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Diffusion Tensor Imaging in adults with dyslexia demonstrates left superior longitudinal fasciculus involvement in reading, phonology and speech perception

1. What & why

Functional neuroimaging research has indicated two distinct left lateralized reading routes:

(i) a dorsal phonological route (including temporoparietal and inferior frontal areas)

(ii) a ventral orthographic route (including the occipitotemporal area)

However, the anatomical counterparts of these reading routes have not been investigated. Diffusion Tensor Imaging (DTI) tractography is a structural MRI technique allowing reconstruction and assessment of the integrity of 3D-white matter tracts, as indexed by their fractional anisotropy (FA). The present DTI study aims to investigate :

(i) whether the group differences in FA between dyslexic and typical readers reported in the literature can be traced back to a dysfunction of the left SLF. In particular, we aim to pinpoint which subcomponents of the SLF may be dysfunctional.

(ii) whether the left IFOF and subcomponents of the left SLF may constitute a plausible neuroanatomical candidate of, respectively, the ventral orthographic and the dorsal phonological route.

2. Method

Participants:

In this study 20 dyslexic readers were included, who all had a formal diagnosis of developmental dyslexia and a reading score below percentile 3 on two standardized reading tests. The 20 typically reading individuals reported no history of reading difficulties and scored above percentile 20 on both reading tests. Concerning the reading-related subskills, results showed the expected group difference for phoneme awareness and orthographic processing, but not for speech-in-noise perception.

	Dyslexic readers Mean *(SD)*	Typical readers Mean *(SD)*	Test statistics
Subject characteristics			
N	20	20	/
Sex (male/female)	7/13	8/12	χ^2 (1) = 0.10, p = .75
Age (years)	22.1 (3.1)	21.4 (3.0)	t(38) = -0.66, p = .51
Non-verbal IQ (WAIS)	108 (10)	106 (10)	t(38) = -0.54, p = .59
Defining literacy measures (standardized scores)			
Word reading	66.1 (1.9)	99.8 (11.4)	t(38) = 13.10, p < .0001
Pseudoword reading	66.0 (1.8)	107.9 (9.8)	t(38) = 18.75, p < .0001
Spelling	69.3 (6.5)	105.8 (9.6)	t(38) = 14.04, p < .0001
Underlying reading processes			
Phoneme awareness	-2.8 (1.3)	0 (1)	t(38) = 7.79, p <.0001
Speech in noise	-8.2 (0.9)	-8.5 (1.1)	t (38)= 1.05, p = .30
Orthographic processing	28.2 (3.6)	34.5 (2.6)	t (38) = 6.33, p < .0001

DTI:

MRI acquisition parameters were the following: 3 Tesla, single spin shot EPI, matrix size = 112x109; FOV = 220 x 220 mm²; TR = 11043 ms, TE = 55 ms, 68 voxel size = 1.96x1.96x2.2 mm³, 45 non-collinear directions with a b-value of 800 s/mm². Two identical DTI datasets were consecutively acquired for each subject.

Pre- and post-processing was done using Explore DTI (Leemans et al. 2009). In order to avoid artifacts due to normalization, we delineated the tracts in native space. For every subject FA was derived for the left and right SLF, the 3 subcomponents of the left SLF and the left IFOF. For details on the placements of the ROIs see Figure 1 and the protocol of Wakana (2007). Delineation of the fiber tracts was carried out by two independent raters (FA intra-class correlation coefficient > .90) and the average FA across the 2 raters was calculated.

