

Dyslexia is characterized by differences in intracortical myelination, but not cortical folding patterns, in the superior temporal plane

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Summary

- Developmental dyslexia is a reading disorder characterized by phonological processing deficits.
- It has been proposed that atypical structural features of the auditory cortex may contribute to these deficits^[1], but prior findings have involved small samples and been inconsistent across studies.
- Genetic evidence suggests that neuroanatomical differences in dyslexia might occur at a finer microstructural scale, potentially stemming from disrupted neural migration^[2].
- We investigated two hypotheses about auditory cortical structural differences in dyslexia that dyslexia is associated with:
 - differences in patterns of macrostructural cortical folding in auditory cortex^[1], and/or
 - microstructural features associated with intracortical myelination^[3].
- Our findings indicate that dyslexia is characterized by auditory cortical hypermyelination, which may underlie the neurocomputational deficits in phonological processing^[4].

Methods

Cortical Folding Pattern Analysis:

Participants: N = 118 adults (63 control / 55 dyslexia).

MRI Acquisition: Siemens Trio 3T, T1-weighted (T1w), 1 mm³ voxel.

Manual Labeling: Cortical reconstruction was performed via the default stream in FreeSurfer 6.0. Manual labelling of Heschl's gyrus (HG) was performed on the inflated surface to classify each HG as one of four *a priori* morphotypes: single gyrus, common stem duplication (CSD), complete posterior duplication (CPD), or multiple duplications (MD)^[5].

Curvature-based Clustering: Individual surfaces were registered to a symmetric template (*fsaverage_sym*). Local measures of curvature in the superior temporal plane were extracted and submitted to a data-driven, elbow-optimized *k*-means clustering algorithm^[6].

	Control (n=63)	Dyslexia (n=55)
Age (mean ± s.d.)	22.56 ± 3.67	22.95 ± 4.08
Sex	33 F, 30 M	44 F, 11 M
Non-verbal IQ	115.73 ± 11.05	111.29 ± 11.63
WRMT ID	109.70 ± 9.54	91.36 ± 9.39
WRMT WA	106.35 ± 13.18	84.40 ± 10.90
TOWRE SWE	108.42 ± 11.24	83.44 ± 11.79
TOWRE PDE	107.09 ± 9.04	80.38 ± 9.83

Microstructural Feature Analysis:

Cortical microstructure features were examined in two unique subsets of the full sample, using either the T1w/T2w ratio^[7] or R1 relaxometry^[8].

T1w/T2w Ratio: n = 50 (25 control / 25 dyslexia); Siemens Trio 3T, T1w (MPRAGE) and T2w (SPACE) images, 1 mm³ voxel. Images were processed via the default stream in FreeSurfer 6.0 and calibrated using the standard pipeline^[9]. The output was smoothed at FWHM=6mm.

R1 Relaxometry: n = 55 (30 control / 25 dyslexia); Siemens Trio 3T, multi-echo FLASH scans (TR = 20, Flip angle = 5° & 30°), 1 mm³ voxel. Images were co-registered and then submitted to *mri_ms_fitparms* to estimate T1 and R1 values. The output R1 maps were then bias-corrected using SPM^[10]. The output was smoothed at FWHM=6mm.

