Left/right asymmetry measures in somatosensory cortex using MEG, ASL and BOLD fMRI.

C. M. Stevenson[1], K. J. Mullinger[1], J. R. Hale[1], P. G. Morris[1], and S. T. Francis[1]
[1]SPMMRC School of Physics and Astronomy, The University of Nottingham, Nottingham, Nottinghamshire, United Kingdom

Introduction: Functional asymmetry in the human brain, as measured by fMRI, has been well documented in motor and language centres [1] but only to a lesser extent in the somatosensory cortex. To understand fully the basis of cerebral lateralisation, one must consider both the underlying electrical activity and haemodynamic variations. Previous EEG/MEG laterality studies of the primary somatosensory cortex have considered the phase locked evoked response and found variable results [2]. Here we combine measures of ultra-high field BOLD fMRI, CBF and modulations in power of electrical oscillatory activity as measured by MEG in order to further elucidate the mechanisms of cerebral lateralisation in the somatosensory cortex.

Methods: 4 right handed subjects participated in the study. Somatosensory stimuli were applied using 4 adjacent piezoelectric stimulators (Dancer Design, UK) to deliver a 33Hz flutter stimulus with ~1mm displacement to the tip of the right or left index finger (~4mm^2 contact area). Stimulation of left hand (LH) and right hand (RH) was carried out in 2 separate experiments, in a randomized order across subjects. These consisted of 10s of stimulation to the index finger followed by 23 seconds of rest, with 30 trials in MEG and 25 in fMRI. 2 or 3 blank trials were also added which subjects were asked to count to maintain attention.

Data Acquisition: MR data were acquired using a Philips Achieva 7T system. A standard EPI localizer scan was used to position 7 contiguous axial slices in the primary somatosensory cortex. A FAIR Double Acquisition Background Suppression (DABS) [3] sequence was used for simultaneous acquisition of ASL and BOLD data (Background suppression at TI1/TI2=403ms/ 638ms; label delay=1550ms; TR=2200ms, TE=16ms (ASL),25 ms (BOLD), 2x2x3mm^3 voxels, 192mm FOV, 7 slices, SENSE factor 2). A local MPRAGE anatomical, alongside base and T_1 maps scans were acquired in the same scan session for quantification of perfusion. Cardiac pulse and respiration were monitored using the scanner's physiological logging system. MEG data were acquired at a sample rate of 600Hz using a third order synthetic gradiometer configuration of a 275-channel CTF system. Co-registration to anatomical MRI was performed using head digitisation (Polhemus Isotrack).

Data Analysis: BOLD data were realigned and parameters applied to the background suppressed ASL data, RETROICOR was applied to reduce physiological noise. Perfusion weighted images were then generated from the ASL data and both ASL and BOLD data were spatially down-sampled to 3x3x5mm voxels to increase the SNR in perfusion measurements. Perfusion data were smoothed with a 7mm kernel. Areas of significant (p=0.05 corrected) activity in fMRI CBF and BOLD were identified using a GLM in SPM5. 20x20x20mm cubic masks of the left and right somatosensory cortices were generated on a subject by subject basis and positioned to encompass equal amounts of the primary somatosensory regions bilaterally. These were used to mask unthresholded SPM images and as a measure of laterality, voxels within each ROI were ranked according to Tstat and the top 5% of voxels summed to calculate the Bertolini laterality index (LI). MEG data were analysed using synthetic aperture magnetometry (SAM) [4]. A notch filter was applied at 33Hz to reduce interference from the piezoelectric stimulators. Spatial localisation of oscillatory power changes in the beta (15-30Hz) band was achieved by comparison of an active contrast window of 0-9s to a passive contrast window of 12-21s. Pseudo T-stat images (1mm^3 resolution) were created showing regions of activity within these bands. Spectrograms were created by extracting wideband (1-150Hz) timecourses from peaks of β activity using SAM derived weights. These were filtered to bands of 4Hz width sliding from 0-40Hz and Hilbert transforms of the resulting timecourses computed to produce envelopes of oscillatory activity in each frequency band. A Bertolini laterality index (LI) was then estimated with MEG derived SAM images of β power.

