Comparing Silent and Overt Speech Using fMRI: Head Motion, Articulatory Motion, and Cortical Activation

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Introduction

Silent speech paradigms are commonly used during mapping of cortical language processing using functional MRI (fMRI). Motion artifacts induced by talking can severely contaminate functional images [1]. A previous study suggests that silent speech and overt speech may activate different neural networks [2]. Furthermore, aphasic patients often complain that the words they speak bear a poor correspondence to the words they think. In this study, we used event-related fMRI methods and motion detection and correction techniques to investigate the feasibility and comparability of silent and overt speech paradigms.

Methods and Materials

Six normal right-handed native English speakers (4 male, 2 female, age from 20 to 35 yrs) participated in the study. Each subject performed four language paradigms: (1) "speaking" a letter name silently; (2) speaking a letter name overtly; (3) silently generating an animal name starting with a given letter; and (4) overtly speaking an animal name starting with a given letter. Sagittal T2* weighted images of a whole head were acquired on a GE 1.5 T clinical scanner using a gradient echo Echo-Planar-Imaging pulse sequence (field-of-view 24 cm, TE/TR=50/2000 ms, flip angle 90 degrees, matrix size 64×64, slice thickness 7 mm). During each paradigm, twelve 32 s long event-related trials were presented in a random order and 192 images per anatomic section were acquired. During each trial, the subject either silently or overtly spoke a letter or an animal name.

Data Analysis:

Motion detection and correction: Images were assessed and corrected for possible planar translations and rotations of the head [3]. Comparison was made between images obtained during silent and overt speaking. *Statistical analysis of activation:* Time courses of images were cross-correlated [4] with sine and cosine reference functions to obtain a pair of complex cross-correlation coefficients (ccc) voxel by voxel [5]. Both magnitude and phase of ccc were further calculated [5]. The phase represents a time delay of signal changes. Activation images were thresholded at the magnitude of ccc > 0.23. Based upon the assumption that the signal change due to head movement during speaking occurs earlier than that of the hemodynamic response, the phase of ccc for above-threshold voxels was analyzed to identify false positives.

Results

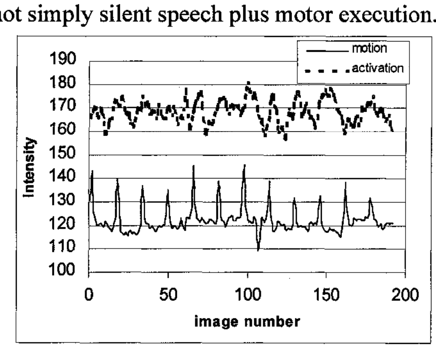
Motion Detection: In all 6 subjects, head movement, less than 1 degree rotation but no translation, was detected in images obtained during both silent and overt speaking. Detected head movement in images during overt speaking was not substantially worse than that during silent speaking. In only two of the six subjects, modest to severe motion artifacts, which were not correlated with speaking, were observed in images during both silent and overt speaking. In short, motion was more subject-dependent than task-dependent.

False positives observed during overt speaking were primarily located outside of brain, in areas of mouth and neck. In these areas, signal changes due to head movement during speaking occurred 2-4 s earlier and were of larger magnitude than those of the hemodynamic response to speaking observed in cortex (Figure). In some voxels in regions of inferior occipital lobe and cerebellum, signals were contaminated by these motion artifacts, exhibiting a drifted baseline and/or double-peaks.

Activation Patterns: During silent speaking paradigms, Broca's area (left inferior frontal region) was consistently activated, and the right inferior frontal region was also activated to a large extent. However, during overt speaking, activation in Broca's area was decreased. Instead, increased activation was observed in primary sensorimotor cortex (PSM) both left and right.

Discussion and conclusions

Motion and motion artifacts in functional images during silent and overt speaking were assessed by two methods. Motion observed during overt speaking was not substantially greater than that observed during silent speaking. Motion is more subject dependent than task dependent. The location of motion artifact caused by talking is generally outside of brain regions. The onset of signal changes due to motion generated by talking occurred before the onset of signal changes due to hemodynamic response. This can be utilized to separate false positives caused by talking from true activation. Our data indicate that Broca's area and PSM play different roles during silent and overt speaking. The neural networks of silent and overt speech are not the same, and they do not appear to be organized in a simple hierarchical fashion -- that is, overt speech is not simply silent speech plus motor execution.



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