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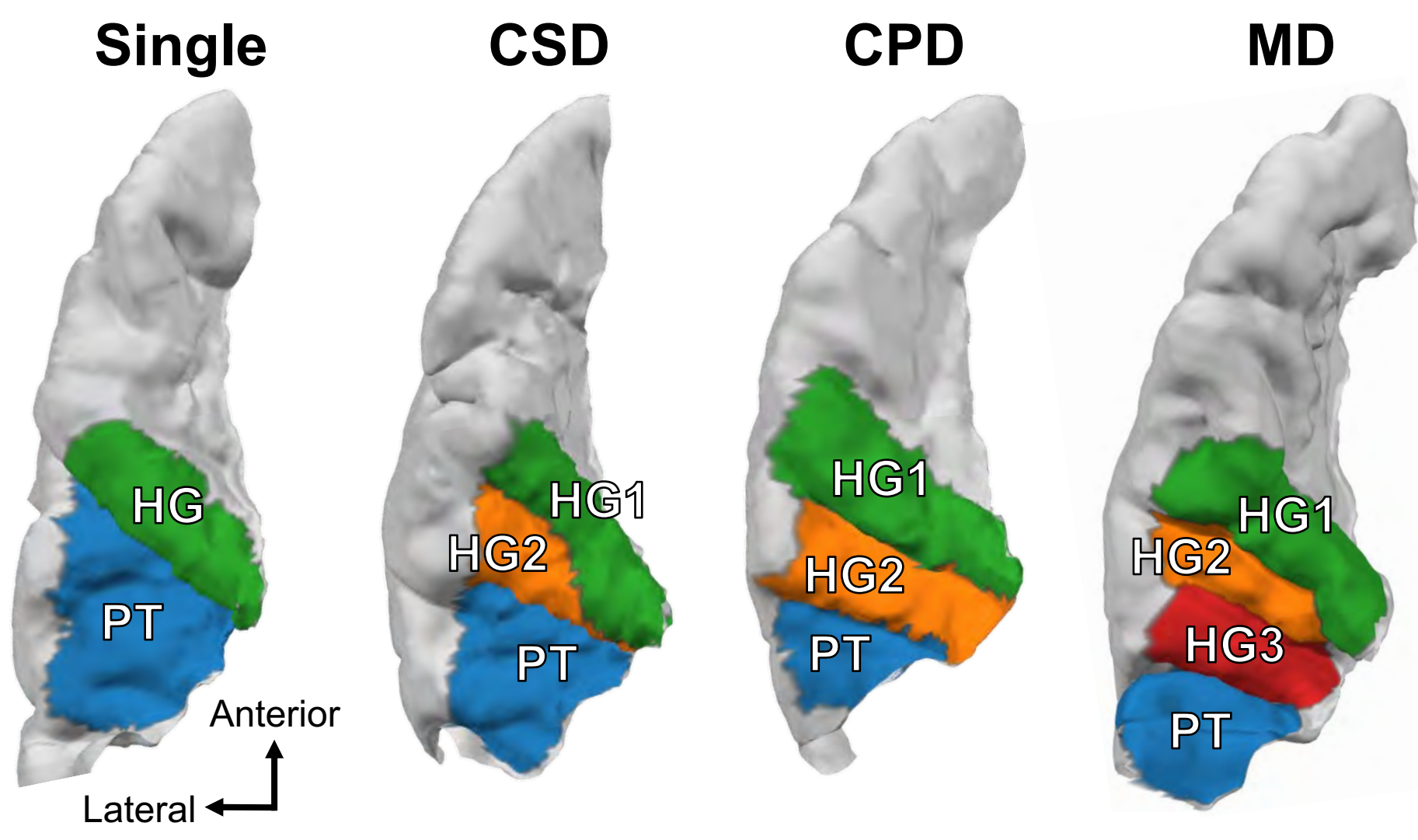
References: [1] Leonard et al., 2001, *Cereb Cortex*. [2] Gabel et al., 2010, *Neurobiol Dis*. [3] Skeide et al., 2018, *Neurology*. [4] Perrachione et al., 2016, *Neuron*. [5] Benner et al., 2017, *Brain Struct Funct*. [6] Liu et al., 2025, *SNL* (Poster). [7] Glasser & Van Essen, 2011, *J Neurosci*. [8] Sigalovsky et al., 2006, *Neuroimage*. [9] Ganzetti et al., 2014, *Front Hum Neurosci*. [10] Weiskopf et al., 2011, *Neuroimage*. [11] Marie et al., 2015, *Brain Struct Funct*.

