Evidence for Motor Effector Specificity in the Auditory-Motor Domain: An fMRI Investigation

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Abstract

An area in the posterior Sylvian region, area Spt, has been identified by recent imaging work and is thought to support auditory-motor integration. This region exhibits auditory-motor properties, in that it is active during both perception and production of speech and music. The present 4T study sought to determine whether auditory-motor responses would vary regionally, according to motor effector system. Subjects heard a novel melody and were asked to either covertly hum or imagine playing the melody. Area Spt responded greater to the vocal tract effector while a dorsal parietal region responded greater to the manual effector. Analogous to the visuo-motor system, we suggest that auditory-motor integration systems are organized around motor effector systems.

Introduction

Recent neuroimaging studies have identified a parietal-temporal region (area Spt) that responds both to auditory input (speech, music) and during sub-vocal rehearsal of that input; i.e., it has sensory-motor responses. We have hypothesized that Spt functions to support auditory-motor integration [1]. In the visual domain, several parietal lobe regions have been found in the monkey that appear to support visuo-motor integration, each of which is tuned to a different motor effector system (eye, hand, arm) [2,3]. It is unknown whether auditory-motor integration is similarly organized around motor effector systems. The objective of our study is to determine whether the auditory-motor system is organized around motor output systems by manipulating the effector. We hypothesize that different cortical regions will be activated depending on whether the task predominately involves oro-facial (area Spt) or manual production (dorsal parietal).

Methods

Four right-handed female pianist subjects were used in this paradigm. Skilled pianists were used in this study because they have well established auditory-articulator associations involving distinct modalities, allowing the stimulus to be held constant while manipulating the effector. Each subject was presented with two critical conditions: music+humming, music+playing. Each trial consisted of a 3 second stimulus (music) followed by 0,6, or 12 seconds of production (covert humming, imagined playing); a 1 second visual stimulus was then presented to indicate the end of the rehearsal period followed by 12 seconds of rest. The melodic stimuli were novel, simple tunes written in C major.

Data were collected at the University of California, Irvine in a 4T scanner (Magnex Scientific Inc.) interfaced with a Marconi Medical Systems' EDGE console for the pulse sequence generation and data acquisition. 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). A series of EPI acquisitions were then collected, obtaining the magnetic field map [4]. 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). Motion correction was achieved by aligning all functional volumes to the sixth volume in the series using a 6-parameter rigid-body model in AIR 3.0. Field map correction was later performed on all volumes during the post-processing of the raw data to correct for geometric and intensity distortions in EPI scans. The high resolution structural image was co-registered to the sixth volume of the scan. The time course of the BOLD signal was temporally filtered (bandpass between 0.0147 Hz and 0.125 Hz).

Using AFNI software, single subject analysis was performed with separate regressors for speech perception, music perception, speech production, hum production, and play production. Each predictor variable was convolved with a hemodynamic response function and entered into the analysis. An F-statistic was calculated for each voxel, and activation maps were created for each subject to identify regions significantly activated during rehearsal phases: covert hum and imagined play. The analysis focused on activations during the covert rehearsal phase in the music conditions found in the posterior sylvian region and in a dorsal parietal region. A focus of activation was found in both of these areas in each subject. Subsequent analyses were carried out on these regions of interest.

Results and Discussion

We identified a dorsal parietal region that was responsive to the music+imagined play condition ($p<.0001$). This area activated in the hum condition as well, but with less amplitude when compared to the play condition. The previously identified area Spt also showed activation for both conditions, but was more activated during the hum condition ($p<.001$).

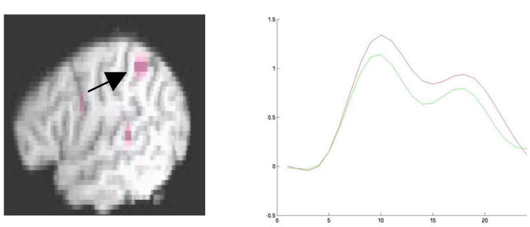

Figure 1. Activation map from one subject showing Area Spt activation during hum production. The group voxel timecourse graph displays the 3 second auditory response followed by the 12 second motor response in area Spt of the top 3 voxels in 4 subjects.

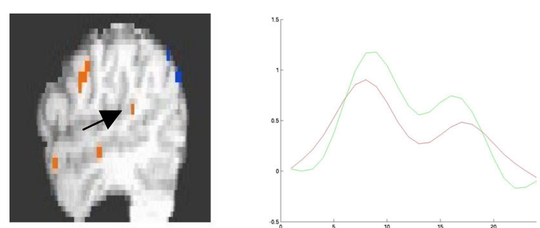

Figure 2. Activation map from one subject showing the dorsal parietal region activation during play production. The group voxel timecourse graph displays the 3 second auditory response followed by the 12 second motor response in area DP of the top 4 voxels in 4 subjects.

In summary, a double dissociation was observed: the hum condition activated Spt more than the playing condition while the reverse held in a dorsal parietal site. These results provide at least partial evidence that the auditory-motor integration system is organized according to motor effector systems. The identified dorsal parietal area and area Spt appear to be a subset of regions serving auditory-motor interaction systems, a part of the dorsal auditory stream.

References

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