Shape analysis of 101 healthy human brains

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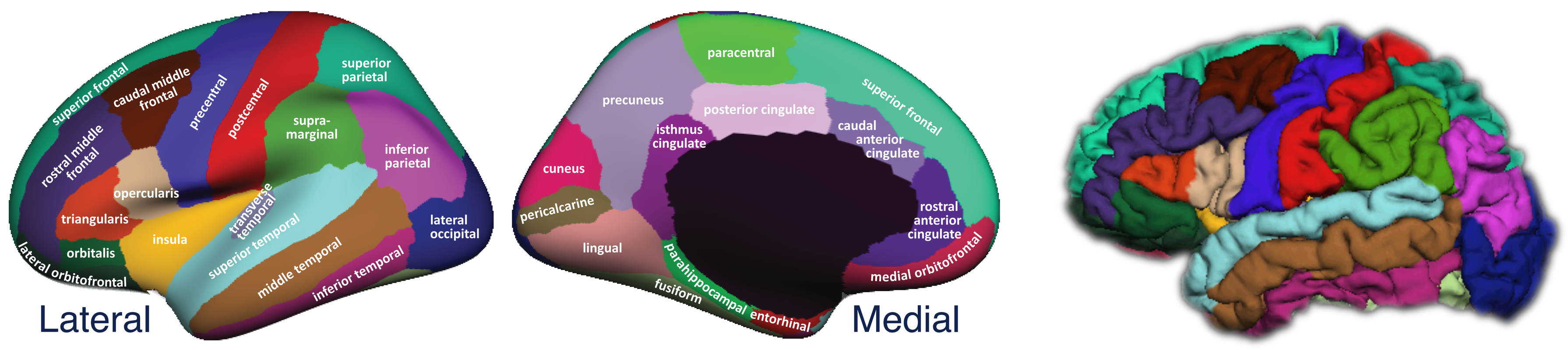
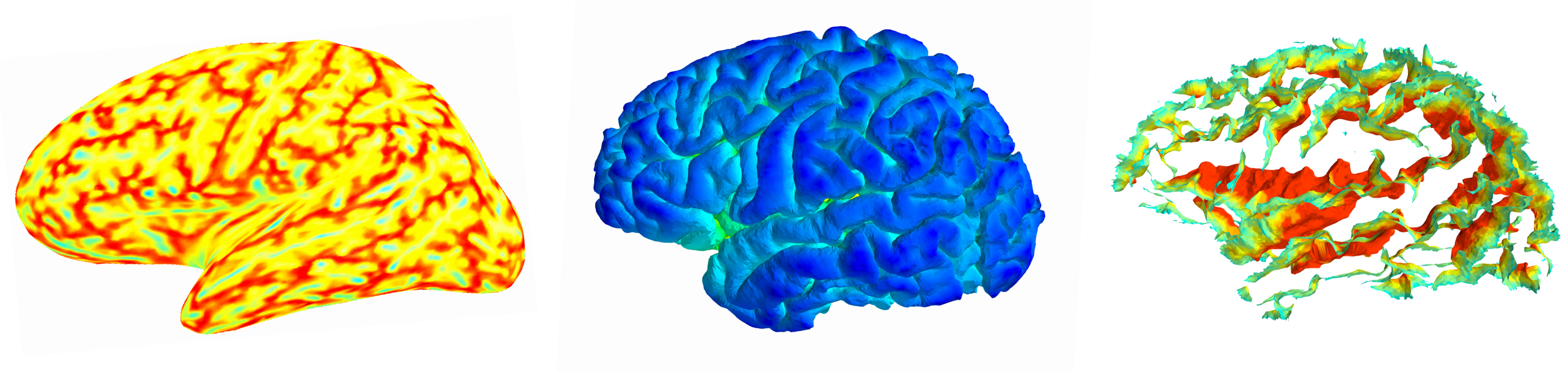
LABELED DATA

The **Mindboggle-101 dataset** [1] is a free and publicly available set of manually edited surface and volume labels assigned to MRI data acquired from 101 healthy adults. Cortical labels follow the Desikan-Killiany-Tourville (DKT) labeling protocol [1] (20 of the brains also have manually labeled subcortices).