Cortical Folding Patterns

Manual labeling:

No difference in the likelihood of finding different HG morphotypes between groups

- Multinomial logistic-regression models with sex as a covariate^[11]:
Label ~ Group + Sex



LH ($p = 0.506$)

CTL	Single (55.6%)	CSD (28.6%)	CPD (15.8%)	MD (0%)
DYS	Single (47.3%)	CSD (32.7%)	CPD (18.2%)	MD (1.8%)

RH ($p = 0.295$)

CTL	Single (33.3%)	CSD (36.5%)	CPD (27.0%)	MD (3.2%)
DYS	Single (49.1%)	CSD (30.1%)	CPD (20.8%)	MD (0%)

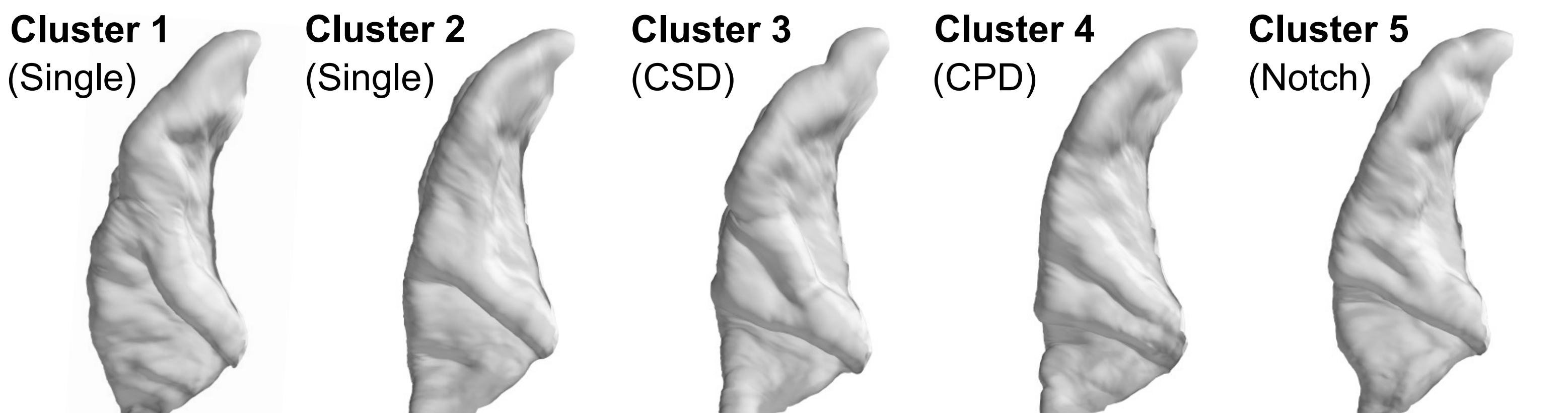
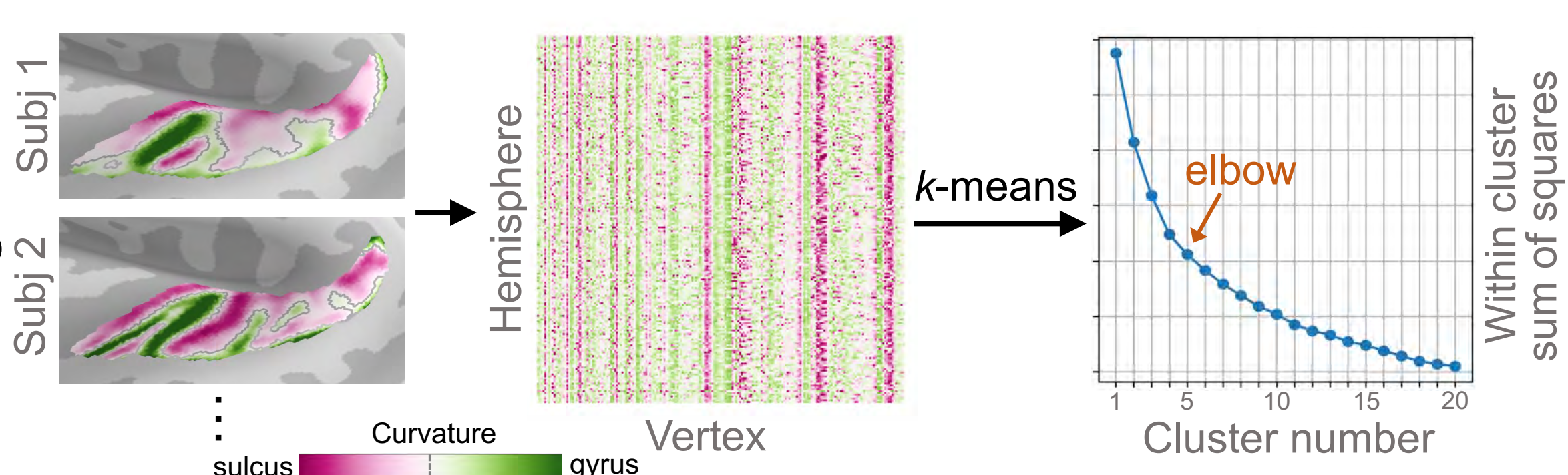
Inter-hemispheric pattern ($p = 0.124$)

