101 labeled brains and a new human cortical labeling protocol

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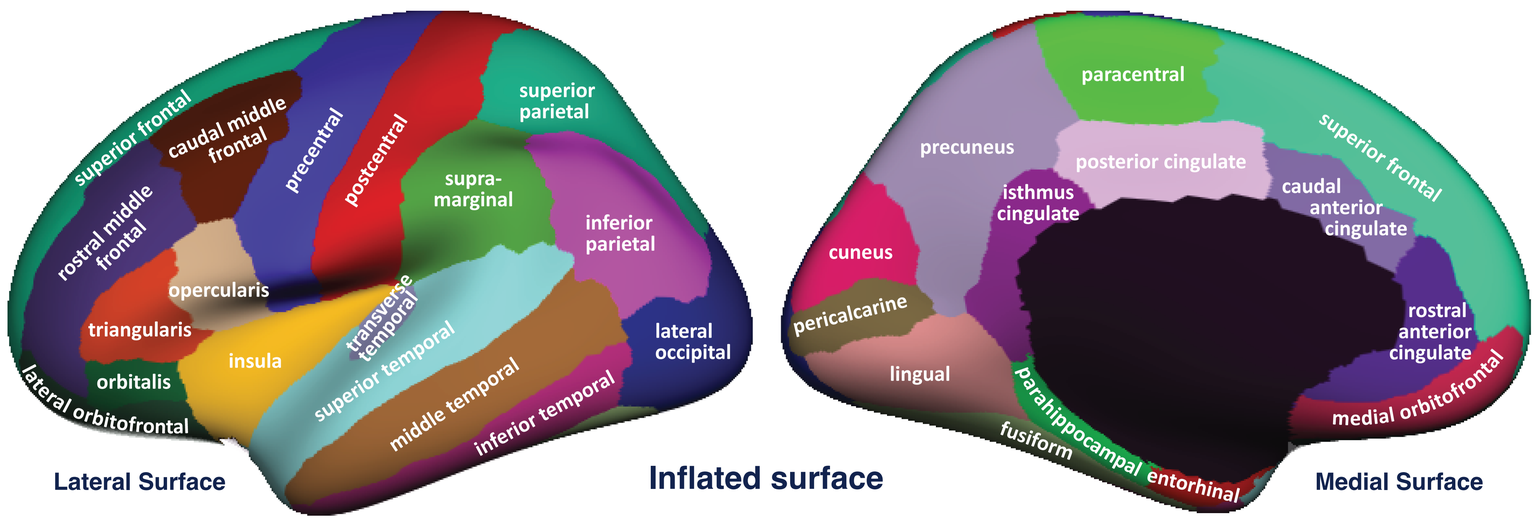


Mindboggle-101 dataset

We introduce the largest and most complete set of free, publicly accessible, manually labeled human brain images. Given how difficult it is to label brains, the Mindboggle-101 dataset is intended to serve as brain atlases for use in labeling other brains, as a normative dataset to establish morphometric variation in a healthy population for comparison against clinical populations, and contribute to the development, training, testing, and evaluation of automated registration and labeling algorithms.

DKT cortical labeling protocol

To manually label the macroscopic anatomy in magnetic resonance images of 101 healthy participants, we created a new cortical labeling protocol that relies on robust anatomical landmarks and minimal manual edits after initialization with automated labels. The "Desikan-Killiany- Tourville" (DKT) protocol is intended to improve the ease, consistency, and accuracy of labeling human cortical areas.

Editing surface labels

We manually subdivided the cerebral cortex in magnetic resonance images of 101* healthy participants into 62 regions of interest (31 per hemisphere) using FreeSurfer image processing software (http://surfer.nmr.mgh.harvard.edu). To do so we created a modified version of the Desikan-Killiany [1] cortical labeling protocol that relies on robust, easily identified anatomical landmarks. The "Desikan-Killiany-Tourville" (DKT) protocol and automatic classifier are intended to improve the ease, consistency, and accuracy of labeling human cortical areas.

All data and related software and updated information will soon be made available on the website: http://www.mindboggle.info/data/

