Uncovering the asymmetry of common temporal lobe folding variants

Poster No:

2084

Submission Type:

Abstract Submission

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Introduction:

The asymmetry of the temporal lobe is thought to play a crucial role in language processing, social cognition, and facial recognition [1,2]. Past investigation of asymmetry has largely focused on the superior temporal sulcus (STS), which shows a deeper [3] and less interrupted [4] right STS throughout the lifespan. One of the methodological obstacles to a more detailed evaluation of cortical folding asymmetry has been the difficulty in disentangling true asymmetry from the large natural cortical folding variability [5]. In previous work we have shown that major cortical folding variants may be characterised through hierarchical surface registration (MSM-HT [6]). In this abstract we set out to use these to perform a detailed analysis of more fine-grained structural asymmetries of the whole temporal lobe.

Methods:

Starting with the null hypothesis that there is no asymmetry of the temporal lobe, MSM-HT was used to co-register all hemispheres from 1110 subjects from the Young Adult Human Connectome Project (HCP) to each other. This was achieved by first mirror-flipping all right hemispheres; then co-registering all pairs using a fast learning-based surface registration algorithm [7] to construct a 2220 × 2220 matrix of pairwise similarities of cortical folding. Here, cortical folding similarity was assessed by measuring the Dice overlap and correlation of sulcal depth feature separately for each of the frontal, parieto-occipital and temporal lobes. Next, 30 clusters of common folding variants were identified for each lobe, through agglomerative hierarchical clustering on these features (Fig.1A). Multimodal surface matching (MSM) [8] was used to co-register curvature maps of individuals within each cluster to generate a family of templates summarising the clusters. To approach lobar asymmetry, the proportion of left hemisphere examples used to generate each template was calculated; clusters were then categorised as left- or right-biased. Significant asymmetry was tested using Fisher's exact test with Bonferroni correction. To further characterise folding asymmetry of the temporal lobe, surface area of this region was normalised by total ipsilateral hemispheric surface area (Fig.2A, B); this was compared between left- and right-biased folding variants using a two-sample t-test.

Results:

The resulting folding variants aligned with the literature [5]. Comparing to frontal and parietal lobe variants (clustered in the same way), a higher proportion of temporal lobe clusters were left-biased (Fig.1B). Left-biased templates present more atypical folding variants, capturing more interruptions on the STS [4]; more branches of the middle segments of the STS extended to inferior temporal sulci (cluster 2,3,4,8 in Fig.1B) and branches of the posterior segments of STS (cluster 4); right-biased templates display a continuous STS with larger cluster sizes compared to the left-biased templates (i.e. patterns were more consistent). Both left and right-biased variants have multiple interruptions of the inferior temporal sulcus.
As expected, subjects with larger hemispheric surface area had larger temporal lobe surface areas (Fig.2B), but when comparing the proportions of temporal lobe surface area in the hemisphere, hemispheres in left-biased folding variants were significantly larger than right-biased folding variants (Fig.2C, $P<0.001$), reflecting increased folds and increasingly branched folding.