CTL	L1R1 (24.6%)	L1R2 (29.5%)	L2R1 (9.8%)	L2R2 (36.1%)	L1: Single L2: Left duplication
DYS	L1R1 (27.8%)	L1R2 (20.3%)	L2R1 (22.2%)	L2R2 (29.7%)	R1: Single R2: Right duplication

Data-driven

curvature-based clustering:

No significant group difference in the cluster distribution per hemisphere



LH (Multinomial logistic-regression model with sex as a covariate; $p = 0.101$)

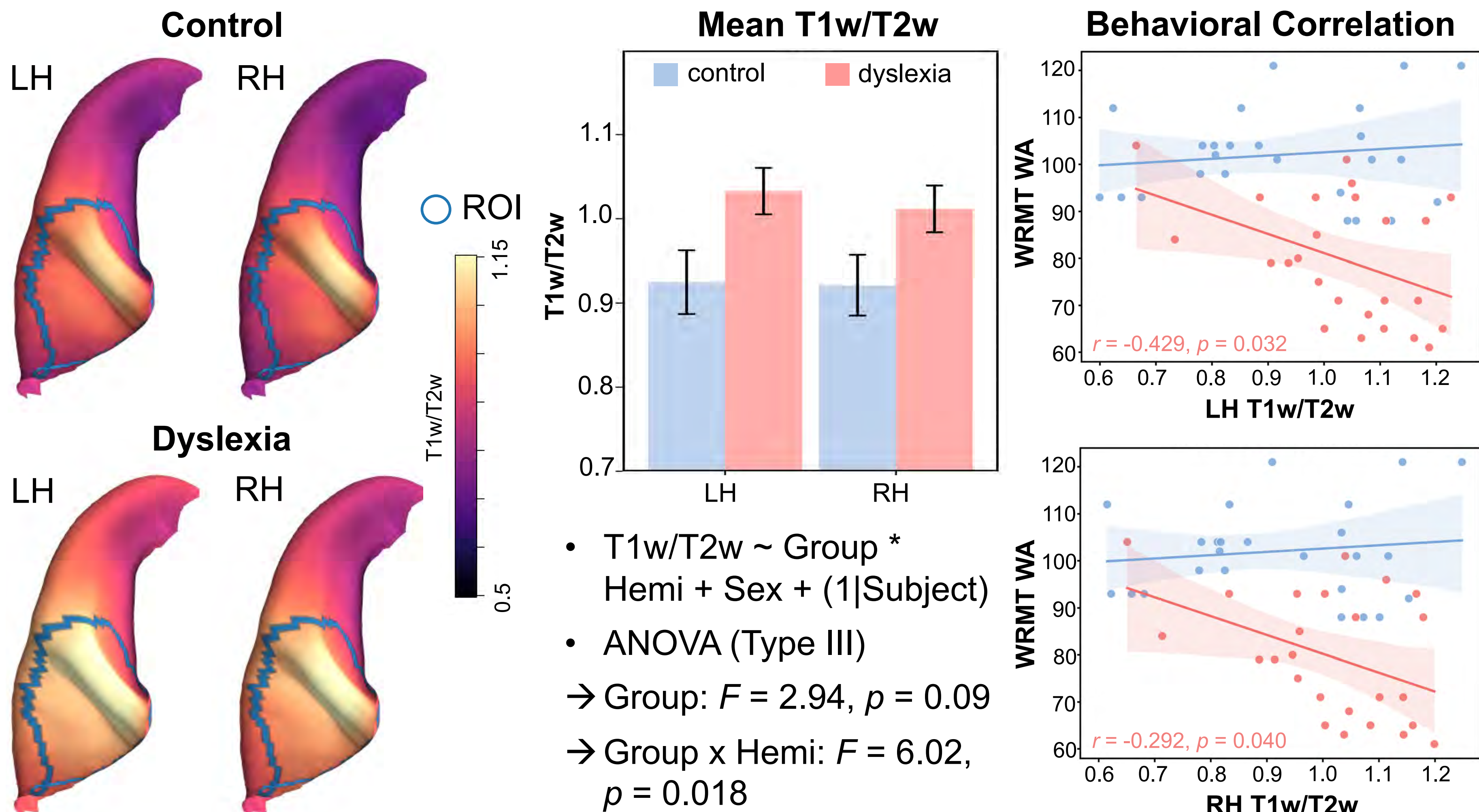
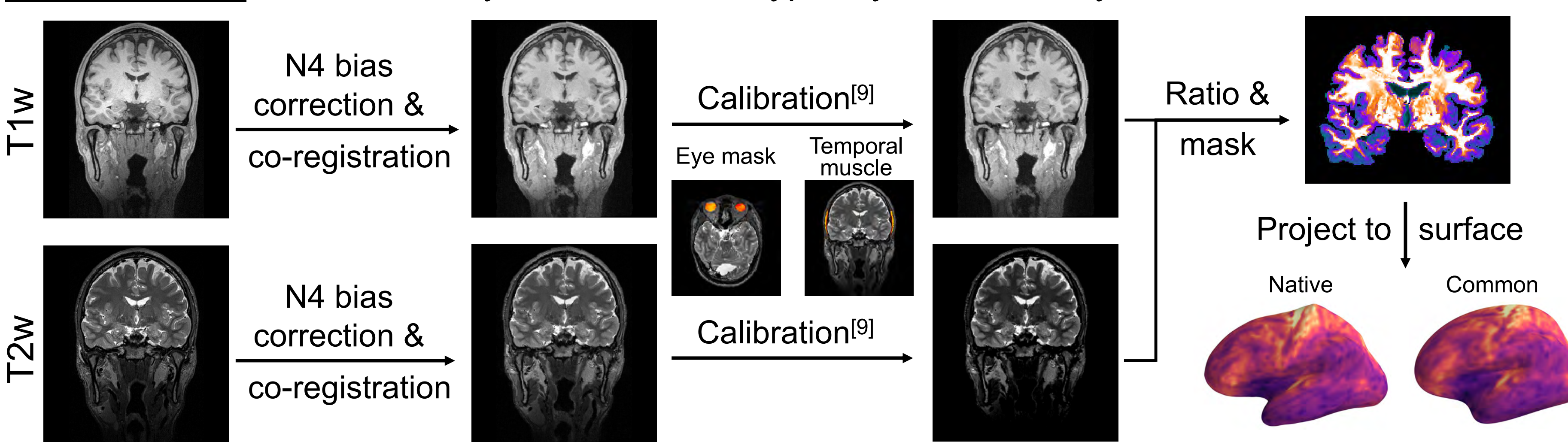
CTL	C1 (14.3%)	C2 (42.8%)	C3 (9.5%)	C4 (11.1%)	C5 (22.3%)
DYS	C1 (34.5%)	C2 (23.6%)	C3 (10.9%)	C4 (7.3%)	C5 (23.7%)

RH ($p = 0.523$)

CTL	C1 (28.6%)	C2 (28.6%)	C3 (12.7%)	C4 (20.6%)	C5 (9.5%)
DYS	C1 (21.8%)	C1 (38.2%)	C3 (14.5%)	C4 (18.2%)	C5 (7.3%)

Auditory Cortex Hypermyelination

T1w/T2w ratio: Predominantly left-lateralized hypermyelination in dyslexia relative to controls



R1 relaxometry: Hypermyelination in dyslexia replicated in a different subset with a different MR contrast