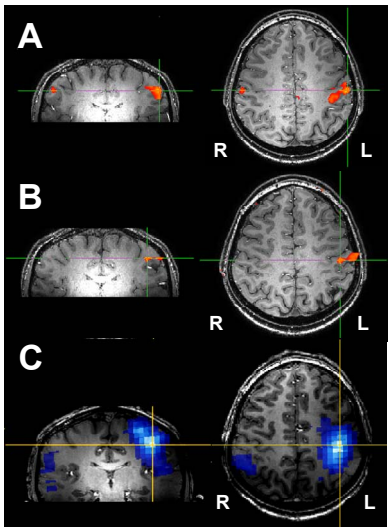

Figure 1: *Spatial localisation of A)BOLD, B)CBF (T>3) and C)β band loss in power (T>3) in a single representative subject in response to right hand index finger stimulation.*

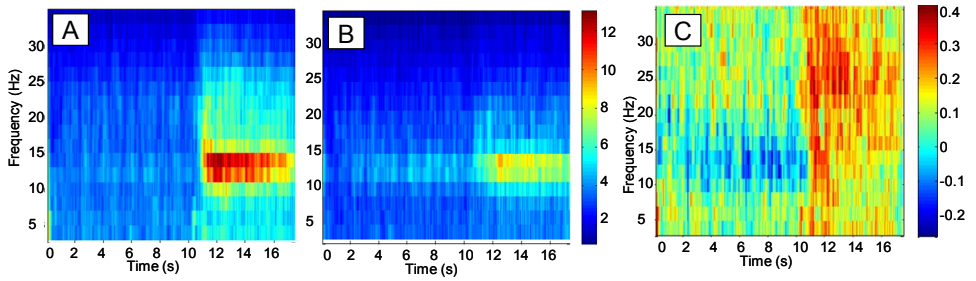

Figure 2: *Cross spectral power modulations in a single representative subject derived from the peak of β-band activity in the A) contra-lateral and B) ipsi-lateral somatosensory cortex resulting from RH stimulation at 0-10s. Colour scale represents the source strength (nAm). C) Laterality index of oscillatory effects ((A-B)/(A+B)).*

Results and Discussion: Figure 1 shows good agreement in spatial localisation of responses in the contra-lateral primary somatosensory cortex for BOLD, CBF and MEG β-band activity, with bilateral (but dominant in contra-lateral cortex) activity evident in BOLD and MEG data at this threshold. Figure 2 shows the characteristic modulations in oscillatory power as measured by MEG during stimulation in the contra-lateral and ipsi-lateral somatosensory cortices, with Figure 2C depicting the lateralisation of oscillatory effects predominantly in the 10-20Hz and 15-30Hz bands. It can be seen that the characteristic loss in beta power during stimulation followed by a sharp increase in power on stimulus cessation is evident in both contra-lateral and ipsi-lateral timecourses although on different scales. It is interesting to note in Figure 2C that the differences between the two hemispheres occur over a wide frequency range and its characteristics modulate dramatically over the time period of a few seconds. BOLD data were, on average, more lateralised during dominant RH (LI=0.8±0.1) compared to LH (LI=0.6±0.1) stimulation, this trend was also reflected in CBF data with all subjects showing a slight increase in LI for RH stimulation. CBF measures showed average LI=0.6±0.1 for RH stimulation and LI=0.5±0.1 for LH. The MEG derived spatial laterality index for β ERD is consistent with the fMRI results showing a stronger response in the somatosensory cortex contra-lateral to that of stimulation although no significant difference was found between the laterality indices, with LI=0.7±0.2 for RH stimulation and LI=0.6±0.1.

Conclusion: Results from all three techniques show a stronger response contra-lateral to the side of stimulation as has previously been reported. The fMRI data suggest an increase in lateralisation when stimulating the dominant hand, as has been seen in previous motor studies [1]. Further subjects are required in order to determine the significance of differences in lateralisation of BOLD and CBF distributions to stimulation of the dominant or non-dominant hand. The changes in β power as measured by MEG illustrate the complex nature of the underlying neural activity and these results serve to reinforce the importance of considering both phase locked and non-phase-locked neural activity when describing the BOLD response.

References:[1] Dassonville, P. et al. (1997) Proc. Natl. Acad. Sci. USA 94:14015-14018. [2] Jung, P. et al. (2003) NeuroImage 19:913-923, [3] Wesolowski, R. et al. (2009) Proc. ISMRM, 6132. [4] S.E. Robinson et. al., Biomag 98, 11th Int Conf on Biomagnetism, 1998.