Literacy and the Arcuate Fasciculus

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Purpose. The acquisition of literacy results from an effortful learning process that leads to functional changes in several cortical regions. With literacy, the Visual Word Form Area (VWFA), in left occipito-temporal visual cortex, dramatically enhances its activation to known scripts (*1*) and acquires a script-specific and case- invariant prelexical representation of letter strings (*2-4*). The left perisylvian language cortex, particularly the planum temporale, also increases its activation to spoken words and sentences (*5*) and encodes phonology (*6*) and grapheme-phoneme correspondences (*7, 8*). In literates, information trafficking between those two brain systems is enhanced in both the bottom-up and top-down directions (*9*). We explored whether learning to read also leads to anatomical changes within the left intra-hemispheric white matter pathways that interconnect these regions.

Material and methods. Using diffusion tensor imaging tractography, we compared illiterates (n = 10), ex-illiterates (n = 10) who learned to read during adulthood and literates (n = 11) who learned to read during their childhood. As a measure of reading performance, we assessed the number of words and readable pseudo-words that could be read per minute. The trajectories of the three segments of the arcuate (i.e. fronto-temporal, fronto-parietal and temporo-parietal portions), the inferior longitudinal, and the inferior fronto-occipital fasciculi were obtained for both hemispheres, as previously described (*10*). For each subject, as reported in a previous study (*5*) we also collected the individual level of activation of the VWFA to written strings relative to checkers, and the level of activation of the planum temporale in response to spoken sentences relative to the rest baseline. Bivariate Pearson correlations were performed between the FA measurement of each single tract dissected and each participant's reading performance and functional activations. Independent sample one tailed t-tests and d// and d⊥correlations were performed for each tract revealed as significant by the correlations analyses between FA and the reading score.

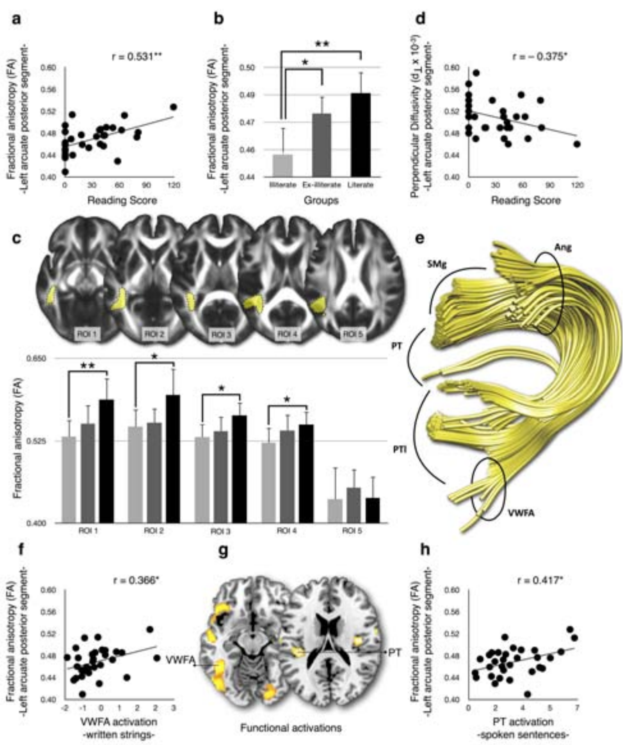

Figure 1. Links between the microstructure of the posterior segment of the arcuate fasciculus, behavioral reading scores, and functional neuroimaging correlates of literacy. (a) Correlation between the FA in the posterior segment of the left arcuate fasciculus and reading performance. (b) Average FA in the left posterior segment (with 95% confidence intervals) for the illiterate (light gray), ex-illiterate (dark gray), and literate groups (black). (c) Average measurements of FA along the left posterior segment of the arcuate fasciculus made using 5 regions of interest selected on axial slices. (d) Correlation between the d⊥in the left posterior segment of the arcuate fasciculus and reading performance. (e) The posterior segment of the arcuate fasciculus and its projections (posterior coronal view). (f) Correlation between the FA in the posterior segment of the left arcuate fasciculus and the level of activation of the VWFA to written strings relative to checkers. (g) Functional activations in response to letter strings (left) and to spoken language (right) (*6*). (h) Correlation between the FA in the posterior segment of the left arcuate fasciculus and the level of activation of the PT in response to spoken sentences. SMg: supramarginal gyrus; Ang: angular gyrus; PT: planum temporale; VWFA: Visual Word Form Area; PTl: posterior temporal lobe; **P < 0.01; *P < 0.05.

Results. Literacy related to an increase in fractional anisotropy Pearson (r = 0.531 ; P = 0.002) (Figure 1a) and a decrease in perpendicular diffusivity in the temporo-parietal portion of the left arcuate fasciculus (r = – 0.375; P = 0.038) (Figure 1d). Independent sample t-tests showed that, in the left posterior segment, illiterates had a lower FA than literates (t(19) = – 2.683 ; P = 0.008), and a lower FA than ex-illiterates (t(18)= – 1.939 ; P = 0.034). There was no significant difference between the ex-illiterate and literate groups (t(19) < 1) (Figure 1b). Measurements of fractional anisotropy along the posterior segment of the arcuate fasciculus using five axial regions of interest confirmed that for four of these five regions illiterates had a lower FA than literates (ROI 1, t19 = –2.647; P = 0.008 ; ROI 2, t19 = –1.970 ; P = 0.032 ; ROI 3, t19 = – 2.265 ; P = 0.018 ; ROI 4, t19 = –1.799 ; P = 0.045 ; ROI 5, t19 < 1) (Figure 1c). The microstructure within this pathway correlated with the reading performance and the degree of functional activation within two dominant brain regions involved in reading: the Visual Word Form Area in response to letter strings, and the posterior superior temporal cortex in response to spoken language (respectively r = 0.366 ; P = 0.043, Figure 1f-g and r = 0.417 ; P = 0.02, Figure 1g-h).

Discussion and Conclusion. The acquisition of literacy is associated with a reinforcement of left temporo-parietal connections whose microstructure predicts overall reading performance and the functional specialization of the Visual Word Form Area. This anatomical magnetic resonance imaging marker may be useful to predict developmental reading disorders.

(1) McCandliss et al. *Trends Cogn Sci* (2003). (2) Braet et al. *Neuroimage* (2011). (3) Dehaene *et al. Nat Neurosci* (2001). (4) Vinckier *et al. Neuron* (2007). (5) Dehaene *et al. Science* (2010). (6) Chang *et al. Nat Neurosci* (2010). (7) Blau *et al. Brain* (2010). (8) van Atteveldt et al. Integration of letters and speech sounds in the human brain. *Neuron* (2004). (9) Yoncheva et al. *Cereb Cortex* (2010).(10) Catani and Thiebaut de Schotten *Cortex* (2008).