Mapping human somatosensory cortex with fMRI at 1 mm isotropic resolution

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Introduction

Functional MRI can be used to reveal the topographic organization of sensory cortical areas. For example retinotopic mapping of visual cortex is routinely used to define visual areas. Here, we took advantage of the increased BOLD contrast to noise ratio at 7T to measure the topographic representation of the digits in somatosensory cortex at 1mm isotropic resolution (c.f. 1-3).

Methods

A 'traveling wave' paradigm was used to locate regions of the cortex responding to tactile stimulation of each distal phalangeal digit. The tactile stimulus was delivered using a 9mm diameter tip attached to a piezoelectric element vibrating at a frequency of 30Hz. Each digit of the left hand was sequentially stimulated for 4.8s from thumb to little finger (24s stimulus cycle), resulting in a travelling wave of activity across cortical regions containing a somatotopic map of the hand. Subjects were visually cued to move the stimulator from one digit to the next with their right hand. Their left hand was fixed. Each functional scan (24s cycle, 10 repeats; total time 240s) was repeated twice.

Scanning was performed on a 7T Philips Achieva system using a 16-channel SENSE coil. The GE-EPI protocol allowed 18 coronal slices of 1mm thickness to be acquired with a TR of 2.4s and a TE of 25ms. Outer volume suppression was used to prevent fold-over in the (L-R) phase-encode direction. We performed two repeats of the functional scans at each in-plane resolution (1 x 1 mm^2 and 2 x 2mm^2) for comparison. Field maps and T_1-weighted MPRAGE image data were also acquired with the same resolution and slice prescription as the EPI data to allow subsequent distortion correction and overlaying of the activation maps onto anatomical images. fMRI data were analyzed using a Fourier-based method originally developed for retinotopic mapping of visual cortex (4). At each voxel, we calculated *c*, the coherence of the BOLD signal variation with the best-fitting sinusoid at the 0.042 Hz stimulus repetition frequency. The phase of the response at this frequency corresponds to the delay with respect to the onset of the stimulus cycle, and therefore the spatial location of the stimulus (which digit) on the hand.

Results and Discussion

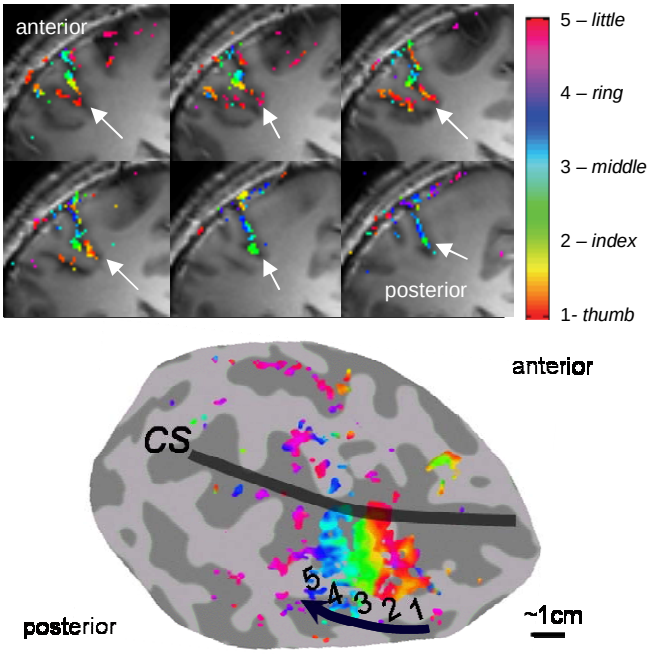

Figure 1: *Phase image colour maps (1 mm isotropic resolution) of two motion corrected averages for a coherence threshold of 0.4 superimposed on anatomical scan (above) and on a flattened patch of the right hemisphere (below) for one subject.*

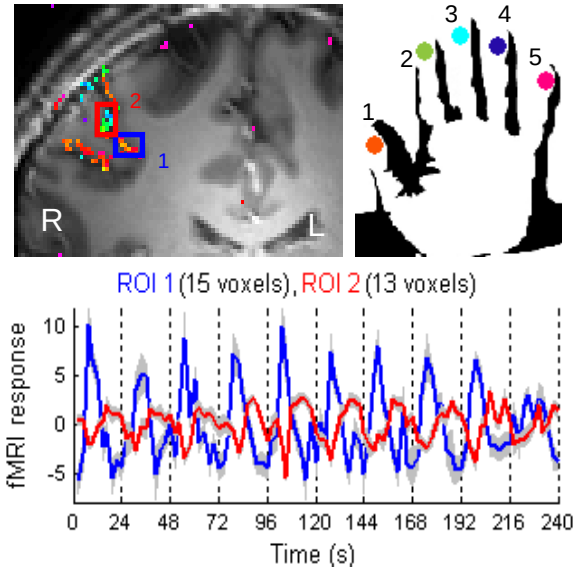

Figure 2: *Time courses for data from the two small regions of interest shown on the top left. Colour encodes fingers as shown on the right.*

An orderly pattern of activation was revealed in the primary somatosensory cortex at both in-plane resolutions. Threshold maps of the BOLD response phase (c>0.4) at 1mm isotropic resolution are shown in Figure 1. These high resolution maps contain all of the regions found to be active at 2 x 2mm^2 in-plane resolution. The colour bar indicates the mapping of the BOLD response phase to the type of digit stimulated. Arrows mark activation in the right primary, somatosensory, cortex which is confined to the grey matter strip and shows the expected digit ordering along the postcentral gyrus. This ordering is depicted more clearly when the activation is superimposed on the flattened cortical patch also shown in Fig. 1. The high resolution of the functional data helps in avoiding spread of activation from one side of a sulcus to the other. The temporal signal-to-noise ratio of the EPI images with 1 mm isotropic resolution was measured as 9.7 and 6.3 for the grey and white matter respectively. Figure 2 shows the time series from two small regions of interest (ROI) in the data with 1mm isotropic resolution. The z-scores for signal (stimulus repetition frequency) compared to noise (all other frequencies) for the corresponding time series from the 1mm and 2mm resolution data are 12.71 & 16.81 (ROI1) and 13.89, & 16.53 (ROI2), respectively, indicating highly significant signal modulation.

Conclusion

We have shown that the signal to noise ratio available at 7T allows the representation of digits in primary somatosensory cortex to be robustly mapped at an isotropic resolution of 1 mm in experimental runs of a less than 10 minutes duration. We have also mapped these data onto inflated and flattened maps of cortex and are currently characterising the temporal and spatial properties of responses to vibrotactile digit stimulation with an event-related design.

References

(1) Overduin S.A., Servos P. NeuroImage. **23** , 462 (2004).
(2) Huang R-S., Sereno M.I., NeuroImage. **34** , 1060 (2007).
(3) Duncan R.O. Boynton G.M., Cerebral Cortex (2007).
(4) Engel, S.A. et al. Nature. **269**, 525 (1994).