Speech Perception and Speech Production Systems Overlap in Posterior Auditory Cortex: An FMRI Study

K. Okada[1], G. Hickok[1]

[1]Department of Cognitive Sciences, University of California, Irvine, CA, United States

Abstract

Neuropsychological data and recent neuroimaging studies converge on the view that there exist cortical sites in posterior auditory cortex that participate in speech perception and speech production. However, it remains unclear whether the same neural regions support both perception and production of speech or whether there exist discrete cortical fields subserving these separate functions. The present 4T FMRI study addressed this issue in an event-related FMRI experiment and each subject participated in a passive listening task and a covert object naming task. Single subject analysis revealed overlapping regions in posterior auditory cortex (Area SPT: Sylvian-Parietal-Temporal) in the left hemisphere. Area Spt activated both during perception and production of words. We suggest that this cortical site is part of an auditory-motor integration system in the dorsal auditory stream that supports the transformation between auditory and motor representations of speech.

Introduction

There is mounting evidence that sites in posterior auditory cortex are involved in perception and production of speech [1]. It remains unclear, however, whether or not input and output systems overlap in posterior superior temporal gyrus (pSTG), or whether subfields of pSTG support perception and production separately. We explored whether speech input and output systems overlap in pSTG in a neuroimaging study. In an event-related FMRI study, we employed two naturalistic tasks using common nouns as stimuli. Subjects engaged in a passive listening task (listened to a list of monosyllabic words) and then subsequently participated in a covert object naming task. Single subject analysis was performed to identify, in each subject, regions that participated both in the perceptual task and the production task. The goal of the present study is to investigate whether there exist shared regions in superior temporal lobe that are involved in both perception and production of speech.

Methods

Ten right-handed subjects participated in the study. There was a total of 4 sessions in the FMRI experiment (2 perception sessions followed by 2 production sessions). During the perception sessions, subjects viewed a line drawing for 2 seconds and they simultaneously heard the name of the picture. Each stimulus was followed by a 10 second rest period. During the production sessions, subjects were shown the same pictures and were asked to covertly name the drawing as quickly as possible. Each picture appeared on the LCD monitor for 2 seconds and this was followed by a 10 second rest period. Stimuli consisted of 48 line drawings of common objects. These stimuli have previously been used in a variety of behavioral studies [2].

Data were collected at the University of California, Irvine, in a 4 Tesla magnet (Magnex Scientific Inc.) interfaced with a Marconi Medical Systems' EDGE console for the pulse sequence generation and data acquisition. First, a high resolution anatomical image was acquired (axial plane) with a 3D SPGR pulse sequence for each subject (FOV = 240mm, TR = 50 ms, flip angle = 50 deg., size = 0.9375 mm x 0.9375 mm x 2.5 mm). We then collected a series of EPI acquisitions and obtained the magnetic field map [3] and this information was used for correcting geometric and intensity distortions in EPI scans. Functional MRI data were acquired using single-shot EPI (FOV = 240mm, TR = 2 s, TE = 31.3 ms, flip angle = 90 deg, voxel size = 2.55 mm x 3.75 mm x 5mm).

First, motion correction was achieved by aligning all functional volumes to the first volume in the series using a 6-parameter rigid-body model in AIR 3.0. Then, field map correction was performed on all volumes. The high resolution structural image was co-registered to the first volume of the scan. Each functional volume was then spatially smoothed (Gaussian spatial filter, 4 mm FWHM) and the time course of the BOLD signal was temporally filtered (bandpass between 0.056 Hz and 0.167 Hz).

Regression analysis was performed on each subject separately using AFNI software. Three predictor variables were entered into the analysis (regressor 1=perception; regressor 2=production; regressor 3=mean time course). Each predictor variable was convolved with a hemodynamic response function (except for regressor #3) and entered into the analysis. First, an F-statistic was calculated for each voxel and activation maps were created for each subject to identify regions significantly activated during perception ($p < 0.0001$, uncorrected) and during covert object naming ($p < 0.0001$, uncorrected). Using these two statistical maps (from perception and production), we identified areas that overlapped in perception and production. Voxels that were significantly activated in perception and production, thresholded at $p < 0.0001$ in each condition, were considered and new activation maps were created to illustrate cortical areas engaged in both perception and production.

Results

Perception of words and object viewing activated superior and middle temporal lobes and ventral visual areas bilaterally (Fig 1). Covert object naming activated the following regions: posterior superior temporal sulcus bilaterally, posterior superior temporal gyrus in the left hemisphere, inferior frontal gyrus, lateral premotor cortex in the left hemisphere, and ventral visual areas bilaterally (Fig 2). In all ten subjects, regions of overlap were found in posterior superior temporal lobe. In particular, a subfield of pSTG, an area in the Sylvian fissure at the boundary of temporal and parietal lobes (Area Spt) was activated in all 10 subjects (Fig 3).

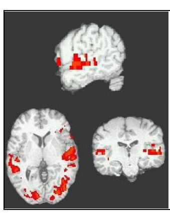

Figure 1.
Activation map from one subject showing a typical activation pattern for passive listening.

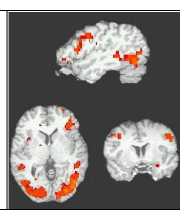

Figure 2.
Activation map from one subject showing a typical activation pattern for covert object naming

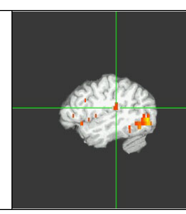

Figure 3.
Activation map from one subject showing areas that overlap in perception and production.
(Crosshair at Area SPT)

Discussion

The goal of the study was to investigate whether speech input and output systems overlap in posterior auditory cortex. In all 10 subjects, Area Spt activated during speech perception and production. Our results are consistent with previous work demonstrating that Area Spt shows both sensory and motor properties. Area Spt is hypothesized as an auditory-motor interface area [1] and performs a mapping between auditory and motor representations of speech. Results from our study confirm and extend previous work implicating Spt as a site involved in auditory-motor transformation function and we support the proposal that Spt is part of an auditory-motor integration system in the dorsal auditory stream.

References

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