Functional MRI of Lipreading in Normal Hearing and Deaf Subjects

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Introduction

A recent fMRI study of lipreading [1] reported the same areas of activation for listening to words and for a silent lipreading task in normal subjects. These areas were the left transverse temporal gyrus (BA 41), right superior temporal gyrus (BA 42 and 22) and left superior temporal gyrus (BA 22) The claim that silent lipreading causes activation of BA 41, referred to as the "primary" auditory cortex, is provocative and not consistent with previous reports that suggest that the primary auditory cortex is responsible for early acoustic processing of elementary auditory sensations. To understand this issue further, we designed a study to identify sites involved in lipreading for normal and deaf subjects, and to contrast these to a simple tone stimulus in normal hearing subject.

Method

Participants in this IRB approved study were right-handed young adults with normal hearing or with profound hearing impairments, all with English as their first language and better-than-average lipreading relative to their normative group. In the lipreading experiment, a sequence of silently mouthed monosyllabic words (stimulus 'on') was contrasted with a sequence of colored-shapes overlayed on a still frame of the same talker's face (control condition). The subjects pressed a button when two lipread words in sequence were the same during the stimulus 'on' condition, and when the color and shape of the pattern in sequence were the same in the control condition. The control condition therefore involved the same motor response, the same type of discrimination judgment, the same duration of stimulus tokens, and the same face. In another experiment with normal hearing subjects only, a 1 kHz tone repeating at 5Hz was contrasted with a silent control condition to locate the primary auditory cortex. Possible contributions from the gradient sound, which was present equally during both conditions, were ignored.

A GE 1.5T EPI Signa Horizon MRI system with its standard quadrature head-coil was used to conduct the fMRI studies. A total of 500 images were acquired from four 10mm thick contiguous transaxial or coronal slices (125 images per slice) covering the auditory regions with TR=4s, effective TE=45ms, 90 deg flip angle, 64x128 acquisition matrix, 20x40cm^2 field-of-view and NEX=1. The first five images per slice were ignored to establish equilibrium and starting at image 6, the task (e.g., lipreading or a 1 kHz tone) and the corresponding control condition were presented in an alternating sequence with 15 images acquired during the task and 15 during the control condition for a total of 4 cycles. The time-series of images was registered using the method described in [2] and analyzed by SPM99b [3] using a box-car reference function delayed by one image to match the hemodynamic response time. Pixels whose z-score was above a threshold ($p<0.001$) were color coded and superposed on corresponding anatomy. No threshold was used for cluster size.

Results and Discussion

Results from the tone experiment in seven normal hearing subjects consistently showed bilateral activation of an area that we believe is correctly identified as the superior temporal plane, i.e., BA 41/42 and some portion of BA22 on the plane. Activation was more widespread in the lipreading than in the tone experiment and included some frontal areas. Though inter-subject variability was apparent, regions within the temporal lobe activated during lipreading were posterior and inferior to those activated by the tone. Small areas of common activation seen in the transaxial slices were likely to be due to partial volume effects. The overlap was significantly reduced in coronal imaging. An example of two coronal slices covering the major portion of the auditory regions in a normal hearing subject is presented in Fig. 1. The tone stimuli resulted in the expected bilateral activation of the superior temporal plane. Lipreading resulted in activation of the superior temporal sulcus predominantly on the right, with some activation in the parietal cortex. These studies suggested that for normal hearing subjects, minimal common activation between lipreading and tone occurred, but not in the primary auditory cortex.

Four deaf subjects were imaged. An example of activation patterns in coronal images of a deaf subject during lipreading is shown in Fig. 2. The activation was within the superior temporal gyrus, extending into the superior temporal sulcus, both of which are secondary auditory cortical areas. There was no evidence of activation in regions that would anatomically conform to the expected location of the primary auditory area in these subjects.

Conclusion

The primary auditory cortex is not activated during silent lipreading in either deaf or normal hearing subjects. Even when deafness is lifelong, the primary auditory cortex is not engaged by visible speech

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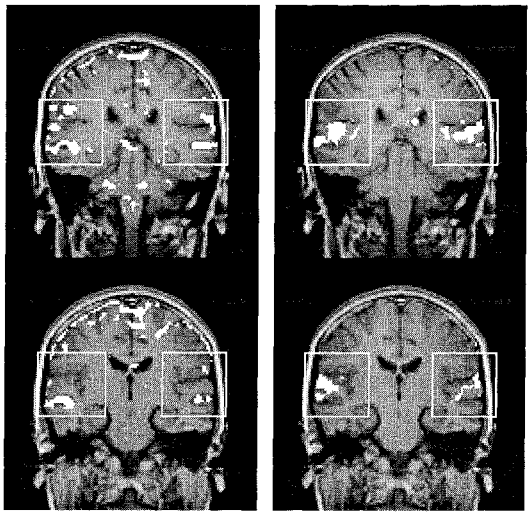

Fig. 1: Two contiguous 10mm coronal slices for a normal hearing subject showing lipreading (left) and tone (right) activation.

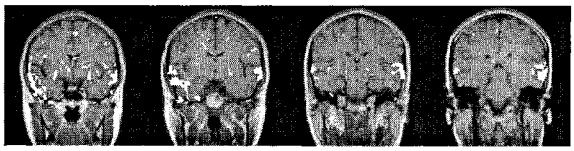

Fig. 2: Activation during lipreading for a deaf subject.