The role of fronto-parietal networks in mental imagery

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Target Audience: neuropsychologists, neurologists, cognitive scientists

Purpose:
When comparing two identical objects oriented differently, subjects perform a rotation of an image of one in the mind's eye until it is congruent with the other. Evidence for this comes from the time taken to make the comparison, which has been shown to increase linearly according to the extent of rotation needed to match the two objects[1]. This linear correlation is only evident in those using a visuospatial rather than verbal strategy to perform the task[2]. A recent diffusion weighted imaging (DWI) tractography study reported a strong correlation between right-hemispheric lateralisation of the second branch of white matter connections supporting the communication between the frontal and parietal lobe (the superior longitudinal fasciculus, Figure 1a) and performance on a visuospatial task bisecting a line[3]. However it is unknown whether this lateralisation influences the spatial mental manipulation of objects. Here we explore the relationship between the lateralisation of the three branches of the SLF and performance in a mental rotation task.

Methods:
Diffusion datasets were acquired for twenty five healthy right-handed subjects (M:F 12:13, aged 22-35 years) 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]. Virtual in-vivo dissections of the three branches of the SLF were performed in each hemisphere and a lateralisation index calculated for tract volume and Hindrance Modulated Oriented Anisotropy (HMOA), a tract-specific measure of microstructural properties[4]. The subjects performed 128 trials of a computer-based mental rotation task using their right hand, with response time recorded using Superlab[5] (Figure 1b). Mental rotation performance for each subject was determined using linear regression, looking at the subject response time dependent on the angle of rotation between the two objects.

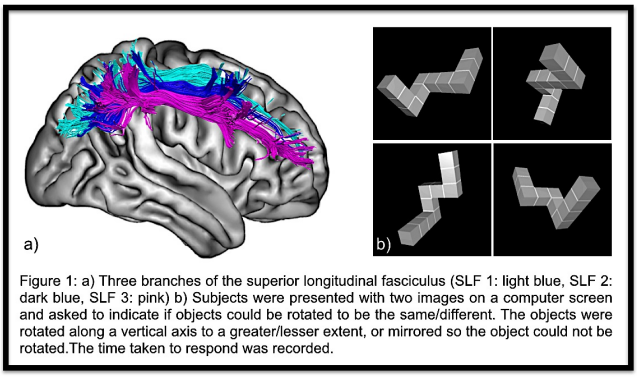

Figure 1: a) Three branches of the superior longitudinal fasciculus (SLF 1: light blue, SLF 2: dark blue, SLF 3: pink) b) Subjects were presented with two images on a computer screen and asked to indicate if objects could be rotated to be the same/different. The objects were rotated along a vertical axis to a greater/lesser extent, or mirrored so the object could not be rotated.The time taken to respond was recorded.

Results:
Of the three branches, a significant positive correlation was found between right lateralisation of the SLF II HMOA and a longer response time for the mental rotation task (2 outliers removed; $r=0.586$, $p<0.005$; see Figure 2).

Discussion:
We found a correlation between the speed of mental rotation and the lateralisation of the second branch of the SLF. This supports previous findings that the SLF II is involved in visuospatial processing, and further we show that a bilateral rather than right-lateralised representation is associated with better performance on a mental rotation task. We propose that this is due to an object rather than location-specific visuospatial task being used. Functional imaging studies reveal differing patterns of bilateral rather than right-lateralised activation during different domain-specific visual working memory tasks, which supports our assertion[6].

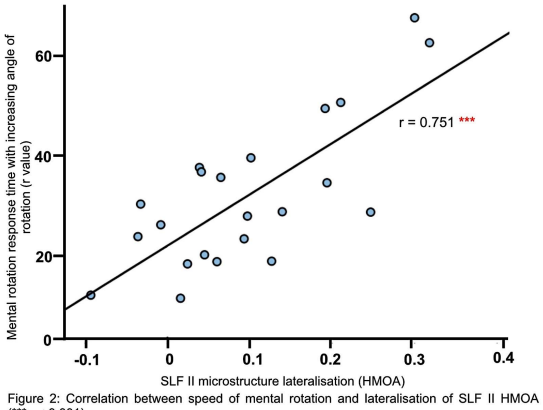

Figure 2: Correlation between speed of mental rotation and lateralisation of SLF II HMOA (***p < 0.001)

Conclusion:
This study contributes to an understanding of the mechanisms of visual neglect. Further research is required to determine why domain-specific visuospatial performance is related to lateralisation of this fronto-parietal network.

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