Investigating digit representation and tactile attention in SI/SII with a novel paradigm

Rosa Sanchez Panchuelo[1], Keren Yang[1], Martin Buehrer[2], Miles Humberstone[3], and Susan Francis[1]
[1]*University of Nottingham, Nottingham, United Kingdom,* [2]*Gyrotools, Zurich, Switzerland,* [3]*Nottingham University Hospitals Trust, Nottingham, United Kingdom*

TARGET AUDIENCE: Researchers interested in fMRI, sensory processing, and cognitive neuroscience.

PURPOSE: fMRI has been extensively used to provide a detailed map of the somatotopic representation of the digits in the human primary somatosensory cortex (SI) [1], however digit somatotopy in human secondary somatosensory cortex (SII), and the effect of tactile attention in SI and SII have not been explored in detail. Here, we use multiband (MB) acquisition for whole brain coverage with high spatial resolution at 7T to investigate the neural networks involved in spatial attention to vibrotactile stimulation and digit somatotopy in SI and SII.

METHODS: Four subjects were scanned in a Philips Achieva 7T system with a 32-channel receiver coil (NOVA medical). Protocol: fMRI data were acquired using a multi-slice gradient echo – echo planar imaging (GE-EPI) with TR= 2 s, TE= 25 ms, FA=75°, FOV=192x162 mm^2 (APxRL). A SENSE factor of 2.5 was used in the RL direction and a multi-band factor of 2, achieving 52 slices of 1.5 mm isotropic resolution. Paradigm: Vibrotactile stimulation (30 Hz) was applied to each digit of the left hand in an "on-off" boxcar waveform using independently controlled piezo-electric devices which each stimulated a ~1 mm^2 skin area. Each digit was stimulated simultaneously with a different periodicity (5s on/19 s off, 8s on/22s off, or 14s on/26s off +/- 180'phase lag). A visual display indicated to the subject to attend to either digit 2, 3, or 4, with attention shifting digit every 40s (Fig. 1). The experiment was of 480s duration, and was repeated 3 times for each subject, so that every digit was stimulated with the three different periodicities. A high resolution structural dataset was acquired with the same slice prescription, allowing registration to an anatomical reference volume for surface rendering. Data Analysis: fMRI data were analyzed using mrTools (http://www.cns.nyu.edu/heegerlab). A GLM analysis was performed to identify cortical areas responding to stimulation of each digit by including all attend and non-attend stimulation trials (i.e. ignoring attention effects). In addition, for Digit 2, Digit 3 and Digit 4, we also investigated the contrast of attention versus not attention (i.e. attention to another digit) to reveal those areas of the cortex that are modulated by digit specific attention. Statistical maps were formed by thresholding (Z>2.3) after FWE correction and transformed into flattened representation of the cortex.

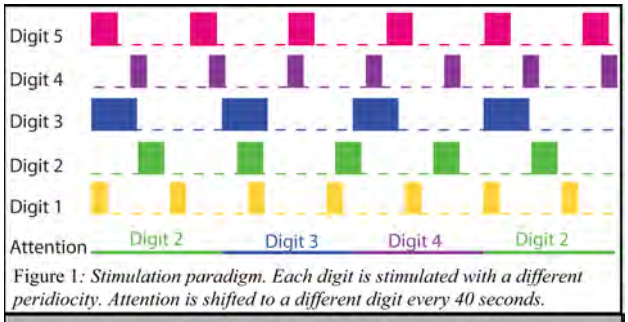

Figure 1: *Stimulation paradigm. Each digit is stimulated with a different peridiocity. Attention is shifted to a different digit every 40 seconds.*

