An fMRI study of the relative laterality of dominant and non-dominant hand sensory function

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Introduction: It is well known that sensory function in humans, like that of motor function, is localised to particular cortical and subcortical regions, and that typically within primary cerebral cortex this function is strongly lateralised contralateral to the movement or sensation. It is also known that in most individuals one side is favoured over the other. However the relative degree of cerebral laterality of sensory functional representation of the dominant side of the body compared to the non-dominant side is still relatively unexplored. We sought to explore this directly using functional magnetic resonance imaging (fMRI) of individuals during sensory stimulation of the fingertips. In particular we employed an adaptive method for determination of laterality that is largely independent of statistical threshold, to examine the degree of laterality in the primary and secondary somatosensory cortices. We hypothesised that the degree of lateralisation would differ with stimulation of the fingertips of the non-dominant hand compared to the dominant hand. If this hypothesis is found to be true, it might help to explain the presence of impaired sensation in the hand ipsilateral to the lesion, in addition to the traditional contralateral hand, observed in approximately 20% of stroke patients (Carey et al., 2011a). It might also guide prediction of this bilateral deficit and a tailored approach to treatment depending upon the side of the injury.

Methods (data acquisition and analysis): Normative data from 13 right-handed healthy control subjects (Age range 23 -79 years; mean±SD = 61.75±12.3 years, 6 males) were analysed. Each subject performed a sensory fMRI study. This paradigm involved six 30-second blocks of task alternating with blocks of rest. During task blocks subjects were subjected to a standardised sensory stimulus via a tactile stimulation device consisting of a plastic texture grating, of set spatial interval, presented to the 2nd, 3rd and 4th digits of the hand at a controlled speed and pressure (Carey et. al., 2011b). Functional echo-planar imaging volumes of the whole brain were acquired using a GE 3T scanner. Analysis was performed using iBrain™ (Brain Research Institute; www.brain.org.au/software) and SPM8 (Wellcome Department of Cognitive Neurology; http://www.fil.ion.ucl.ac.uk/spm). Pre-processing included slice-timing correction, motion correction (realignment), and non-linear warping to a custom local template approximating that of the standard Montreal Neurological Institute (MNI) template. Spatially normalised image data was smoothed with an 8 mm isotropic Gaussian kernel and images were saved at a uniform voxel size of 2x2x2mm. Using the general linear model (GLM), statistical parametric maps were computed for each dataset. Temporal autocorrelation was modelled using a white noise and autoregressive AR(1) model. Motion correction parameters were included as covariates of no interest.

Methods (laterality): Laterality distributions and statistical comparisons thereof were made using a method largely independent of statistical threshold, as described in Abbott et. al. (2010) and implemented in the iBrain Analysis Toolbox for SPM (www.brain.org.au/software). Briefly, for each subject distributions of laterality index (LI) as a function of number of active voxels (nvox) within a region of interest (ROI) were calculated. Regions were first determined separately for left and right hand stimulation using a meta-analysis of previous functional imaging studies of sensory function and the software GingerALE (http://brainmap.org/ale/). Search terms included fMRI, PET, somatosensory, tactile, touch and vibrotactile. MNI and Talairach coordinates reported from 26 papers investigating the stimulation of left and/or right hands of healthy controls were used to define the regions for each hand.. A p-threshold corrected for multiple comparisons using the False Discovery Rate was fixed to 0.05 and a minimum cluster size of 200 mm^3 was applied. The regions were made symmetric by mirroring all contralateral voxels, and then combined to obtain a symmetric region that encompassed activity for both hands. From this we then defined two pairs of final ROIs to interrogate laterality of primary somatosensory cortex (SI), and secondary somatosensory cortex (SII). One of each pair contained only voxels on the left (L), the other only voxels on the right (R). Laterality index for SI and for SII for the right hand sensory stimulus was calculated as: $LI=(N_L-N_R)/(N_L+N_R)$ where N_L and N_R number of voxels above a chosen threshold in each of the left and right hemisphere ROIs respectively. LI of the left hand stimulus was calculated as the negative of the formula above, so that a positive LI always referred to contralateral cerebral dominance. For SI, the family of LI distributions for left-hand stimuli were statistically compared to the family of LI distributions for right-hand stimuli using the method described in Abbott et. al (2010). Specifically, the distributions were each adjusted such that at each value of nvox the mean LI's of all subjects (including both left and right-hand stimuli) was set to zero. This yielded an all-subject-both-hand-zero-mean-adjusted LI distribution (as a function of nvox) for each hand of each subject. A summary score for each distribution was obtained by averaging the adjusted LI over the range of nvox in which all subjects were normally distributed (as determined using the Jarque-Bera normality test). This yielded a single score for each hand of each subject; the scores for left-hand stimuli were then compared to the scores for right-hand stimuli using a paired two-tailed Student's t-test. A similar procedure was conducted for the SII ROI pair.

Results: SI: All subjects exhibited contralateral dominance in SI for left hand and right hand stimuli. There was no significant difference between the SI laterality curves for stimulation of the left hand compared to stimulation of the right-hand.

SII: Subjects tended to exhibit contralateral dominance for stimuli of their dominant (right) hand (Figure right). However the situation was mixed for stimulation of the non-dominant (left) hand (Figure left), with subjects exhibiting laterality dominance ranging from strongly contralateral through to strongly ipsilateral; the mean laterality across subjects for left-hand stimulation was close to zero. The difference between the left-hand and right-hand laterality curves was statistically significant (P=0.034).

Conclusion: This study demonstrates that healthy subjects are more strongly lateralised in SII for sensory stimuli of the fingertips of their dominant right-hand than for similar stimuli on their non-dominant left hand. This dominance was determined independent of variations in the overall strength of each subject's activation by using an adaptive method for determination of laterality largely independent of statistical threshold.

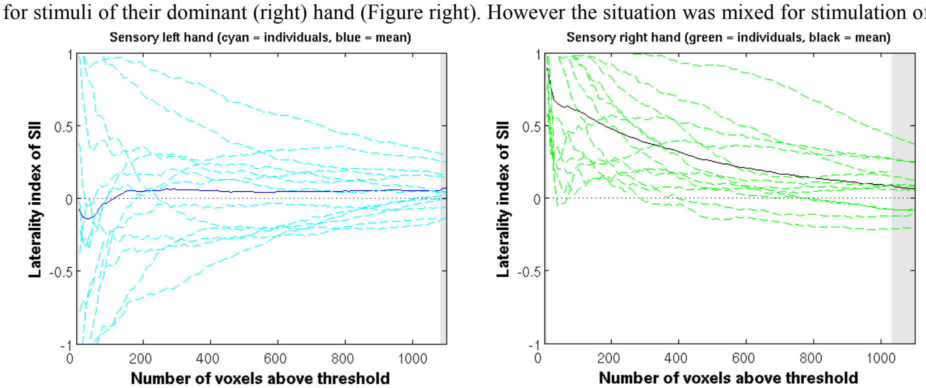

Figure. Plots of laterality index as a function of number of voxels above threshold within SII regions for 13 healthy subjects. Individual subject laterality curves are shown for the left-hand sensory stimuli in the graph on the left (cyan dashed curves) with mean in solid blue, and for right-hand sensory stimuli in the graph on the right (dashed green curves) with mean in solid black. A pairwise statistical test of the subjects' curves confirms stronger lateralisation for the right sensory task compared to the left (P=0.034).

References:

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