SHAPE PROCESSING

The **Mindboggle software** [2] combines FreeSurfer [3] and ANTs [4] tissue-class segmentations, propagates (in this case manual) labels through each class, and measures the volume of each label and the average thickness of each cortical label. Mindboggle also computes surface shape measures for each vertex (e.g., curvature, geodesic and travel depth, area), and for each label or sulcus (Laplace-Beltrami spectra and Zernike moments, as well as summary statistics across vertices within a label or sulcus).



ANALYSIS of SHAPE VARIATION

To estimate the variation of shape in healthy adult human brains, we computed shape measures on the 101 MRI scans. We fitted 24 distinct linear mixed models for each shape measure and brain region combination to assess the importance of each of the covariates (sex, handedness, and age as fixed effects) and nested classification factors (lab, subject, and brain hemisphere as random effects):

Total variance of each shape measure =
variance between labs +
variance between subjects within a lab +
variance between brain hemispheres within a subject +
variance within brain hemisphere

For each shape measure / brain region combination, we used the Bayesian Information Criterion score to select the best model.

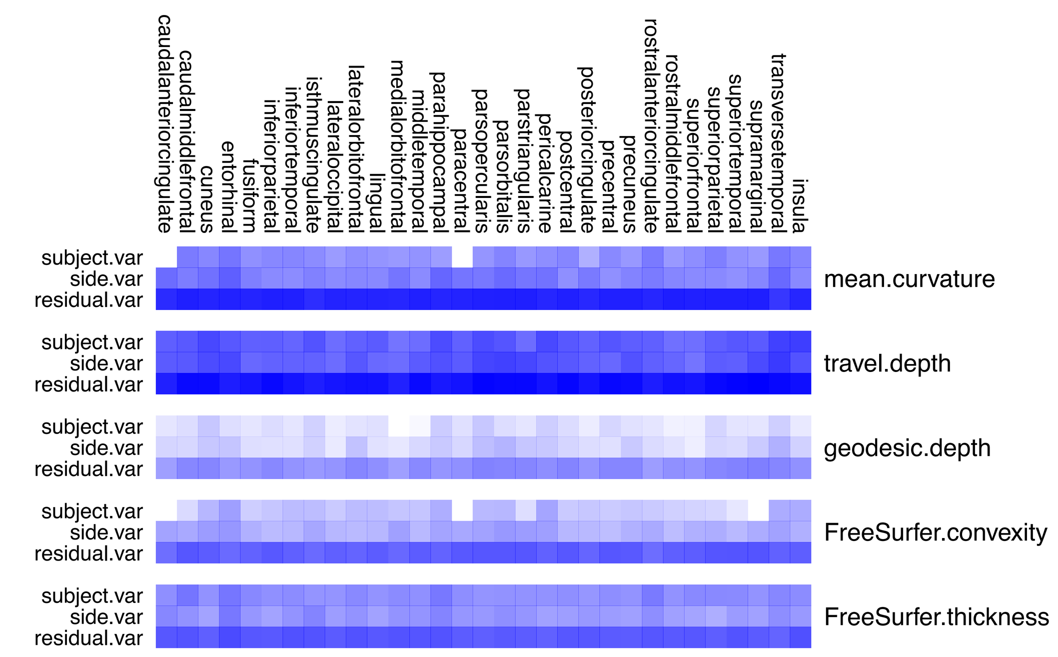
DISCUSSION

This is the largest set of shape measures computed on openly available healthy human brain data. We are treating these as normative data against which we will compare different healthy populations as well as patient populations. All of our data, software, and results are free and open.

