Lateralisation of the connections between Broca's area and the pre-SMA in relation to handedness

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Target Audience: cognitive neuropsychologists, neurologists, radiologists, neurosurgeons

Purpose:
The frontal aslant tract (FAT) is a newly described pathway connecting the posterior Broca's territory with medial frontal areas including the pre-supplementary motor area and cingulate cortex[1]. It has been suggested that these medial regions of the frontal lobe facilitate speech initiation through direct connection to the pars opercularis and triangularis of the inferior frontal gyrus. Support for this interpretation comes from a case report showing bilateral orofacial weakness following disconnection of this tract[2]. Intraoperative direct stimulation of the pre-SMA and anterior cingulate cortex in humans produces both vocalisation movements and arrest of speech[3]. Preliminary tractography using 12 right-handed subjects suggests this tract is bilateral and lateralized to the left hemisphere[1]. Whether a left lateralisation of the frontal aslant tract is also present in left-handed subjects is unknown.

Methods:
Diffusion datasets were acquired for 36 healthy subjects (aged 22-37 M:F 17:19, LH:RH 19:17) on a 3T GE MRI scanner using HARDI acquisition (voxel size 2.4x.2.4x2.4 mm^3, 128x128 matrix, 60 slices, b-value 3000s/mm^2, 60 diffusion-weighted directions and 7 non diffusion-weighted volumes). Data was initially corrected for head motion and eddy current distortions using FSL and then processed for spherical deconvolution using StarTrack[4] (see Figure 1). A two ROI approach was used to locate the FAT in both hemispheres, with the first ROI placed in the IFG, and the second ROI placed in the anterior SMA and pre-SMA. A third 'not' ROI was used to remove streamlines running through the caudate nucleus. Volume of the FAT in each hemisphere was extracted and a lateralisation index constructed. A one-sample t-test was used to analyse significant deviation from symmetry, and a two-sample t-test to analyse the difference between left and right-handed subjects.

Results:
The frontal aslant was present bilaterally in all subjects. There was a statistically significant left lateralisation of the frontal aslant tract volume in right-handed subjects ($T(16)= -4.2$, $p=0.001$) which was not present in the left handed group ($T(18)= -1.4$, $p=0.16$). Direct comparison showed there was not a statistically significant difference in lateralisation of the frontal aslant tract between left and right-handed subjects.

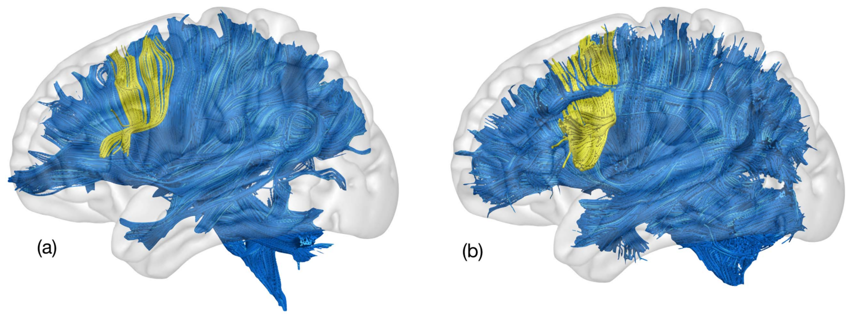

Figure 1. Tractography reconstructions of the frontal aslant tract (yellow) in the left hemisphere. The limitation of crossing fibres in (a) classical diffusion tensor methods is resolved in this study using (b) spherical deconvolution tractography

Discussion:
The results confirm a left lateralisation of the frontal aslant tract in right-handed subjects, suggesting a possible role for this tract in language. A more bilateral distribution was present in the left-handed group, which is consistent with previous functional imaging data showing a more bilateral pattern of language activation in left-handed people[5]. However, the lack of significant differences in the pattern of lateralisation between left- and right-handed subjects suggests a high degree of overlap between the two groups.

Conclusion:
Further studies are necessary to identify possible correlations between anatomical and functional lateralisation of this tract in relation to handedness. The relevance of this tract for speech initiation means that this research will assist predictions of speech recovery following stroke or lesions.

References:
1. Catani, M. (2012) 'Short frontal lobe connections of the human brain' Cortex
2. Martino, J. (2012) 'Foix-Chavany-Marie syndrome caused by a disconnection between the right pars opercularis of the inferior frontal gyrus and the supplementary motor area: Case report' Journal of Neurosurgery
3. Penfield, W. (1949) 'Vocalization and arrest of speech' Archive of Neurology and Psychiatry
4. Dell'Acqua, F. (2013) 'Can spherical deconvolution provide more information than fiber orientations? Hindrance modulated orientational anisotropy, a true□tract specific index to characterize white matter diffusion' Human Brain Mapping
5. Knecht, S. (2000) 'Handedness and hemispheric language dominance in healthy humans' Brain