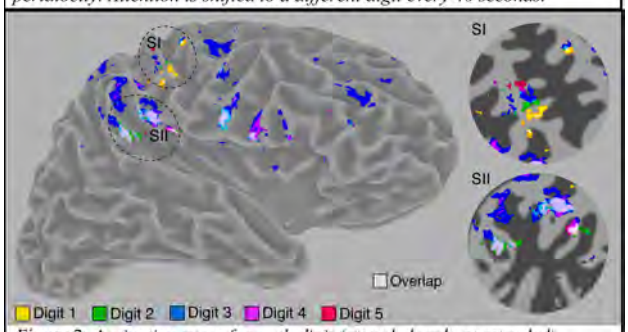

Figure 2: *Activation maps for each digit (attended and not attended) superimposed onto semi-inflated representation of the right hemisphere for subject 1. Flat patches of the SI nd SII are also shown.*

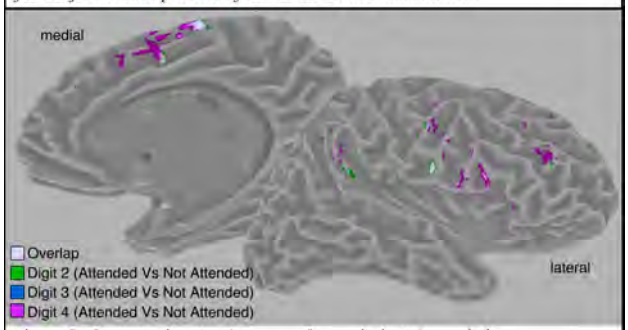

Figure 3: *Statistical activation maps for each digit (attended versus not attended) in the right hemisphere for subject 1. White regions show overlap of the three conditions.*

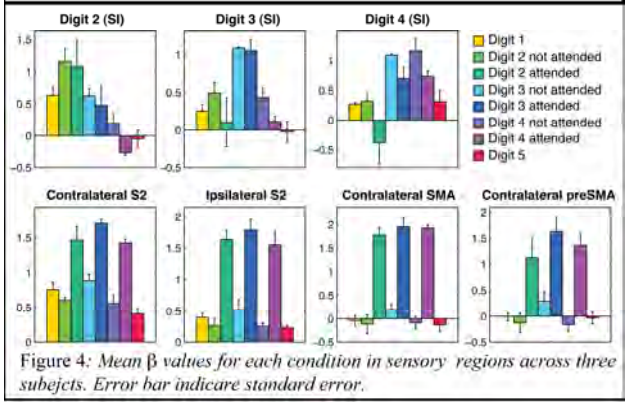

Figure 4: *Mean β values for each condition in sensory regions across three subjects. Error bar indicare standard error.*

RESULTS: The stimulation paradigm produced robust activation patterns for each digit in the posterior bank of the central sulcus (SI), and parietal operculum (SII), for all three subjects scanned. Within contralateral SI, digits stimulation led to clear somatotopic organization along the medio-lateral axis from Digit 5 to Digit 1 (Fig. 2). Within SII, there was no clear digit somatopic pattern as the responses to stimulation of any digit largely overlap, as can be seen by the white regions in Figure 2. Assessing the pattern of cortical modulation due to attention revealed no activation in SI but showed a consistent pattern of activation across subjects with a network including bilateral SII, SMA, lateral premotor, prefrontal, posterior parietal cortex and pre-SMA (Fig. 3). Figure 4 shows the modulation of the BOLD response in sensory related areas across three subjects scanned. In S1, there was little modulation of the BOLD response by attention. In contrast, attentional modulation was strong in SII, SMA and pre-SMA.

DISCUSSION This study demonstrates somatotopic digit maps to the left hand, with little attention related modulation of digit specific activity in right SI, and overlapping digit representations modulated by attention in SII. This lack of modulaton by attention in SI is in line with previous work using electrical stimulation of the median nerve [2]. A widespread network of cortical activity is seen responding specifically to the pattern of stimulation in the attended digit, despite the focus of attention switching between digits during the paradigm.

CONCLUSION: We have successfully mapped the digits of the left hand in SI and SII with high spatial resolution simultaneously using a novel paradigm. In SI there is no modulation to attention, whereas in SII the representation of the digits and their modulation by attention largely overlaps.

References. [1] Sanchez-Panchuelo et al, *J Neurophysiol,* 103:2544-56, 2010 [2] Backes et al, *Clin Neurophysiol,* 111:1738-44, 2000