3. Results

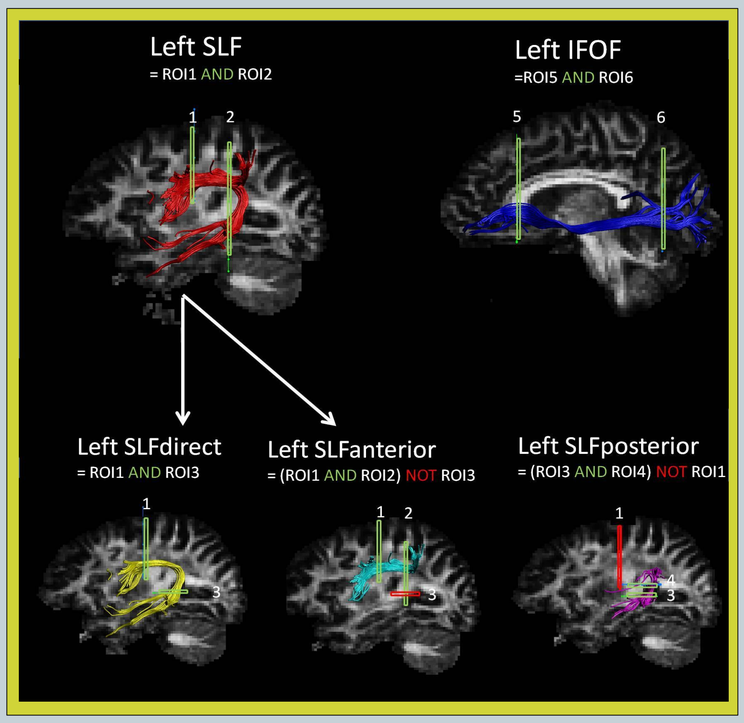


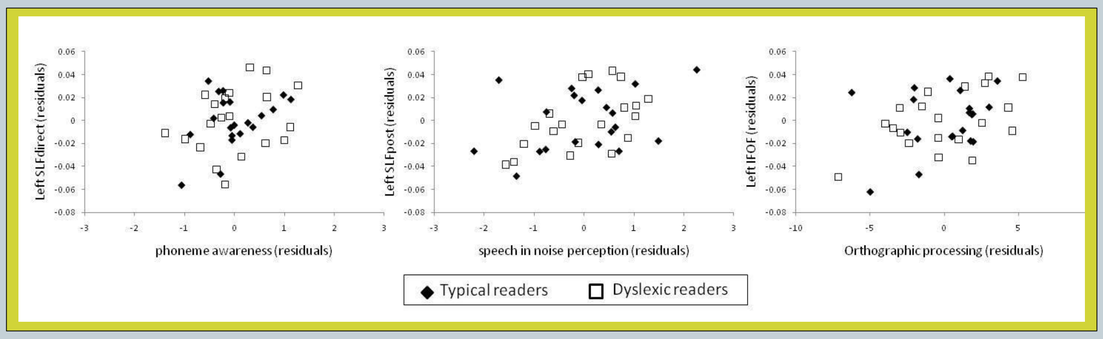
Figure 1:
DTI fiber tracking of the various SLF components and of IFOF.

Group comparisons show a significantly reduced FA in the left SLF of adults with dyslexia, in particular in the segment that directly connects posterior temporal and frontal areas. This FA reduction might reflect a lower degree of myelination in the dyslexic sample, as it co-occurred with a group difference in radial diffusivity. In contrast, no significant group differences in FA were found in the right SLF nor in the left IFOF.

	Dyslexic readers Mean *(SD*	Typical readers Mean *(SD)*
Fractional anisotropy (FA)		
Left SLF *	**0.460 (0.025)**	**0.474 (0.017)**
Right SLF	0.426 (0.021)	0.422 (0.030)
Left SLFdirect *	**0.479 (0.029)**	**0.493 (0.024)**
Left SLFanterior	0.434 (0.027)	0.441 (0.019)
Left SLFposterior	0.444 (0.027)	0.455 (0.026)
Left IFOF	0.486 (0.024)	0.485 (0.027)
Radial Diffusivity left SLF *	**0.511 x 10^{-3} (0.036)**	**0.499 x 10^{-3} (0.026)**
Axial Diffusivity left SLF	1.07 x 10^{-3} (0.040)	1.07 x 10^{-3} (0.029)

Correlational analyses (controlled for reading status) demonstrated a specific relation between performance on phoneme awareness and speech perception and the integrity of left SLF as indexed by FA, and between orthographic processing and fractional anisotropy values in left IFOF.

	Phoneme awareness	Speech perception	Orthography
Left SLFdirect	**.33***	.31(*)	-.04
Left SLFanterior	.02	.18	-.05
Left SLfposterior	.21	**.42****	.00
Right SLF	.15	-.16	.22
Left IFOF	.04	.18	**.39***



4. Conclusions

The present study reveals structural anomalies in the SLF in adults with dyslexia. This finding corroborates current hypotheses of dyslexia as a disconnection syndrome. In addition, our study demonstrates a correlational double dissociation which might reflect neuroanatomical correlates of the dual route reading model: the left SLF seems to sustain the dorsal phonological route underlying grapheme-phoneme decoding, while the left IFOF seems to sustain the ventral orthographic route underlying reading by direct word access.

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