Separation and Reproducibility of Touch Activations in Areas 3b and 1 within the Primary Somatosensory Cortex by High Resolution fMRI at 7T

E. A. Stringer[1], R. M. Friedman[2], J. C. Gatenby[1], L. M. Chen[1], and J. C. Gore[1]

[1]Institute of Imaging Science, Vanderbilt University, Nashville, TN, United States, [2]Department of Psychology, Vanderbilt University, Nashville, TN, United States

Introduction

The primary somatosensory (S1) cortex is the principal neural region for processing touch sensation. S1 comprises four distinct cytoarchitectural regions each responsive to different stimuli; Brodmann's areas 3a, 3b, 1, and 2 receive input from muscle stretch receptors, rapidly and slowly adapting cutaneous receptors, rapidly adapting cutaneous receptors, and deep pressure receptors, respectively. Nonhuman primate studies have shown topological organization of areas 3b and 1, as well as preferential activation patterns in areas 3b and 1 to different cutaneous stimuli [1]. Human imaging studies have lacked the spatial specificity to distinguish these functional and anatomical subdivisions within S1. The advent of ultra-high field fMRI (7T) provides greater sensitivity and increases spatial resolution, resulting in finer scale activity maps than at lower fields. Here, we test the feasibility of 7T fMRI to visualize somatotopy and functional activations along the cytoarchitectural subdivisions (areas 3b and 1) within S1.

Methods

Healthy human subjects were studied using a 7T Philips Achieva scanner with a 16-channel NOVA head coil. High spatial resolution functional images covering S1, S2, 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 (2Hz air puffs) stimuli were delivered to the glaborous skin of alternating fingers. The stimuli were presented in a 24s on/off design with three epochs for each finger (D2 and D4) presented in a single run. The functional images were distortion corrected using a field-map technique, and then imported into BrainVoyager QX for standard analysis. No spatial smoothing was performed. Images are thresholded and displayed at q(FDR)<0.005 and cluster threshold of 4 voxels.

Results

Repeated trials within single subjects showed reproducible topological activations within areas 3b and 1 of the primary somatosensory cortex. Figure1 shows the non-overlapping touch representations within area 3b, located along the posterior bank of the central sulcus, and area 1, located at the crest of the postcentral gyrus, for each of the four trials. There is strong spatial agreement across trials. The mean digit separation between D2 and D4 in area 3b is 7.99mm ± 1.25mm, and the mean digit separation between D2 and D4 in area 1 is 3.70mm ± 0.88mm. The mean distance between areas 3b and 1 are 7.75mm ± 1.36mm and 5.90mm ± 0.53mm for D2 and D4, respectively. The mean t-score for each ROI is 5.13 ± 0.38. The timecourse of each ROI is displayed in Figure2. The signal magnitude of each digit is similar; the mean maximal change in BOLD and the mean area under the curve for D2 and D4 are 3.42% ± 0.62%, 31.83 ± 6.80, and 3.49% ± 0.77%, 31.37 ± 7.63, respectively. However there are magnitude differences between areas 3b and 1. The mean maximal change in BOLD and the mean area under the curve for area 3b is 3.11% ± 0.54% and 29.00 ± 5.77, while for area 1 the means are 3.79% ± 0.65% and 34.19 ± 7.47.

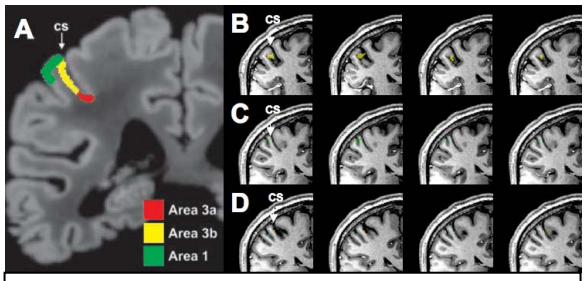

Figure1. A: Schematic of cytoarchitectural subdivisions within S1 [2]. CS stands for the central sulcus. *Adapted from Meyer et al.* B: D2 activations within area 3b (yellow) from each of four runs localized along the bank of the central sulcus. C: D2 activations within area 1 (green) from each of the four runs localized along the crest of the postcentral gyrus. D: D4 activations within areas 3b (peach) and 1 (teal).

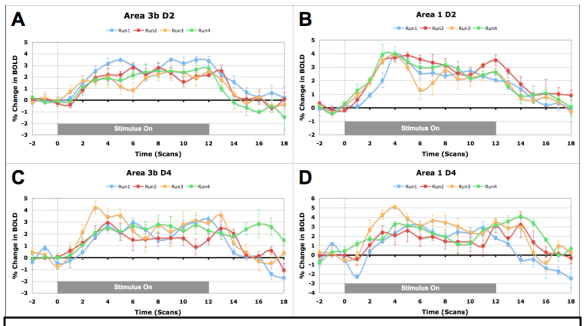

Figure2. The timecourse of percent change in BOLD signal from ROIs within S1. A: The average timecourse from D2 ROIs within area 3b across four runs. B: The average timecourse from D2 ROIs within area 1 across four runs. C: The average timecourse from D4 ROIs within area 3b across four runs. D: The average timecourse from D4 ROIs within area 1 across four runs.

Conclusion

High-resolution EPI-BOLD fMRI at 7T can resolve fine-scale digit maps in areas 3b and 1 of the primary somatosensory cortex (S1) in individual subjects. These maps are reproducible across runs. Imaging with voxel dimensions < 2mm^2 is essential for mapping somatotopy and interaeral differences within S1. Our data showing larger digit separation in area 3b than in area 1 support nonhuman primate studies that have shown area 3b has a larger digit representation than area 1, known as the cortical magnification factor.

References

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2. Geyer S, et al, Anat Embryol, 2001. 204: pp. 351-366