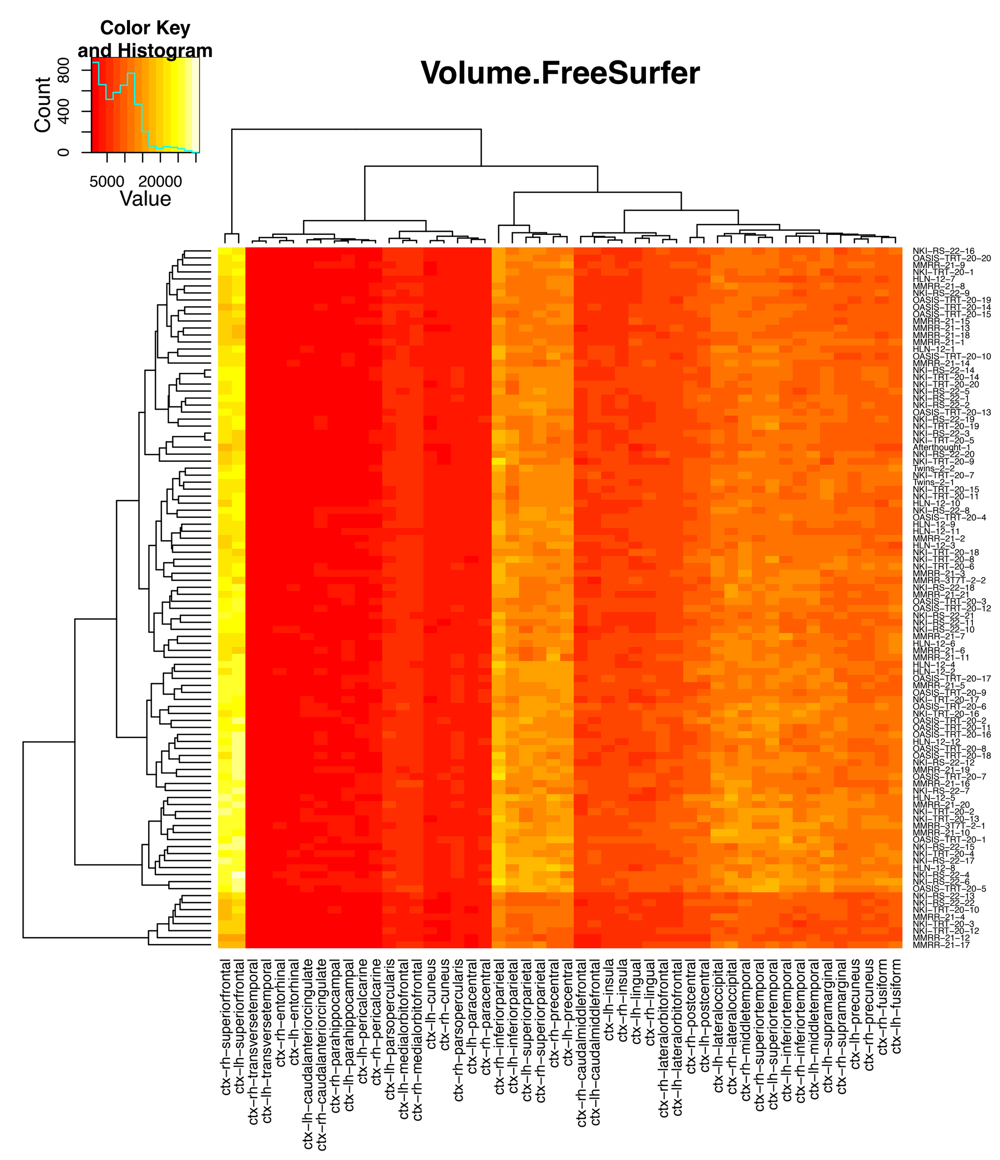
Please see **http://mindboggle.info** for more details.

