Hemispheric asymmetries in the cortical myeloarchitecture parallel the functional lateralization of language

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Summary

The faculty of language is well known to be predominately left-lateralized in the human brain. However, even 150 years after Broca and Wernicke's original observations, the reasons for functional language lateralization remain uncertain. We asked whether language lateralization is related to hemispheric asymmetries in cortical micro-structure (intracortical myelin assessed by the T1w/T2w ratio). We found striking left-lateralization of intracortical myelin among language areas. Moreover, lateralization of intracortical myelin and functional selectivity for language were correlated in core language regions across subjects.

Methods

Subjects: We used structural and functional MRI scans from the Human Connectome Project (HCP) Young Adult 1200 Subjects dataset (Van Essen et al., 2013) to measure intracortical myelination, cortical thickness, and functional selectivity for language within each anatomical region of the Desikan-Killiany Atlas from *FreeSurfer* (Desikan et al. 2006). From this dataset, N=1065 had suitable structural MRI data for the intracortical myelin and cortical thickness analyses, and N=1040 had suitable functional MRI data for the language selectivity and structure—function correlation analyses.

Intracortical myelin: Using T1w and T2w anatomical volumes, we obtained the T1w/T2w ratio—a measure of tissue microstructure sensitive to local differences in intracortical myelination (Glasser & Van Essen, 2011).

Cortical thickness: We used the HCP cortical thickness measures from the T1w volume (Glasser et al., 2013).

Language selectivity: We used the HCP Language Processing fMRI task (Binder et al., 2011), which contrasts BOLD responses to auditory presentation of stories (*Story* condition) vs. auditory arithmetic problems (*Math* condition). We operationalized language selectivity as the proportion of voxels within each anatomical region that had greater Story vs. Math response among those with positive response to the Story condition.

For each dependent measure, we computed its regional lateralization index (L.I. or λ) as the difference between left and right hemisphere values divided by their sum:

$$\lambda = 100 \times (L - R) / (L + R).$$

Linear models testing structure—function relationships in each region accounted for subjects' age and handedness:

Language Selectivity ~ Myelin + Age + Handedness

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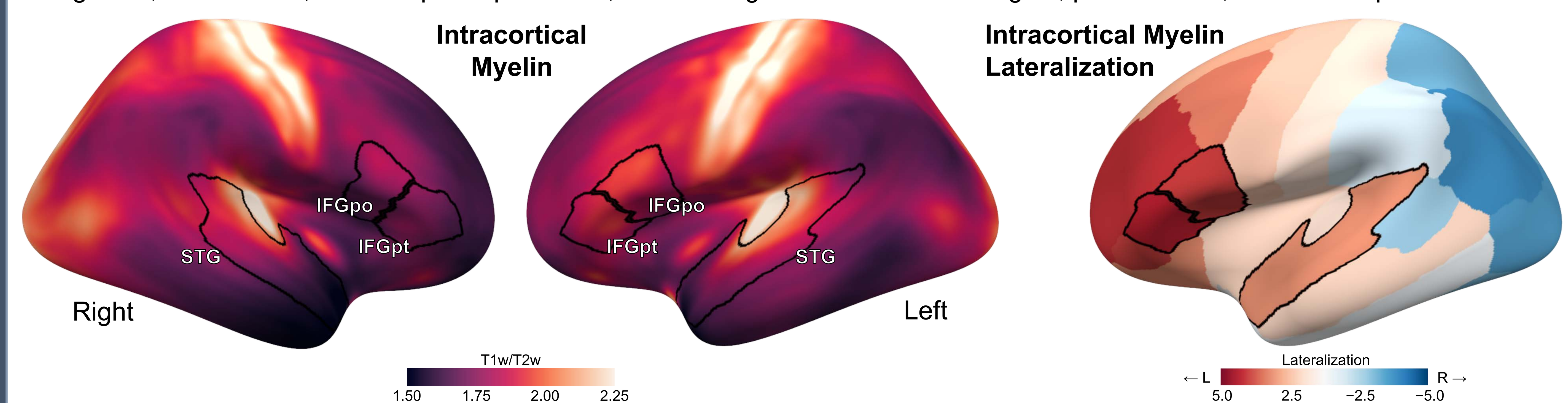
Lateralization of the Cortical Myeloarchitecture

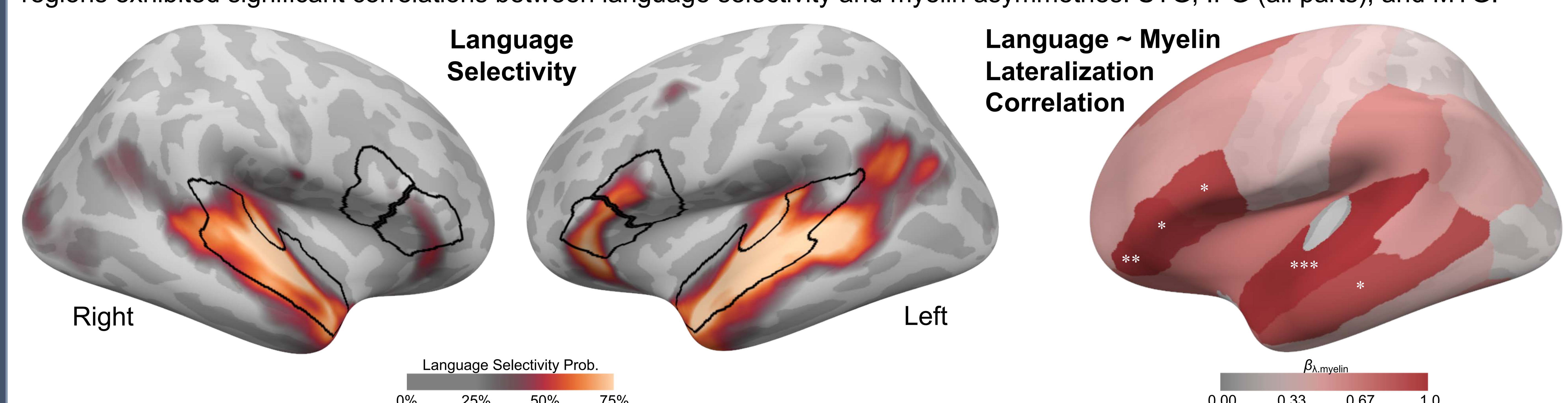
We observed a striking anterior-posterior gradient in intracortical myelination. Frontal and temporal regions were significantly left-lateralized, whereas parietal and occipital regions were significantly right-lateralized. The most left-lateralized regions were IFG pars triangularis, rostral MFG, and IFG pars opercularis; the most right-lateralized were lingual, pericalcarine, and inferior parietal cortex.



