Regionally Specific Microstructural Maturation of Adolescent Reading Networks: A Longitudinal qMRI Study of the QTAB Cohort

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Reading acquisition depends on coordinated maturation of distributed cortical systems linking visual word recognition, phonological mapping, semantic integration, and language control [1,2], yet their microstructural development across adolescence remains poorly characterized because most developmental reading studies rely on macrostructural MRI or functional activation rather than quantitative tissue-sensitive measures. This longitudinal qMRI study uses the Queensland Twin Adolescent Brain (QTAB) dataset [3] to test whether MP2RAGE-derived T1/R1 markers show regionally specific maturation over approximately two years. Longitudinal T1 decreases and reciprocal R1 increases are interpreted cautiously as changes consistent with ongoing myelination and microstructural refinement [4,8], recognizing that MRI-derived measures are indirect and that cortical maturation varies along a sensorimotor-to-association gradient [8]. The completed primary analysis used a protocol-clean longitudinal sample of 33 adolescents (27 right-handed, 6 left-handed; mean ages 12.24 and 14.42 years; mean interval 2.18 years). An ongoing secondary robustness analysis will apply Longitudinal ComBat [5] to the larger sample including session-2 scans acquired using the different MP2RAGE_wip925B_VE11C-0p8mm protocol, yielding 183 participants, to test whether developmental effects remain robust after accounting for acquisition-related variance. The central hypothesis was that posterior reading-related regions, including left ventral occipitotemporal and fusiform cortex encompassing the visual word form area, angular gyrus, supramarginal gyrus, posterior superior temporal cortex [6], and middle temporal regions, would show stronger longitudinal maturation than left inferior frontal and non-language control regions because occipitotemporal and temporoparietal circuits support reading specialization, whereas frontal regions contribute more domain-general controlled processing [1,2,7]. Mean T1 and R1 values were extracted per ROI at both sessions and analyzed using longitudinal mixed-effects models with session, ROI network, age group, and their interactions as predictors. T1 decreased significantly from session 1 to session 2 ($\beta = -0.0595$, $SE = 0.0083$, $t = -7.21$, $p = 1.25 \times 10^{-12}$), and change differed across networks (network × session: $F(2,844) = 7.82$, $p = 0.00043$). Relative to control regions, classical-language regions showed a smaller T1 decrease ($\beta = 0.0299$, $p = 0.0069$), and reading-network regions showed a further attenuated decrease ($\beta = 0.0451$, $p = 0.00012$). Change also differed by age group (age group × session: $F = 9.04$, $p = 0.0027$), with a significant network × age group × session interaction ($F = 5.05$, $p = 0.0066$). Contrary to the initial prediction, control regions demonstrated the largest T1 decline, whereas reading and classical-language networks showed more attenuated change, indicating differentiated developmental timing across reading, language, and domain-general cortical systems.

References

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Figure 1: Longitudinal Cortical T1 Maturation Across Reading, Language, and Control ROI Networks

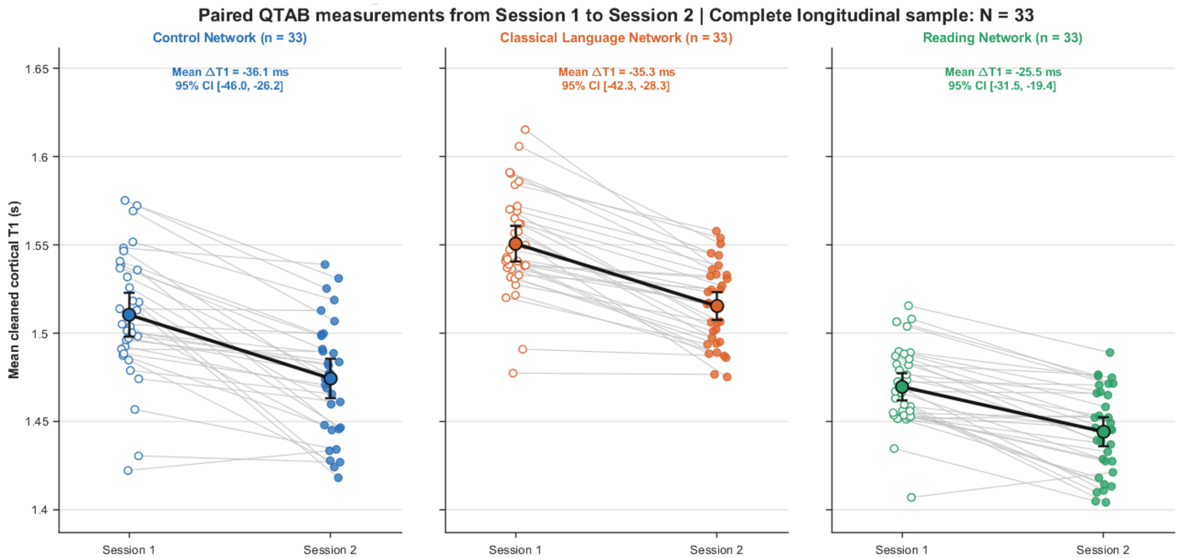

Figure 2: Anatomical visualization of the predefined regions of interest included in the control, reading, and classical language networks. ROIs were defined using the AAL3 atlas and literature-based masks.