fMRI During Overt Production of Alternating Elemental English Sounds

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Purpose: The goal of this research is to develop methodology that will facilitate the use of fMRI for research in the neurophysiology of speech production. The specific purpose of this abstract is to describe recent fMRI results using a new overt-speech protocol, which is introduced here. See Fig. 1.

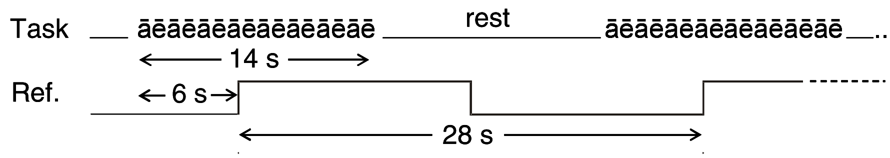

Fig. 1. Overt speech paradigm.

Strategy: We were unsuccessful in obtaining robust fMRI activation in a block trial protocol using extended phonation of vowels of 14 s duration alternating with rest for 8 cycles. Nor were we successful with paradigms that required continuous repetition of the same sound, for example a block of "āāāāā . . ." sounds alternating with rest, again for 8 cycles. It occurred to us that use of repeated sound pairs, as shown in Fig. 1, might yield a more robust fMRI response in the presence of susceptibility-based motional artifacts. In this paradigm, alternation of the articulation muscles of speech production (tongue, jaw, lips, velum) between the configuration required for one sound and the configuration required for the other sound occurs repeatedly during a period of 14 s, followed by a 14 s period of rest – repeated for 8 cycles.

Methods: Six subjects were scanned using a 3.0 T GE Long Bore Signa Excite scanner and a GE 8-channel brain array coil assembly with summation of signals from the eight channels for best SNR. Whole brain low resolution (3×3×6 mm voxels) were acquired with the following parameters: 20×20 cm FOV; 64×64 matrix; 18.5 ms TE; 2s TR; 90° flip angle. High resolution (2×2×2 mm voxels) axial image parameters were: 25.6×25.6 cm FOV; 128×128 matrix; 19.5 ms TE; 2 s TR; 23 contiguous slices; 90° flip angle. Sound instructions and timing were presented visually. Images were analyzed initially using real-time AFNI (1) and more extensively, post-acquisition, using the methods of Ref. 2. Typically, the reference function was offset by 6 s, to accommodate the hemodynamic delay. The 14-s task activation was selected, following Ref. 2, so that motion artifacts are separated from the BOLD response by about 90°.

Results: Intense fMRI signals were consistently seen as illustrated for an ā-ē pair in Fig. 2. The low-resolution image revealed 5 major areas of activation with the following Talairach coordinates: SMA (premotor) (2, 4, 61), left and right precentral gyrus (motor area) (-49, -3, 48; 53, 5, 50), left inferior parietal lobe (Wernicke's area) (-41, -40, 22) and left superior temporal gyrus (auditory) (-57, -33, 8 and -51, -17, 6). A representative pattern of time courses in a 1 × 1 cm region at high resolution without post-processing is shown in Fig. 2. Some pixels show correlation coefficients as high as 0.6. Several vowel and nasal consonant pairs as well as an ā-ē-n trio of repeated sounds were tested with strong activation in all cases. The high resolution data show complex patterns of activation in the regions identified by the low-resolution acquisition.

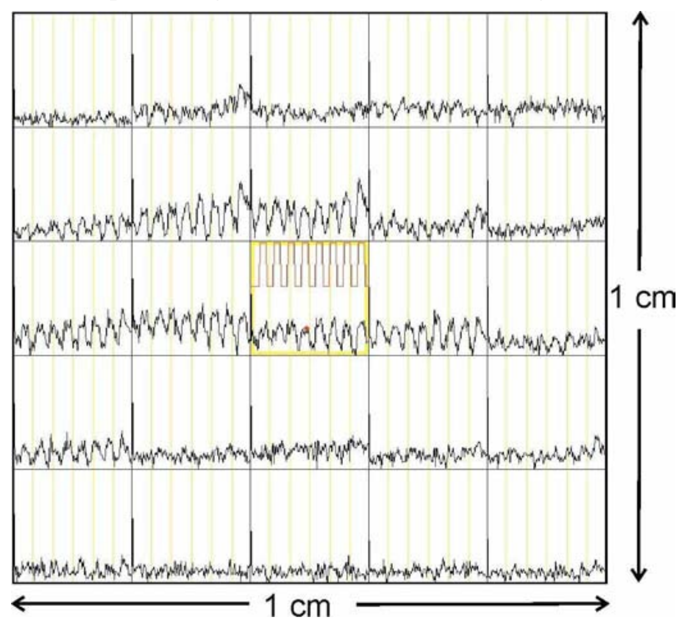

Fig. 2. Representative 5×5 array of pixel time courses using the paradigm of Fig. 1.

Discussion: Motional artifacts are the primary concern for overt speech paradigms. If the motional artifact were identical for all speech pairs in the paradigm of Fig. 1, there would be no motional harmonic content corresponding to the harmonic content of the reference function. In fact, the initial sounding of "ā" is from a resting state, whereas the other soundings of "ā" are from the articulation required for "ē", resulting in a motional component at the fundamental harmonic of the reference function. Motional artifacts were always present, but not overly severe. The methods of Ref. 2, which were designed to overcome motional artifacts during mastication, facilitated separation of true and false positives. In data not shown from two subjects, sounding of alternating pair of one-syllable words as well as repeated two-syllable words resulted in intense fMRI responses using the high-resolution parameters listed above. The method of alternating sound pairs introduced here to study the neurophysiology of speech production has, in our hands, been consistently robust.

References: 1. Cox RW, Jesmanowicz A, Hyde JS. Magn Reson Med 1995;33:230–236. 2. Soltysik DA, Hyde JS. Strategies for Block-Design fMRI Experiments During Task-Related Motion of Structures of the Oral Cavity. NeuroImage (in press 2005).