Using high-resolution fMRI to identify individual-specific speech motor regions

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Introduction. Previous studies of overt speech sequencing [1] identified activity in several brain regions such as ventral motor and pre-motor cortex, frontal operculum, posterior inferior frontal gyrus, supplementary motor area (SMA) and the pre-SMA. However, accurate localization of functional activity in these areas has been limited by: (a) the close spatial proximity of the ventral motor regions of the frontal lobe; (b) the moderate resolutions typically used for BOLD fMRI; and (c) the effect of spatial smoothing in the statistical analysis. Specifically, it has been difficult to reliably identify precise locations of activity in individuals. The aim of this study was to demonstrate that we can reliably extract individual-specific activity using high-resolution fMRI in combination with a multi-channel array coil.

Methods. High-resolution EPI data from neurologically normal participants were acquired using a 3T Siemens MAGNETOM Trio, a TIM System (Siemens Medical Solutions, Erlangen, Germany) and two different receive coils: a 32-channel phased array [2] and a 12-channel Matrix coil. Single shot gradient echo EPI data were collected using the following imaging parameters: TE = 30ms, flip angle = 90º, TR = 12s, TA = 2.5s, delay = 9.5s, GRAPPA reconstruction with acceleration factor of 2. Using the 32-channel array high resolution 1mm isotropic and 2mm isotropic data acquired. For comparison, 2mm isotropic data also obtained using the 12-channel Matrix coil. A pre-product Siemens 32-channel phased array head coil was also used for reproducibility of the high resolution acquisitions. Participants performed an overt speech sequencing task consisting of 3 conditions: (a) speaking complex sequences of complex syllables (e.g., stra-spli-stru), (b) speaking simple sequences of simple syllables (e.g., ba-ba-ba), and (c) passively viewing the letter string xxx-xxx-xxx (baseline). Each functional run consisted of 20 stimuli from each condition and lasted approximately 12 minutes. A single volume was collected with acquisition time of 2.5s, 5.75s after the onset of the stimulus. The volume comprised 25 slices centered on an oblique plane passing through ventral pre-motor cortex and covering the SMA as shown in Figure 1. Data analysis, including motion correction, smoothing and GLM fitting, was performed using SPM5. The 1mm and 2mm data were smoothed with 2mm and 4mm FWHM Gaussian kernels respectively. Two contrasts were evaluated: (A) speaking trials compared to baseline trials; and (B) complex trials compared to simple trials. We controlled False Discovery Rate at 0.05.

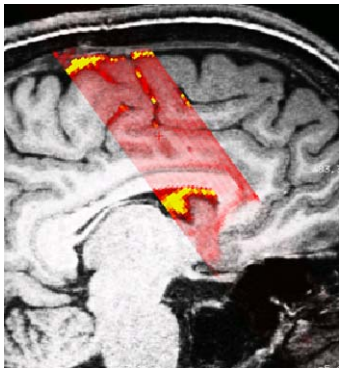

Figure 1: Mean 1mm isotropic EPI data overlaid on structural image showing slice prescription for 1mm scan.

Results and Discussion. Data from a single subject are shown in Figure 2 illustrating the t-statistics derived from contrast B. Activity in the anterior bank of the pre-central sulcus is found in all three acquisitions (1mm-32ch, 2mm-32ch and 2mm-12ch). As expected, the 32-channel coil showed greater sensitivity to the task than the 12-channel Matrix coil. The greater spread with the 2mm data from the 32-channel coil is due to the increased smoothing. Without smoothing, the 2mm data from the 32-channel coil shows very similar coverage as the smoothed and unsmoothed 1mm data using an uncorrected $p < .001$. Increased activity to this contrast was also found in left, but not right, SMA. The results were reproduced in one subject scanned using the Siemens 32ch investigational device.

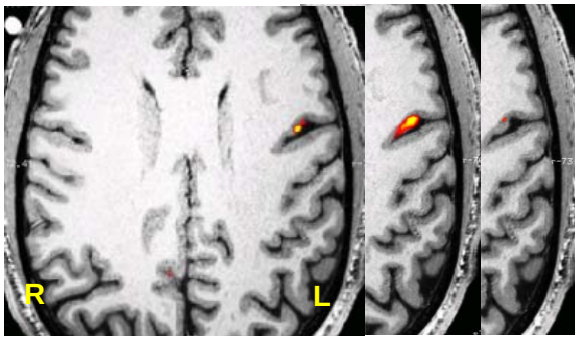

Figure 2: T-statistics comparing complex sequences to simple sequences evaluated using three different sets of data (from left to right: 1mm-32ch, 2mm-32ch, 2mm-12ch). Localized activity is in the anterior bank of the pre-central sulcus. (Overlay on 0.6mm iso MPRAGE)

Conclusions. Using a high-resolution EPI protocol, we were able to demonstrate sulcal bank-specific localization of speech motor activity related to producing complex sequences of syllables. We were also able to limit the amount of smoothing to a minimum, thus preventing extensive smearing of activity across sulcal banks. Such high-resolution data will enable accurate individual specific mapping of speech and other cognitive task related brain networks. It also provides an alternate non-invasive method for pre-surgical planning and exploration of speech and language regions.

References.

[1] Bohland, J.W., et. al.,, *NeuroImage*, 32(2): 821-841, 2006, [2] Wiggins, G.C., et al. Magn Reson Med,56 (1):216–23, 2006.