SPEECH PERCEPTION AND THE INFERIOR FRONTAL NEURAL SYSTEM FOR MOTOR IMITATION

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Abstract

Visual observation of mouth movements can aid or alter the perception of the acoustic speech signal: Speech comprehension is significantly improved during face-to-face conversation when oral-facial gestures are visible. Recent primate work has suggested that "mirror cells" in the ventral premotor area are involved in specific hand or mouth movements or the visualization of these same movements. This suggests a mechanism that could account for the improved speech perception, whereby activity in mirror neurons is integrated with activity in auditory (and perhaps other) cortical areas to facilitate speech comprehension. In the present work, we tested the prediction that such activation depends on the direct visualization the oral-facial gestures that accompany speech during face-to-face conversation. Ten right-handed subjects were imaged with fMRI while listening to interesting stories (audio only), listening to stories while seeing the storyteller (audiovisual), or just seeing the storyteller (visual). Comparison across conditions revealed significant ($t = 3.916$; $df = 18$; $p < .003$ corrected) activation in the inferior frontal cortex (BA 44/45) in the audiovisual condition that was not present in either other condition. This result suggests that neural activity in the imitation-matching motor system, thought to localize to the inferior frontal cortex in humans, plays a role in speech perception only during natural face-to-face conversation, when oral-facial movements are directly observed, but not when this visual information is absent. The emergence of context-specific patterns of cortical activity during face-to-face conversation may have implications for understanding the integration of motor information with perceptual information.

Introduction

Motor theory (Liberman & Mattingly, 1985) predicts that inferior frontal cortex may play an active role in speech perception.

"Mirror cell" theory (e.g. Rizzolati & Arbib, 1998) predicts inferior frontal cortex may be active during observation of mouth movements.

McGurk effect (McGurk & Macdonald, 1976) and other findings (e.g., Sumby & Pollock, 1954) show perception of mouth movments during speech modifies speech perception.

Do these findings reflect cortical activity consistent with motor theory or mirror cell theory?

Method

Participants: 5 female and 5 male right-handed native English speakers.

Acquisition: fMRI, 1.5T with head coil; 24 spiral gradient echo T2* functional images; TR = 3, 226 whole brains collected in each of 4 runs.

Stimuli: spoken stories (audio only), spoken stories with video of storyteller (audiovisual), or video of the storyteller (video alone). Subjects viewed and/or heard stimuli. No overt motor response or linguistic judgment was required.

FIGURE 1

fMRI Data Analysis: Deconvolution analysis (Ward, 2001); Group analysis: transformed to Talairach coordinate space, 8 mm Gaussian full-width half-max smoothing.

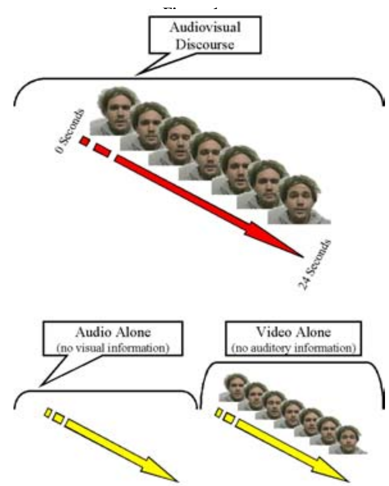
Results

FIGURE 2: shows activation for one subject

ANOVA: significant effect of presentation ($F = 10.38$; $df = 2, 18$; $p < .003$ corrected) across subjects.

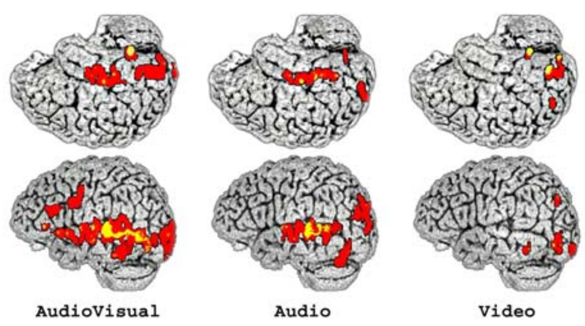
Contrast: Audio-Visual condition different from combined Audio and Visual conditions ($t = 3.916$; $df = 18$; $p < .003$ corrected); activation in STG and IFG (Brodmann areas 44/45 and 9) in Audio-Visual condition *not present* in either the Audio condition or the Visual condition.

FIGURE 3: shows volume of activation in the three conditions for STG and IFG.



Graphical representation of stimuli and conditions (Arrows represent time)

Figure 2

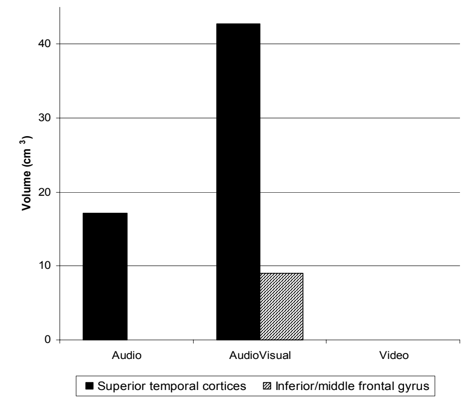


Areas of activation ($F_{6,872} = 5.58$; $p < .00001$ uncorrected) for the audiovisual, audio, and video conditions in one subject in the left (bottom) and right (top) hemispheres.

red-yellow intensity scale where yellow is stronger intensity.

Note: frontal activation patterns present in the audiovisual condition absent in the audio and video conditions.

Figure 3



Volume of activation (cm^3) in superior temporal cortices and inferior and middle frontal gyrus during the audio, audiovisual, and video conditions.

Note: frontal cortices not active during the audio condition.

Conclusions

Results show activity in inferior frontal cortex during audiovisual speech perception that is not present during listening without visual information and is not present during visual observation of mouth movements.

In addition, audiovisual speech perception changes the amount and lateralization of STG activity. This change in left STG activation may reflect the cortical mechanism by which visual information about mouth movements affects speech perception in previous behavioral studies.

Visual observation of mouth movements during speech perception may activate motor cortical mechanisms consistent with the Mirror Cell Theory and with the Motor Theory of speech perception.

The lack of inferior frontal cortex activity during the auditory-alone condition suggests that speech recognition is not always mediated by inferior frontal cortex. Instead, speech perception appears to be mediated by active cortical circuits that tune auditory sensitivity depending on the context of perception.

Participants were not instructed to lipread which might explain the lack of inferior frontal cortex activity during the video-alone.

Contact Information

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