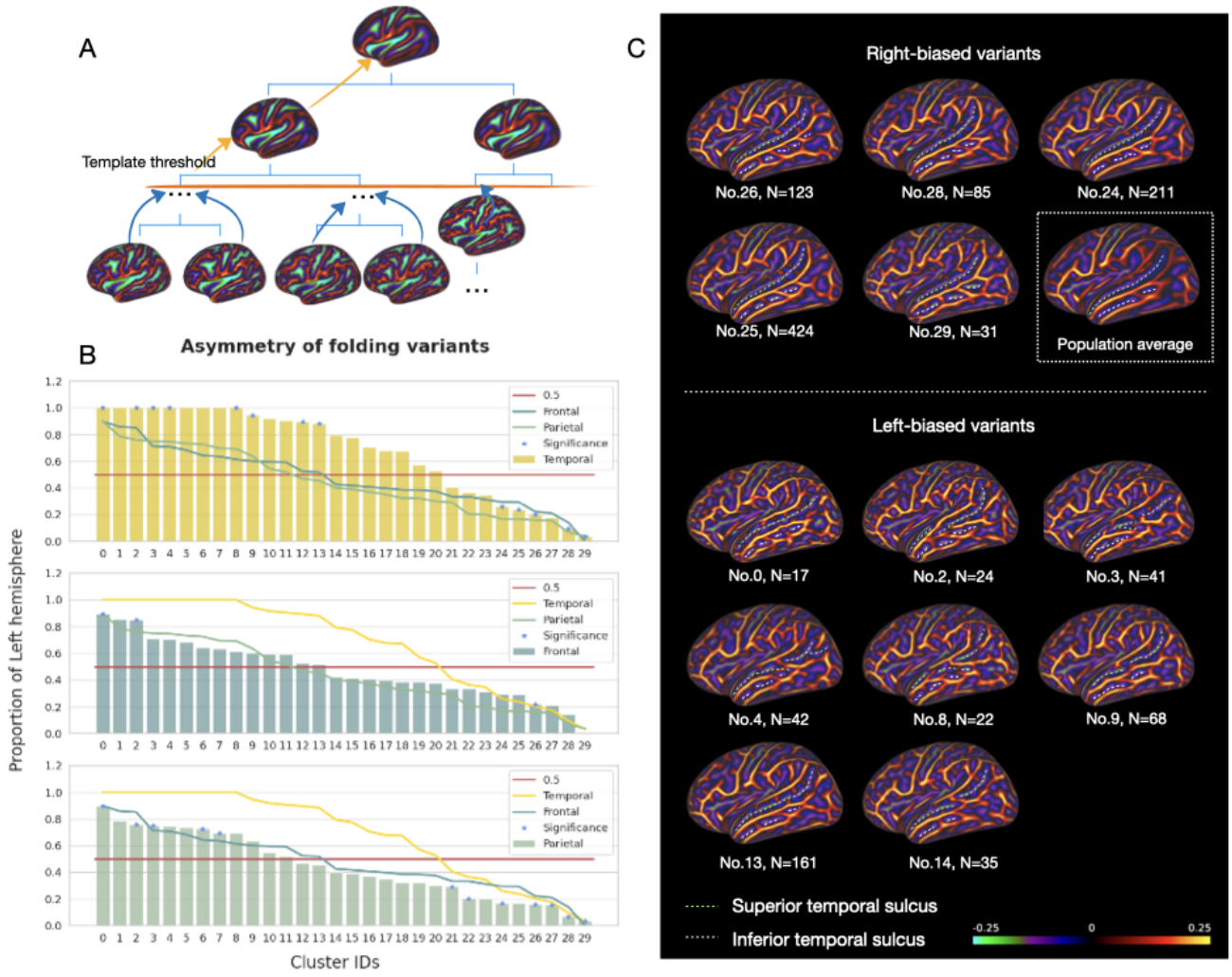

Figure 1: In 1110 subjects from the HCP, all right hemispheres were mirror flipped to the left and we applied MSM-HT [panel A] to co-register all hemispheres (left and right). Relative to asymmetries calculated for frontal and parietal lobes, leftward asymmetric variants were more frequent in the temporal lobe [panel B]. Significantly biased templates were shown in [panel c]. Left-biased templates presented more atypical folding capturing more interruptions on the STS, more branches of the middle segments of STS extending to inferior temporal sulci (cluster 2,3,4,8), and branches of the posterior segments of STS (cluster 4); right-biased templates displayed a continuous STS with larger cluster sizes compared to the left-biased templates (i.e. patterns were more consistent).

