INTERHEMISPHERIC DIFFERENCES IN WHITE MATTER FRACTIONAL ANISOTROPY (FA) – A DIFFUSION TENSOR IMAGING (DTI) STUDY

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Introduction:

- Functional as well as structural brain asymmetry has been observed in humans.
- The specialization of the left hemisphere for language and the more common tendency toward right hand preference were among the earliest asymmetries to be studied
- Interhemispheric differences of white matter organization have been difficult to study in vivo thus far
- Diffusion tensor imaging (DTI) is an MRI technique, which incorporates pulsed magnetic field gradients into a standard MRI sequence, thus eliciting the differences in the diffusion of water molecules among various biologic tissues.
- The anisotropy of white matter and nerves is caused by tightly packed axonal membranes and, if present, the myelin in these tissues, which allow diffusion only in a direction parallel to the fibers.
- DTI is able to provide structural data about brain tissue and information about white matter in particular, which cannot be obtained by other imaging techniques.

Methods:

SUBJECTS:
- 11 normal volunteers:
  - aged 19-46, median 29
  - 4 males / 7 females
  - 10 right-handed / 1 left-handed
  - no history of neurological illness, seizures or structural MRI abnormalities

IMAGING:
- 1.5 T Phillips Gyroscan ACS NT
  - DTI acquisition:
    - 50-60 axial slices with a slice thickness of 2.5 mm
    - diffusion weighting was applied along 30 independent axes
    - other imaging parameters: TR=6543, TE=80, acquisition matrix 96x96, reconstruction matrix 256x256, FOV 240, 3 acquisitions

ANALYSIS:
- fractional anisotropy (FA) maps were calculated using software developed in-house
- statistical parametric mapping (SPM2)
  - grey-white matter segmentation
  - normalization of study subject data onto a standard white matter template
  - (for confirmation normalization was also performed onto a symmetrical white matter template)
  - voxel-wise paired t-test of FA values on flipped and non-flipped images
  - reported results are significant at $p_c < 0.05$ (corrected for multiple comparisons), cluster size > 5 voxel
- region of interest (ROI) analysis
  - masking of data with a combination (intersection) of individual white matter masks (95% probability) and a temporal lobe mask from the WFU PickAtlas (http://www.fmri.wfubmc.edu)
  - Masking of data with a combination (intersection) of individual white matter masks (95% probability) and a medial frontal lobe mask from the WFU PickAtlas
  - paired t-test of the mean FA values within ROIs (slice by slice)

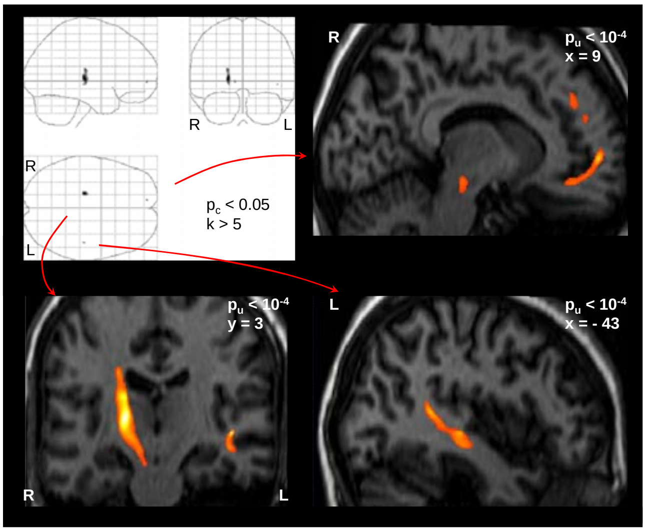

Fig. 1: Areas of significantly higher FA as derived by a voxel-wise paired t-test between hemispheres, group level. Note the difference in p-threshold between the glass brain representation and the overlay-representation onto the anatomical image of a single subject brain. Positions of the coronal and sagittal slices in MNI-space are indicated. p_c = p with familiy wise error correction, p_u = p, uncorrected for multiple comparisons, k = cluster size threshold.