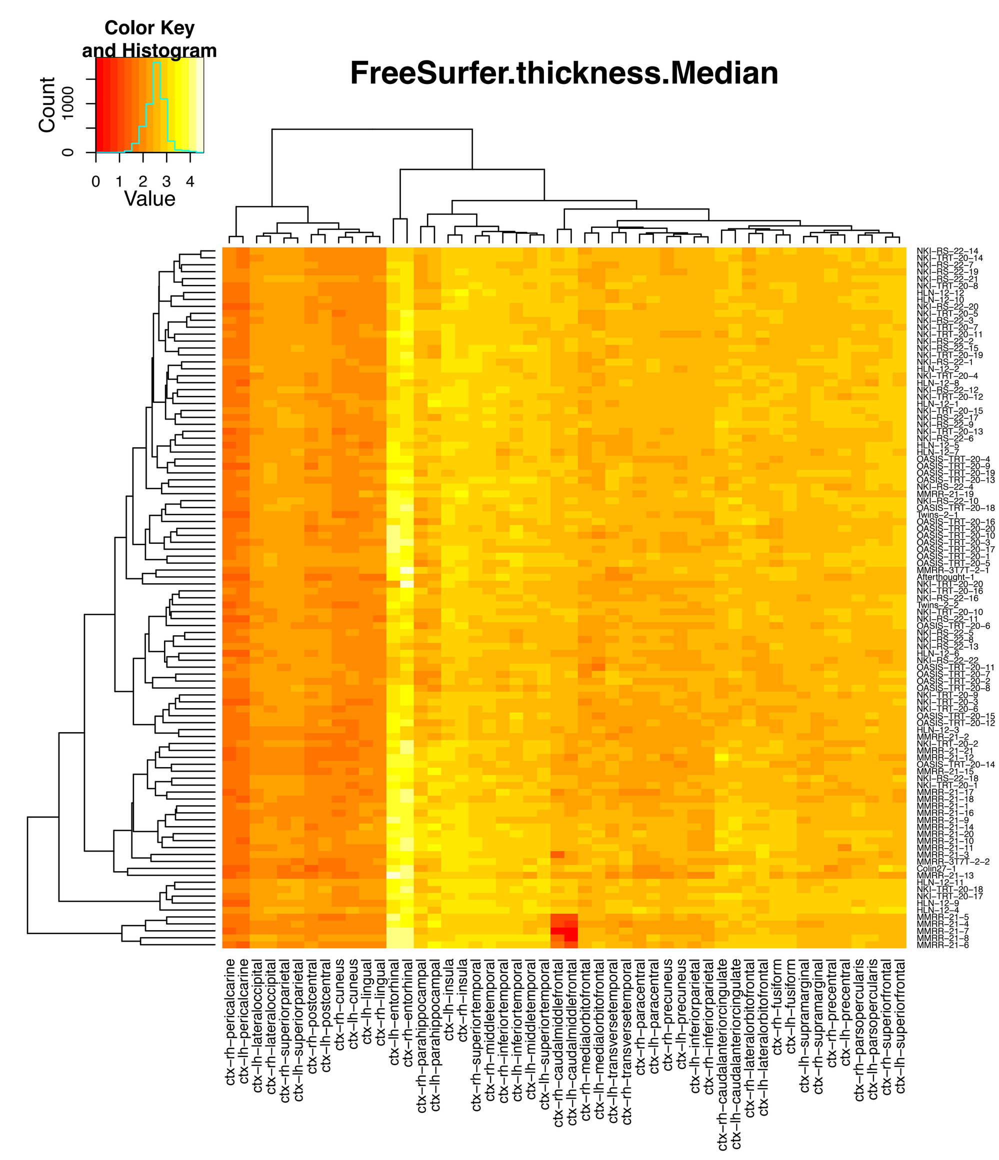
EXAMPLE RESULTS

The top figure presents an overview of the variance results for labels. For all shape measures and brain regions, most of the variability was concentrated at the residual component. For geodesic depth, the model with subject and hemisphere parameters tended to rank first across most brain regions. For all other shape measures, two models were the best and only differ by the inclusion of the "subject within lab" parameter in one of the models.

