Brain Mapping
— putting the pieces together —

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Why label?
The case for a common reference frame

(1) to communicate and compare results

(2) to classify data

(3) to discover patterns in data

Why label?
The case for a common reference frame

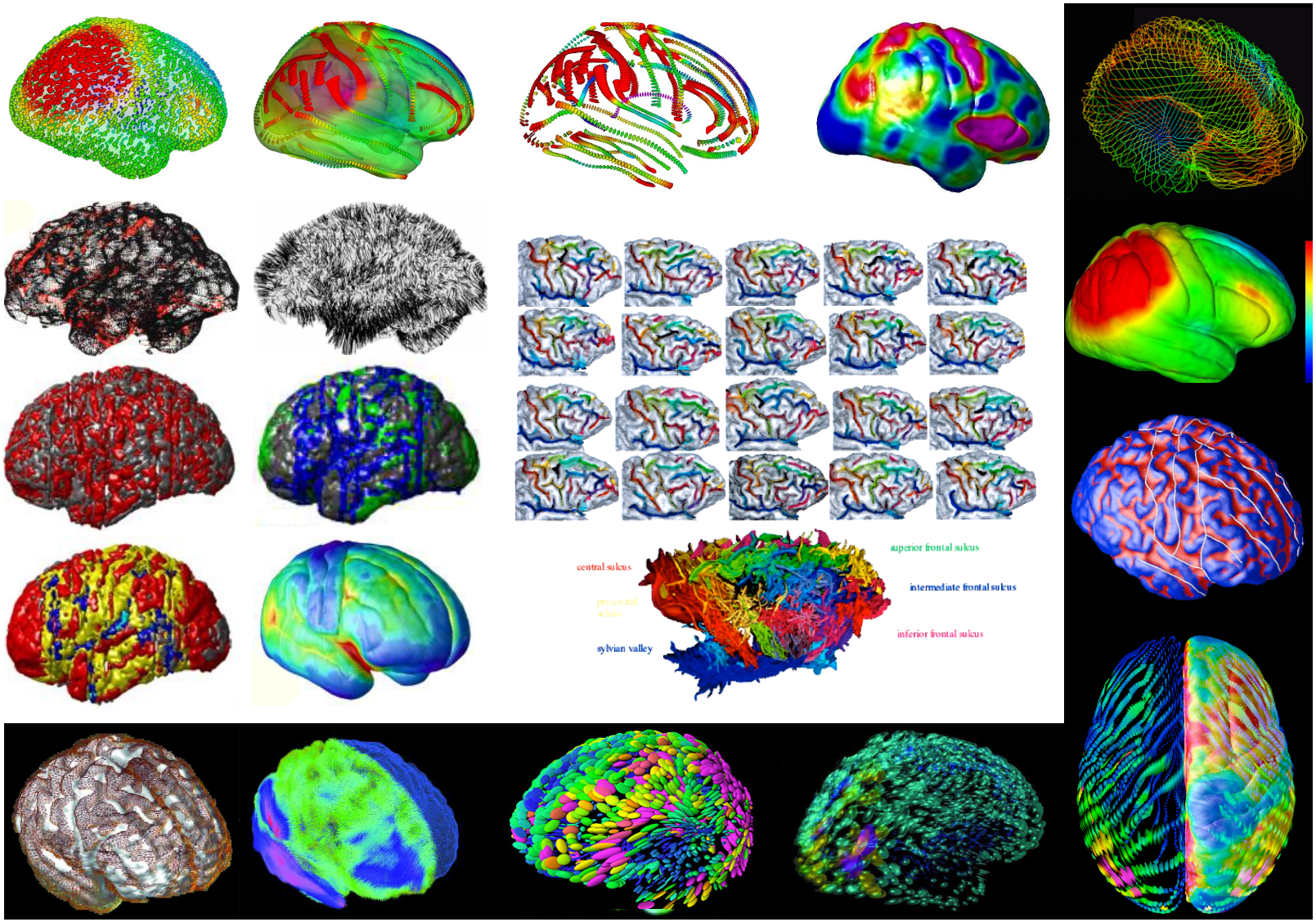
(1) to communicate and compare results
- across subjects
- across conditions
- across time
- across brain imaging techniques

(2) to classify data
- Parceling a brain into regions of interest
  provides a natural way to parcel (cluster) data acquired from a brain.

- to discover patterns in data
- The spatial arrangement and connectivity of brain regions
  can reflect an underlying pattern in the distribution of data
  acquired from those regions.

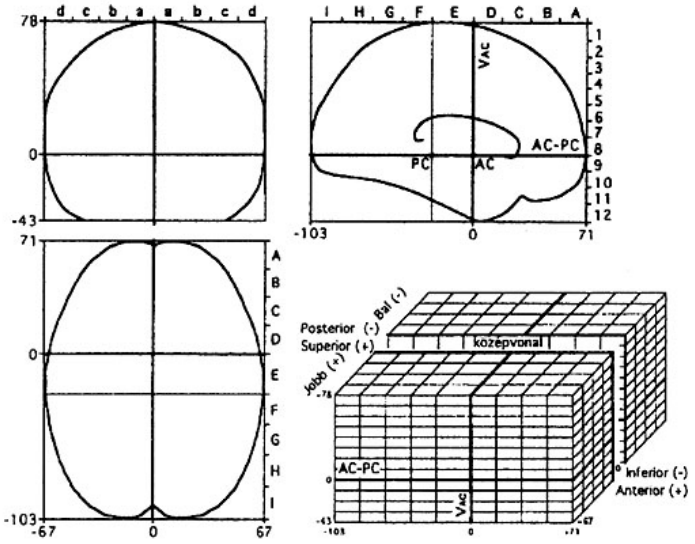
The above all rely on the use of a common reference frame (labeling system).
To establish correspondences across brains, brain image data must be coregistered (spatially normalized).

