Are larger pathways faster ? a spherical deconvolution tractography study on the visuo-spatial pathways

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Introduction. Little is known about how the size of tract can actually modify the speed of conduction. Larger tract volumes could depend on a number of factors, including greater fibre myelination, higher number of axons and larger axonal diameter. Experimental physiology has shown that the conduction speed of larger diameter (1), or more myelinated (2) axons is faster. A higher number of axons would also boost the speed of conduction by assuring a parallel processing. So, are larger pathways faster?
In this study, we tried to test this hypothesis in the human living brain using the example of the fronto-parietal network (superior longitudinal fasciculus, SLF). The SLF contribute drastically to the orientation of attention in the brain in order to detect and explore visual event in our environment (3). Given that our hypothesis is correct, subjects with a bigger fronto-parietal pathway in the right hemisphere compared to the left should be quicker in detecting visual targets appearing in the left visual hemifield than in the right. Here we propose to use advanced diffusion imaging to dissect the three branches of the SLF in 20 participants and correlate their volume with the detection speed of visual events.

Material and methods. Diffusion weighted datasets from 20 healthy volunteers aged 23-38 (M:F 11:9) were acquired on a 3T GE Signa HDx TwinSpeed system (General Electric, Milwaukee, WI, USA) with the following parameters: voxel size 2.4x2.4x2.4 mm, matrix 128x128, slices 60, NEX 1, TE 90 ms, b-value 3000 s/mm2, 60 diffusion-weighted directions and 7 non-diffusion-weighted volumes, using a spin-echo EPI sequence. Cardiac Gating was applied with effective TR of 20/30 R-R intervals. Diffusion datasets were corrected for motion and eddy current distortions (4) and then process with a Spherical Deconvolution algorithm based on a damped version of the Richardson-Lucy algorithm (5). Tractography was performed following the method described in (6). Virtual in vivo dissections of the three branches of the fronto-parietal connections (superior longitudinal fasciculus, SLF I, SLF II, and SLF III) were performed on both hemispheres and a lateralization pattern calculated for the volume of each tract. A similar lateralization index was calculated for the detection speed of the target appearing either in the right or the left visual hemifield. Lateralization indexes of the fronto-parietal connections and the detection speed were then correlated.

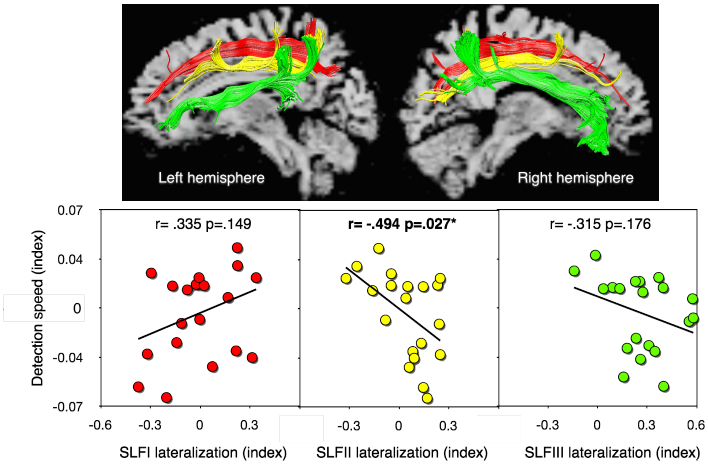

Figure 1. On the top row Human in vivo spherical deconvolution tractography in the left and the right hemisphere of the SLF I in red, the SLF II in yellow and the SLF III in green. On the bottom row lateralization indexes of the volume of the tracts are correlated with the detection speed.

Results. As illustrated in figure 1, of the three branches, the SLF II lateralization significantly correlated with the speed of detection of the target (Pearson's correlation r=-0.494 p=0.027) with subjects with a bigger SLF II in the right hemisphere compared to the left being quicker in detecting visual targets that appears in the left than in the right visual hemifield.

Discussion and Conclusion. The volume of the SLF2 reconstructed with spherical deconvolution tractography significantly correlated with the detection speed of visual events. This result suggests that the conduction within larger SLF2 is faster. Whether this effect is due to greater fibre myelination, higher number of axons and larger axonal diameter remains unknown but the emergence of new diffusion techniques such as AxCaliber techniques (7,8) and Apparent Fiber density indices (9) will give the opportunity to determine the exact anatomical origin of this effect.

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(3) Corbetta and Shulman. Nature Reviews Neuroscience (2002). (4) Smith et al. NeuroImage (2004). (5) Dell'acqua et al. NeuroImage (2009). (6) Schmahmann et al. Brain (2007). (7) Assaf et al. Magnetic Resonance Medicine (2008). (8) Alexander et al. NeuroImage (2010). (9) Dell'Acqua et al. ISMRM (2010)