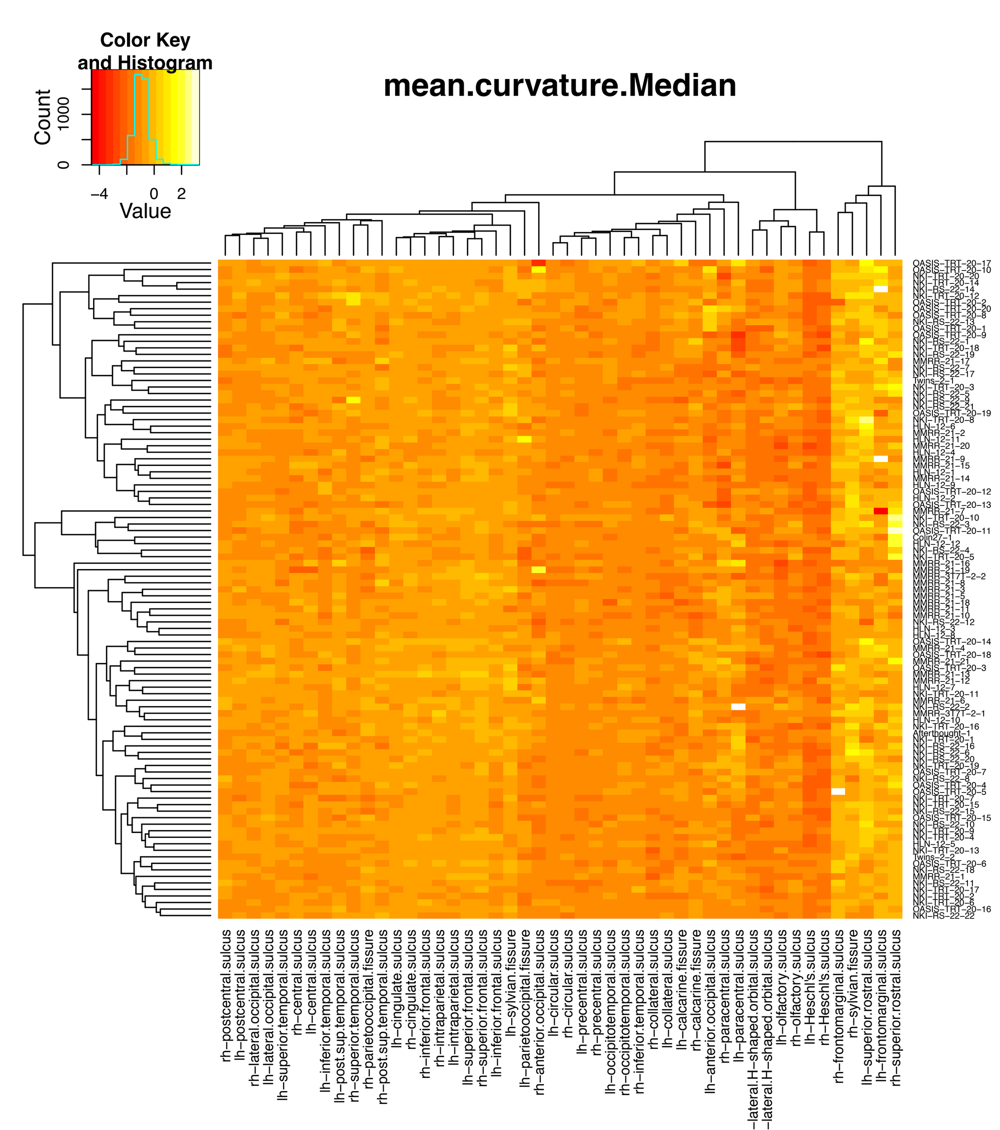


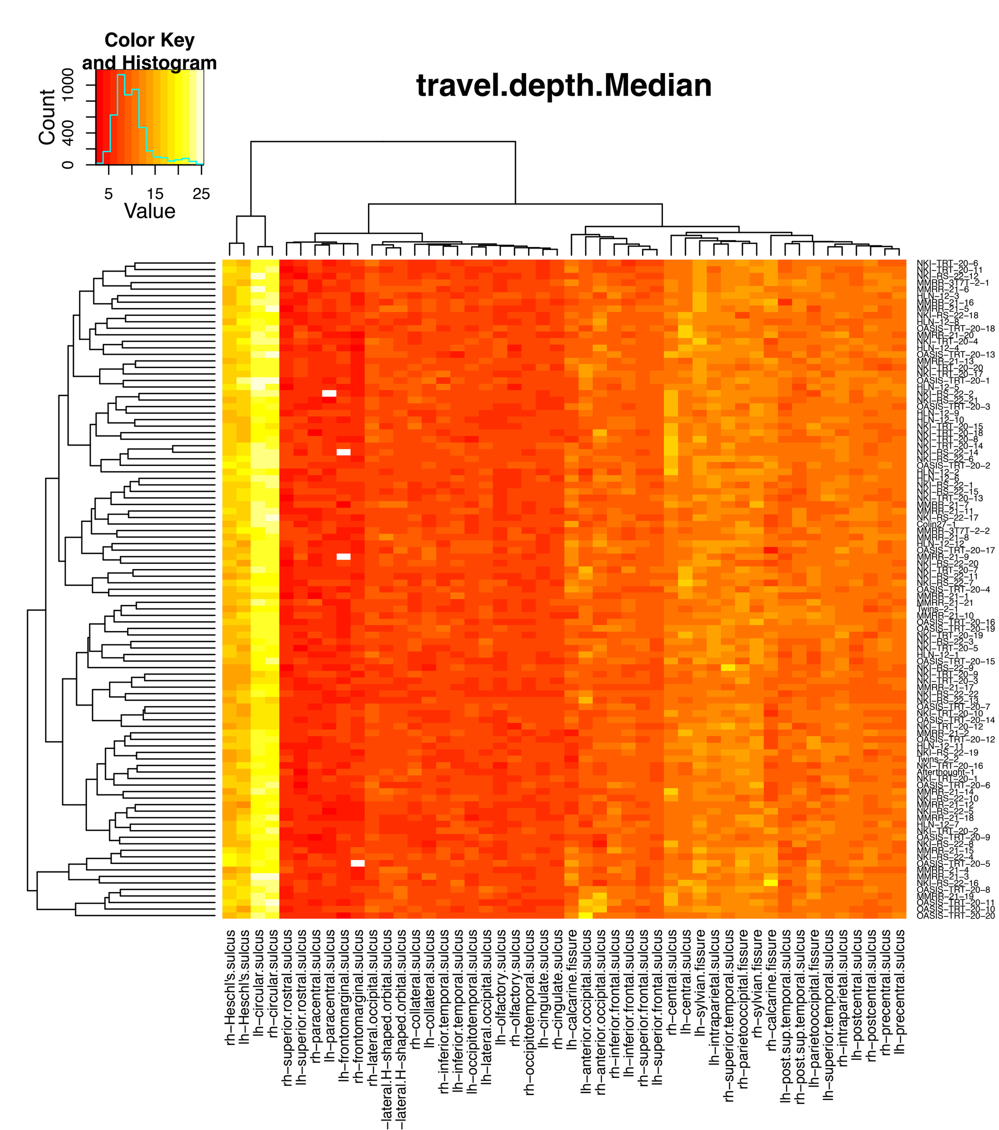
Label data





Sulcus data





References

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[1] Klein, A, Tourville, J. (2012). 101 labeled brain images and a consistent human cortical labeling protocol. Frontiers in Brain Imaging Methods. 6:171.
[2] http://mindboggle.info/
[3] https://surfer.nmr.mgh.harvard.edu/
[4] http://stnava.github.io/ANTs/