHL > left USNHL). ($T > 3.5$, spatial extent threshold = 15 voxels. Images in radiologic orientation.)

Task performance represents a potential confound. Two of the children with left USNHL performed below chance level for the "advanced" trials, and not significantly above chance level for the "simple" trials. The comparisons between children with left USNHL vs. children with right USNHL however retained significance when these two subjects were excluded from the analysis.

Conclusion

An fMRI study was performed on children with left and right USNHL using a receptive speech task, using acquisition and post-processing techniques specialized for this population. Results indicate preferential formation of pathways for speech processing ipsilateral to the hearing ear.

References

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