Somatotopic mapping at 7T using a natural stimulus.

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Introduction The primary somatosensory cortex (SI) contains Brodmann areas (BA) 1, 2, 3a, and 3b (Fig. 1), each containing a full representation of the body[1]. BA3b usually presents a better defined somatotopy than BA1 and 2[2], which are further down the processing stream and have larger receptive fields and more specialized inputs[1]. The use of fMRI for somatotopic mapping of SI has yielded variable results in the past. The spatial extent of the cortical areas representing a digit is close to the resolution of most fMRI experiments, complicating acquisition of consistent maps for individual subjects[2], while inter-individual variability in sulcal anatomy impedes group studies. Here, the high spatial resolution and BOLD sensitivity available at 7 Tesla were used to map the somatosensory cortex using a natural stimulus, i.e. human touch.

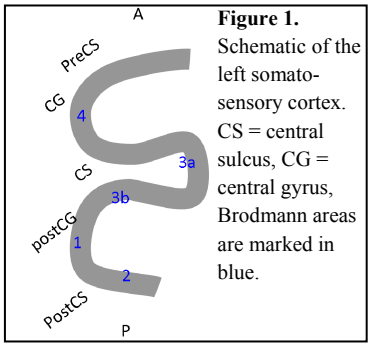

Figure 1. Schematic of the left somato-sensory cortex. CS = central sulcus, CG = central gyrus, Brodmann areas are marked in blue.

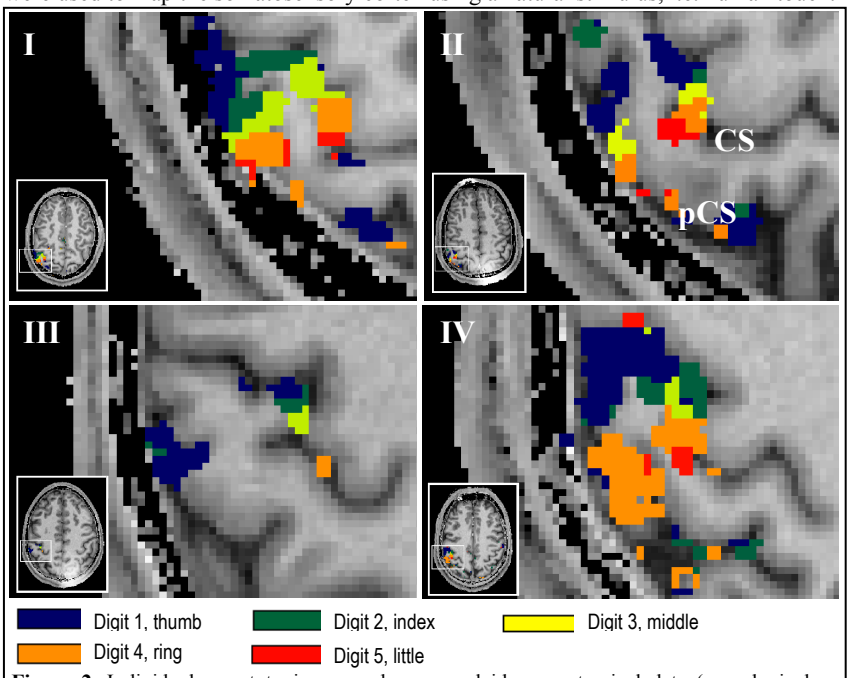

Figure 2. Individual somatotopic maps shown overlaid on anatomical data (neurological convention). Insets show the position of the magnified area. Different digits are indicated by different colors (see legend). CS = central sulcus (BA3b), pCS = post central sulcus (BA2).

Methods Four male subjects were scanned on a 7T scanner (Siemens Medical Solutions, Germany) with an 8-channel Tx/Rx rf-coil (Rapid Biomedical GmbH, Germany). 1.3*1.3*1.3 mm^3 resolution fMRI data were acquired using a sinusoidal readout EPI sequence[3] and FOV=210mm, TE/TR=27ms/2.5s, GRAPPA=2. One volume contained 28 transverse slices covering SI. A single EPI volume with 64 slices was acquired to aid coregistration. 1*1*1 mm^3 anatomical data were acquired using the MP2RAGE sequence[4] ($TE/TR/TI_{1,2}/TR_{mprage}$ = 2.63ms/7.2ms/0.9,3.2s/5s).

Subjects were positioned supine in the scanner with their right arm comfortably against the magnet bore. An experimenter was positioned at the entrance of the bore where he could easily reach and stroke two distal phalanxes of a digit (one at a time). The order of digits being stroked was D1(thumb)-D3-D5-D2-D4, with 20s ON, 10s OFF alternated. This sequence was repeated four times per run and two functional runs were acquired per subject. E-prime was used to cue the experimenter via MR-compatible headphones (NNL, Norway).

Realignment, smoothing (FWHM 2 mm), coregistration of the anatomical to the fMRI data and calculation of t-statistics were done using SPM8. An SI mask was obtained via an F-contrast ($p<0.001$) over all digits. Within the mask, voxels were labeled as representing the digit demonstrating the highest t-value for that particular voxel.

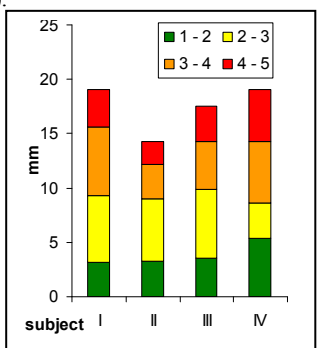

Figure 3. Cumulative Euclidian distances between neighbouring digits (centre of mass), within BA3b, per subject.

Results For all subjects, areas corresponding to the five digits were identified in the contralateral SI. No significant ipsi-lateral activation was detected. Slices taken from individual somatotopic maps are presented in Fig. 2. The most consistent somatotopic representation (4 out of 4 subjects) was found in BA3b. Digits 1 to 5 were localised consecutively in the cortex, with the thumb most anterior, inferior and distal and the little finger (D5), most posterior, superior and medial. D5 of subject III was located 6mm superior to the slice shown, neighbouring the representation of D4. Subject I and II also presented an orderly representation of the digits in the posterior bank of the central gyrus, in BA1 and 2. The inter-digit distances (Fig. 3) confirm significant inter-subject variability in anatomy. Mean euclidian distance between digits was 4.5 ± 0.7 mm (mean ± stderr).

Discussion and Conclusion General topography of individual subjects corresponded well to previous group studies in terms of organisation and distance between digit representations[25]. The small distance between digit representations highlights the need for high spatial resolution in somatotopic mapping. While the somatotopic representations on the posterior bank and crown of the central gyrus are less well defined than in BA3b, orderly digit representations were detected in 2 out of 4 subjects.

As these somatotopic maps are highly consistent in identification of representations of all five digits, they can be included in further studies as functional localizers. We conclude that the increased BOLD sensitivity at 7T and the high spatial resolution used in this study allow consistent somatotopic mapping using human touch as a stimulus.

References and acknowlegdements [1]Kandel et al, Principles of Neural Science, 4th Ed. McGraw Hill, [2]Schweizer et al 2008, Neuroimage,42:28-35, [3]Speck et al, 2008, Magma 21(1-2):73-86, [4]Marques et al, 2009, NeuroImage. [5]v. Westen et al, 2004, BMC NeuroScience, 5:28. Supported by the Centre d'Imagerie BioMédicale of the UNIL, UNIGE, HUG, CHUV, EPFL and the Leenaards and Jeantet Foundations.