The Ability of fMRI at 7T to Detect Functional Differences between Areas 1 and 3b of Primary Somatosensory Cortex

E. A. Stringer[1], L. M. Chen[1], R. M. Friedman[2], J. C. Gatenby[1], and J. C. Gore[1]
[1]Institute of Imaging Science, Vanderbilt University, Nashville, TN, United States, [2]Psychology, Vanderbilt University, Nashville, TN, United States

Introduction

The ability of high field (7T) fMRI to achieve higher spatial resolution and sensitivity has been demonstrated in studies of human primary somatosensory cortex (SI), the principal cortical area for processing touch sensation. Four distinct cytoarchitectural areas comprise SI in primates, and each area is differentially involved in various somatic functions. Brodmann's area 1 contains dominantly rapidly adapting neurons, while Brodmann's area 3b contains both rapidly and slowly adapting neurons. Nonhuman primate studies have shown topological organization of body surface, as well as preferred responses to different cutaneous stimuli in areas 1 and 3b [1]. Previous human imaging studies have lacked the spatial specificity to distinguish these functional and anatomical subdivisions within SI, though we have demonstrated the ability of fMRI at 7T to detect topographical organization of digits in areas 1 and 3b [2]. Here we examine whether fMRI at 7T can detect the functional differences between these regions.

Methods

Healthy human subjects (N=5) were studied using a 7T Philips Achieva scanner with a 16-channel NOVA head coil. High spatial resolution functional images covering SI, SII, insula, and thalamus were acquired using GE-EPI (TE/TR: 25ms/2s; 16 oblique coronal slices, 1x1mm in plane, 2mm thick, no gap; R=3; volume selective 2nd order shimming with pencil-beam method). Innocuous tactile stimuli (2Hz air puffs) were delivered to the glaborous skin of individual distal pads separately. Stimuli were presented in a 24s on/off block design. Functional images were corrected for distortion using a field-map technique, and then imported into BrainVoyager QX for GLM analysis. No spatial smoothing was performed. A threshold was applied and images were displayed at q(FDR)<0.001 and cluster threshold of 4 voxels. To make the time course measurements comparable, the same size ROIs (the five most statistically significant voxels for a given activation cluster) were used in both area 3b and area 1. The time course of BOLD signal change was extracted from these peak voxels for comparison.

Results

Single subject activity maps reveal distinct representations of digit topography in both areas 1 and 3b. Figure 1 shows the activity map (D2–Rest) in SI for a single subject with unique representations of D2 along the crest of the post-central gyrus, corresponding to area 1, and along the posterior bank of the central sulcus, corresponding to area 3b. The five most statistically significant voxels from each area were defined and the time courses of the BOLD signal were extracted. The time courses in Figure 1 reveal a response trend in these two areas. In area 1, while the D2 location shows reliable responses to D2 stimulation (blue periods), it also responds to D4 stimulation but more weakly (traces in green periods in middle panel of Figure 1). In contrast, in area 3b, the D2 location selectively responds to D2 stimulation but not to D4 stimulation (lower panel in Fig1). Temporally, the response to stimulation in area 1 contains an initial transient and a sustained component, while the response in area 3b is more sustained throughout the duration of the stimulus. This response likely reflects the neuronal response properties in each of these areas. The mean of the BOLD signal time courses across all subjects (N=5) is displayed in Figure 2. The time course trends in the single subject are in agreement with the mean across subjects.

Conclusion

By taking advantage of the greater sensitivity to BOLD signal changes and higher signal to noise ratio at 7T, we show how differential responses to subtle tactile stimulation of a single fingerpad can be detected between areas 3b and 1 at very fine spatial scale (millimeters) in each individual subject. These findings are consistent with what has been reported in non-human primate high resolution functional imaging studies. We conclude that high-resolution fMRI at 7T not only resolves fine-scale digit maps in areas 1 and 3b of SI in individual subjects, but it also reveals functional differences within these adjacent closely spaced regions. These data support previous findings that using fMRI at high fields allows the detection of more stimulus selective responses.

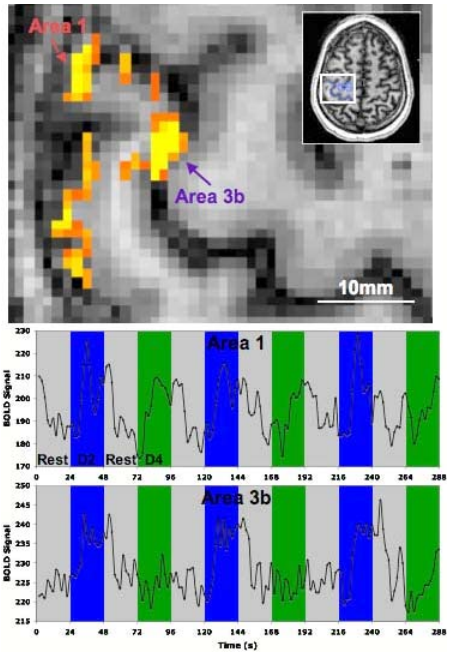

Fig1. Activity map and time course of digit responses in areas 1 and 3b. The axial slice of the anatomical image is displayed in the inset with the central sulcus (CS) highlighted in blue. The activity map (D2 - Rest) is displayed in the zoomed image, with distinct representations in areas 1 and 3b. The time course of BOLD signal change was extracted from the peak 5 voxels and displayed in the time course plots below for a single run; Rest grey, D2 blue, D4 green.

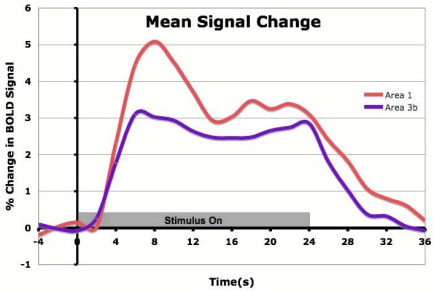

Fig2. The mean percent BOLD signal change across all subjects (N=5). The time courses from the peak five voxels were averaged across digits and subjects. The response to digit stimulation in area 1 (red) is greater in amplitude and is more transient, while the response in area 3b (purple) is more sustained. The grey box indicates the stimulus duration.

References

1. Chen LM, et al, *J Neuroscience*, 2005. **25**(33): pp. 7648 –7659
2. Stringer EA, et al, ISMRM Hawaii: **50**, 2009.