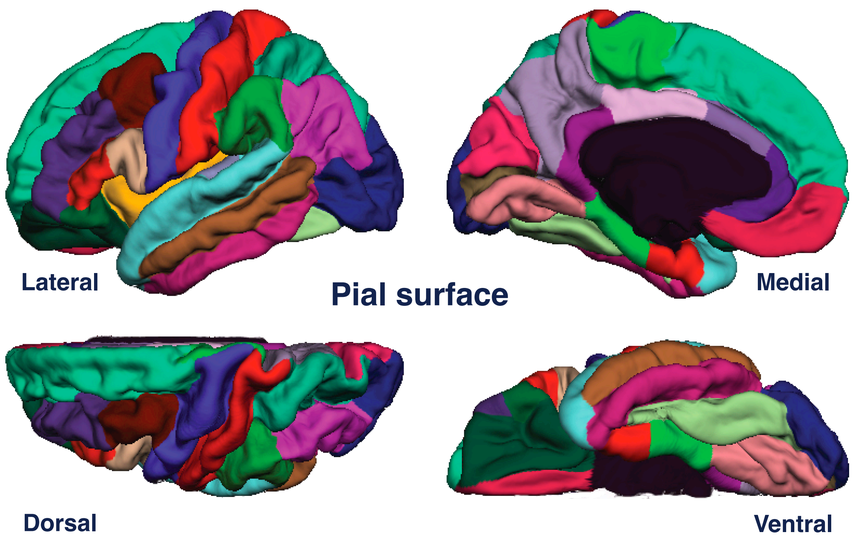
*1 brain to go!

[1] Desikan, R. S., Segonne, F., Fischl, B., Quinn, B. T., Dickerson, B. C., Blacker, D., Buckner, R. L., et al. (2006). An automated labeling system for subdividing the human cerebral cortex on MRI scans into gyral based regions of interest. NeuroImage, vol(3), 968–980.

Acknowledgments

We would like to thank Andrew Worth and Greg Millington of Neuromorphometrics, Inc., for their dedication to meticulous, consistent, and accurate manual labeling of brain image data. We are extremely grateful to Michael Milham, Bennett Landman, and Satrajit Ghosh for making multimodal scans available for this project and for their shared interest in open data and open science.

This work was funded by the NIMH R01 grant MH084029 ("Mindboggling shape analysis and identification"). The OASIS project was funded by grants P50 AG05681, P01 AG03991, R01 AG021910, P50 MH071616, U24 RR021382, and R01 MH56584. The MMRR project was funded by NIH grants NCRR P41RR015241, 1R01NS056307, 1R21NS064534-01A109, and 1R03EB012461-01. The NKI project was funded primarily by R01 MH094639. The HLN project was funded by NIH grant EB000461.



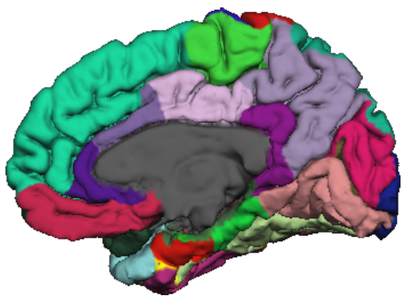
Subjects

Name	Source	N	Age (mean, SD)	Gender M	Gender F	Hand R	Hand L
NKI-RS-22	"Nathan Kline Institute / Rockland Sample"	22	20-40 (26.0, 5.2)	12	10	21	1
NKI-TRT-20	"Nathan Kline Institute / Test-Retest"	20	19-60 (31.4, 11.1)	14	6	15*	3*
MMRR-21	"Multi-Modal MRI Reproducibility Resource"	21	22-61 (31,8, 9.2)	11	10	18	1
MMRR-3T7T-2	2 3T/7T subjects acquired after the MMRR-21 subjects	2	22, 24	2	0	2	0
HLN-12	"Human Language Network" study subjects	12	23-39 (27.8, 4.6)	6	6	12	0
OASIS-TRT-20	"Open Access Series of Imaging Studies" test-retest ("reliability") sample	20	19-34 (23.4, 3.9)	8	12	20	0
Colin27-1	Colin Holmes template	1	33	1	0	1	0
Twins-2	Two identical twins, incl. AK	2	41	2	0	2	0
Afterthought-1	Brain imager SG	1	36	1	0	1	0

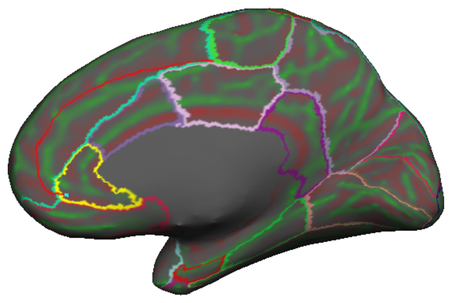
NKI-RS-22	http://fcon_1000.projects.nitrc.org/indi/pro/nki.html
NKI-TRT-24	http://fcon_1000.projects.nitrc.org/indi/pro/eNKI_RS_TRT/FrontPage.html
MMRR-21	http://www.nitrc.org/projects/multimodal
MMRR-3T7T-2	http://www.nitrc.org/projects/multimodal
HLN-12	https://masi.vuse.vanderbilt.edu/public/plos12.tar.bz2
OASIS-TRT-20	http://www.oasis-brains.org/app/action/BundleAction/bundle/OAS1_RELIABILITY
Colin27-1	http://www.bic.mni.mcgill.ca/ServicesAtlases/Colin27
*(2 ambidextrous)	