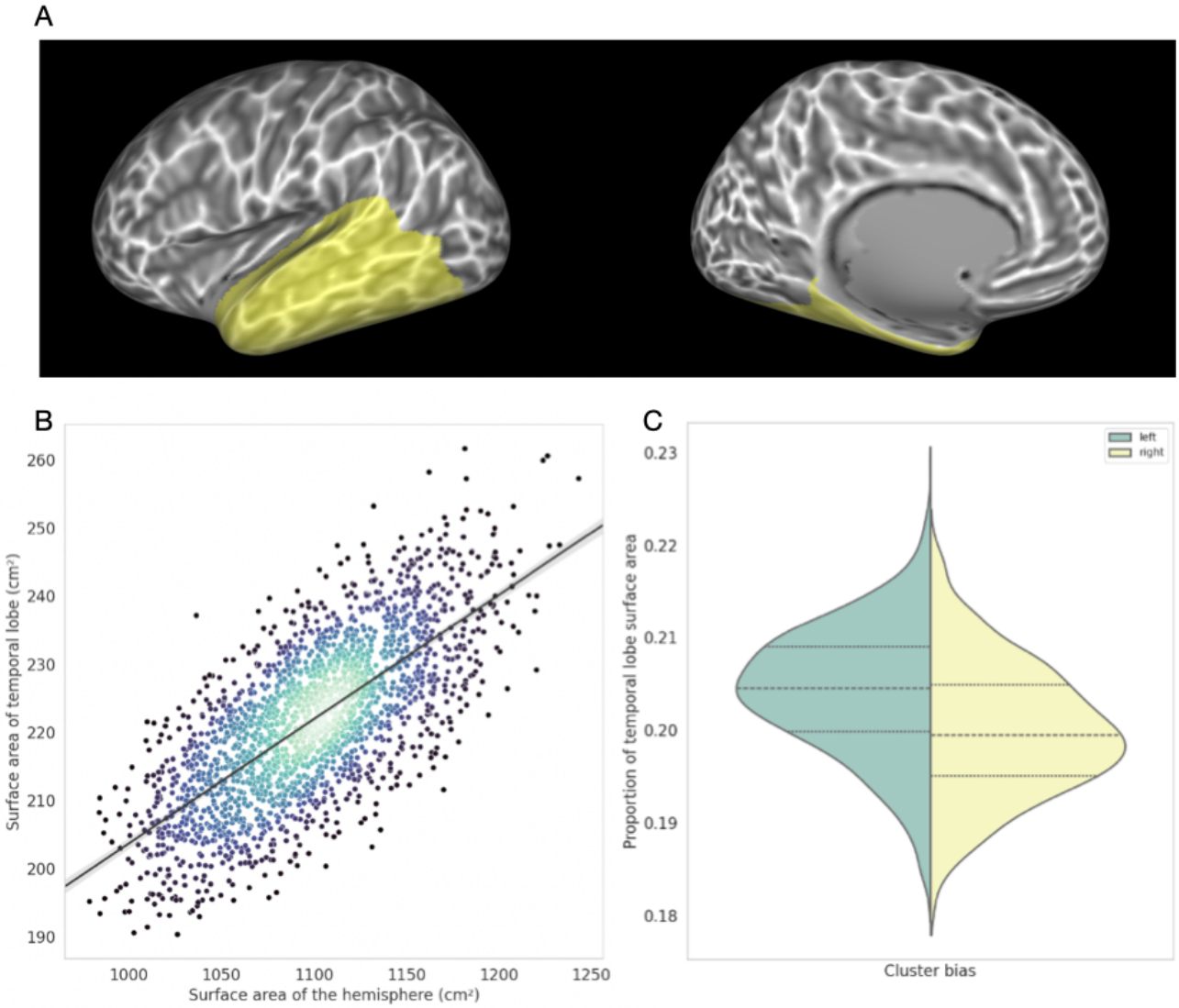

Figure 2: To approach lobar asymmetry, the proportion of left hemisphere examples used to generate each template was calculated and clusters were then categorised as left- or right-biased. The temporal lobe was defined by summing temporal regions of the Desikan-Killiany Atlas [9] [panel A]. Subjects with larger hemispheric surface area had larger temporal lobe surface areas [panel B]. But when comparing the proportions of temporal lobe surface area in the hemisphere, hemispheres in left-biased folding variants are significantly larger than right-biased folding variants [panel C, P<0.001], reflecting increased folds and increasingly branched folding.

Conclusions:

Using hierarchical registration and clustering, the present study uncovered strongly lateralised common variants of cortical folding in line with the literature in specific sulci. Differences between left/right-biased folding variants are evident in the temporal lobe, with increased surface area on the left. This aligns with the known higher computational demands of language processing in the left hemisphere, suggesting that MSM-HT offer opportunities for more detailed investigation into the links between lateralised folding variants and function.

Modeling and Analysis Methods:

Image Registration and Computational Anatomy [1]

Neuroanatomy, Physiology, Metabolism and Neurotransmission:

Cortical Anatomy and Brain Mapping [2]

Keywords:

Cortex

MRI
Structures
Other - Cortical folding, Surface-based analysis

[1|2]Indicates the priority used for review

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Structural MRI

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