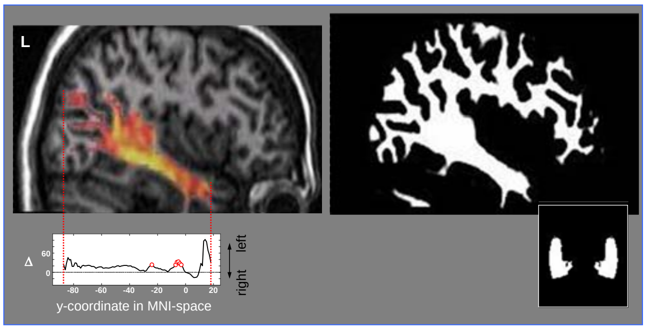

Fig. 2: Temporal lobe: evaluation according to slices within mask. The right side of the figure shows the 95%-probability mask of finding white matter for a single subject, as well as the masks for the left and right temporal lobes as taken from the WFU PickAtlas (small inlay). On the left side the FA-map of the same subject masked by the combination (intersection) of the masks is superimposed onto the anatomical image. In addition the difference (Δ) of FA (means over coronal slices with a thickness of 1mm within left and right masks; left minus right sided values) in arbitrary units is plotted against the MNI-y-coordinate of the slices. Positions of significant differences ($p_c < 0.05$, Bonferroni-corrected for multiple comparisons) are marked by red circles. The position of the sagittal slice in MNI-space is x = -40.

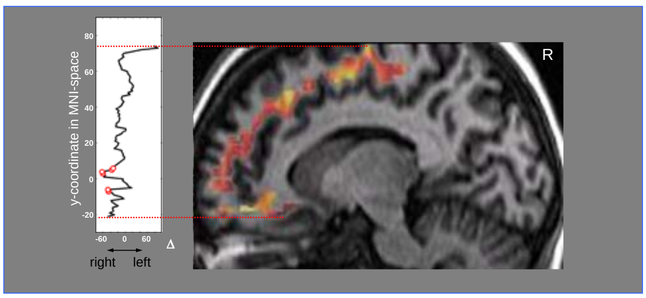

Fig. 3: Frontal lobe: evaluation according to slices within mask. Analogous plot to the one shown in Fig. 2. Difference (Δ, left minus right sided values) of FA (means over axial slices) in arbitrary units is plotted against the MNI-z-coordinate of the slices. Positions of significant difference ($p_c < 0.05$, Bonferroni-corrected for multiple comparisons) are marked by red circles. The position of the sagittal slice in MNI-space is x = 12.

Results:

Areas of significantly higher anisotropy in one hemisphere as compared to the other hemisphere were found in:
- The left temporal lobe
- The right frontal lobe
- The right pyramidal tract

Region of interest analysis in the temporal and the frontal lobes confirmed the results of the voxel-wise test

Discussion:

Left temporal lobe:
- Post-mortem as well as structural MRI studies have shown that the left planum temporale is bigger than its right sided counterpart, a fact that has been linked to language evolution
- more recently there has also been DTI evidence of increased anisotropy in the left temporal lobe confirming our findings

Right frontal lobe:
- A previous DTI study has already commented on increased anisotropy in the anterior limb of the right as compared to the left internal capsule, a finding of unclear significance
- It is also known that the right frontal lobe encompasses a larger volume than the left (note: Yakovlevian torque)

Right pyramidal tract:
- Interestingly we found higher anisotropy of the right as compared to the left pyramidal tract (PT) although most of our subjects were right handed
- Coordinates of maximum significance did have a higher probability of being within white matter in the right PT as compare to the left (paired t-test p < 0.06)
- This error may have contributed to our finding

Conclusions:

- Our findings provide further evidence that DTI can provide detail about white matter structure beyond that available from conventional MR imaging
- Brain asymmetry reflects functional specialization of the hemispheres with increased anisotropy of the left temporal lobe likely reflecting enhanced connectivity to enable language function
- The areas of increased anisotropy in the right hemisphere remain of unclear significance

References:
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