Bounding sulci

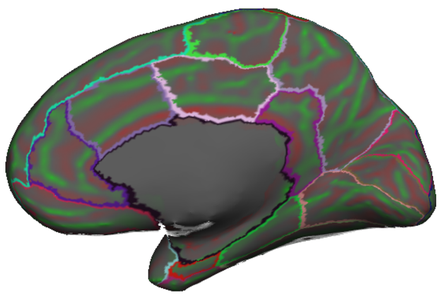
aals	anterior ascending ramus of the lateral sulcus
ahls	anterior horizontal ramus of the lateral sulcus
aocs	anterior occipital sulcus
cas	callosal sulcus
ccs	calcarine sulcus
cgs	cingulate sulcus
cos	collateral sulcus
crs	circular insular sulcus
cs	central sulcus
csts1	caudal superior temporal sulcus, first segment
csts2	caudal superior temporal sulcus, second segment
csts3	caudal superior temporal sulcus, third segment
fms	frontomarginal sulcus
ftts	first transverse temporal sulcus
hs	Heschl's sulcus
ifrs	inferior frontal sulcus
ihs	interhemispheric sulcus
itps	intraparietal sulcus
its	inferior temporal sulcus
lhos	lateral H-shaped orbital sulcus
locs	lateral occipital sulcus
ls	lateral sulcus
mhos	medial H-shaped orbital sulcus
olfs	olfactory sulcus
ots	occipitotemporal sulcus
pals	posterior ascending ramus of the lateral sulcus
pcs	paracentral sulcus
phls	posterior horizontal ramus of the lateral sulcus
pis	primary intermediate sulcus
pocs	postcentral sulcus
pos	parietooccipital sulcus
prcs	precentral sulcus
prts	pretriangular sulcus
rhs	rhinal sulcus
sbps	subparietal sulcus
sfrs	superior frontal sulcus
sros	superior rostral sulcus
sts	superior temporal sulcus
ti	temporal incisure
tcos	transverse occipital sulcus



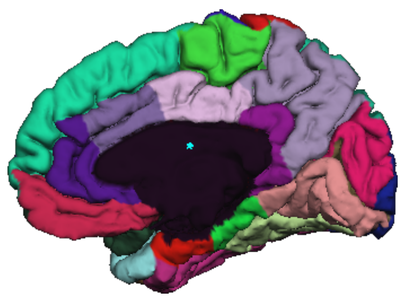
Example: identify label error (missed double cingulate)



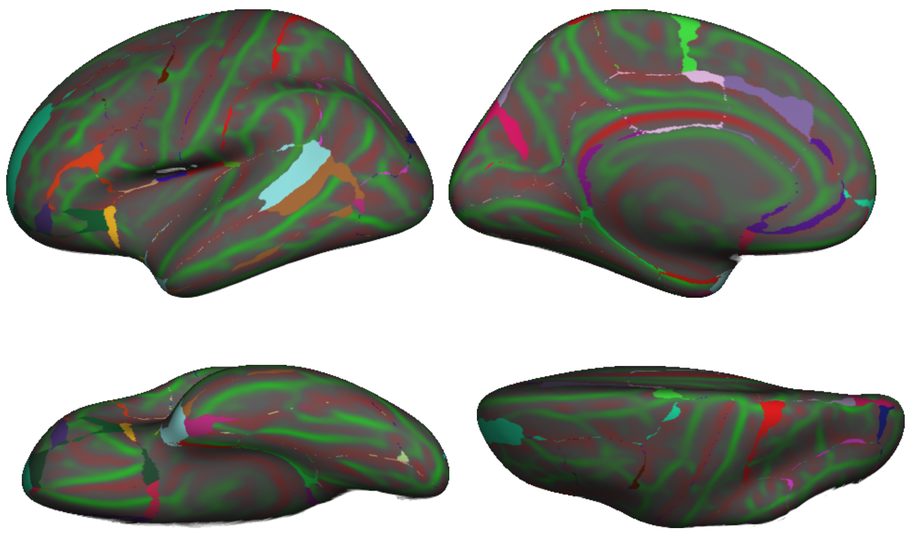
Edit region boundaries on inflated surface using curvature as a guide



Relabel regions within new boundaries



Review edits on pial surface



Comparison of Desikan-Killiany and DKT classifier atlas labels

The figure to the left is a comparison of the automatic labeling of the FreeSurfer 'fsaverage' cortical surface by the DK and DKT classifier atlases. Areas in color (overlaid atop the red-green surface) indicate areas that were labeled differently by the classifiers. Differences are largest in areas corresponding to a removed region (frontal and temporal poles, banks of the superior temporal sulcus), as well as in areas of high variability, including along the cingulate sulcus, the inferior frontal sulcus, the orbital portion of the inferior frontal gyrus, and along the lateral border of entorhinal cortex.