Region	T1w/T2w Left	T1w/T2w Right	L.I. (λ)
IFG po	1.883	1.746	3.777
IFG pt	1.887	1.737	4.129
STG	1.827	1.749	2.177
IFG porb	1.773	1.656	3.423
MTG	1.704	1.652	1.562
Banks STS	1.794	1.856	−1.682
Caudal MFG	1.856	1.759	2.700
HG (TTG)	2.293	2.232	1.062
Sup. Parietal	1.847	1.933	−2.240
Calcarine S	2.104	2.236	−3.017
Lat. Occipital	1.907	2.012	−2.625

Intracortical Myelin – Language Lateralization Correlations

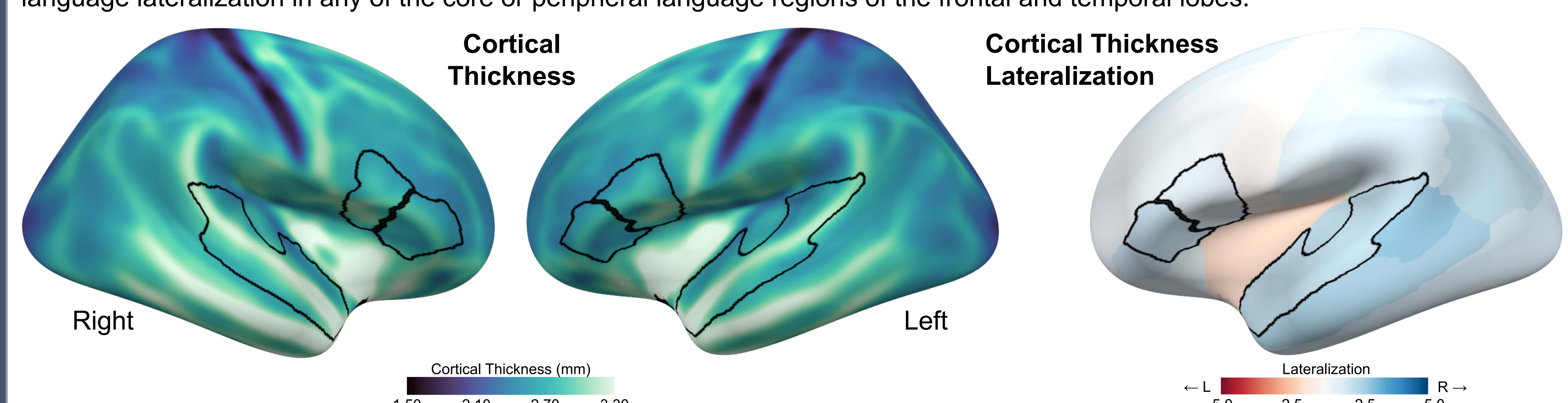
Functional selectivity for language also showed a leftward asymmetry, with the most left-lateralized language selectivity in IFG pars opercularis, caudal MFG, and IFG pars triangularis. Lateralization was significant but weaker in MTG and STG. Five core language regions exhibited significant correlations between language selectivity and myelin asymmetries: STG, IFG (all parts), and MTG.



Region	Co-Lateralization $\beta_{\lambda.myelin}$	$p_{uncorr.}$	p_{Holm}
IFG po	0.092	0.003	0.028
IFG pt	0.098	0.003	0.028
STG	0.173	0.000	0.000
IFG porb	0.121	0.000	0.001
MTG	0.088	0.004	0.028
Banks STS	0.052	0.092	0.552
Caudal MFG	0.048	0.118	0.591
HG (TTG)	−0.002	0.972	1.000
Sup. Parietal	0.022	0.482	1.000
Calcarine S	0.011	0.743	1.000
Lat. Occipital	0.015	0.635	1.000

Cortical Thickness

Cortical thickness exhibited a subtle but significant pattern of predominantly rightward lateralization across most of the brain. In contrast to the intracortical myelin results, there were no relationships between cortical thickness asymmetries and functional language lateralization in any of the core or peripheral language regions of the frontal and temporal lobes.



Region	Thick. L.I. (λ)	Co-Lateral. $\beta_{\lambda.thick}$	p_{Holm}
IFG po	−0.742	−0.022	1.000
IFG pt	−1.178	0.026	1.000
STG	−0.900	−0.049	1.000
IFG porb	−0.908	0.035	1.000
MTG	−1.225	−0.044	1.000
Banks STS	−2.133	−0.026	1.000
Caudal MFG	−0.347	−0.027	1.000
HG (TTG)	−1.408	0.037	1.000
Sup. Parietal	−0.847	0.099	0.105
Calcarine S	−0.074	0.069	0.350
Lat. Occipital	−1.122	0.096	0.126