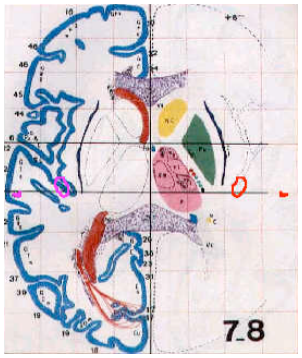
Brain variation

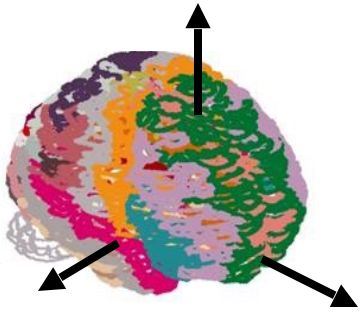


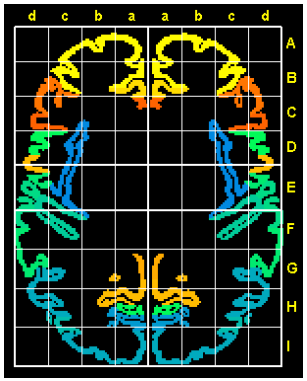
UCLA (LONI), INRIA, Timone U., NIMH, Cornell U., Columbia U.

Brain atlases
Talairach



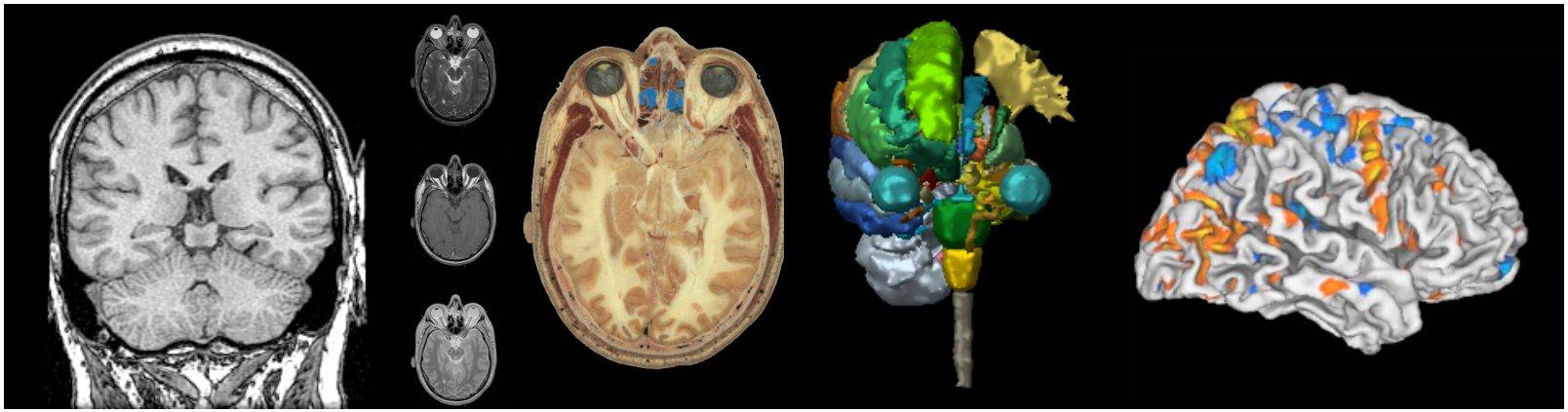






NIH Visible Human Male, Harvard's Whole Brain and SPL Atlases, vanEssen's CARET Atlas (top)

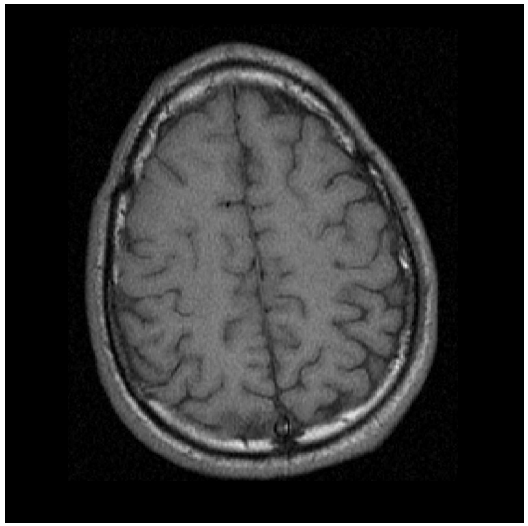
Brain atlases
Individuals



NIH Visible Human Male, Harvard's Whole Brain and SPL Atlases, vanEssen's CARET Atlas (top)

Image data

Structural



Functional

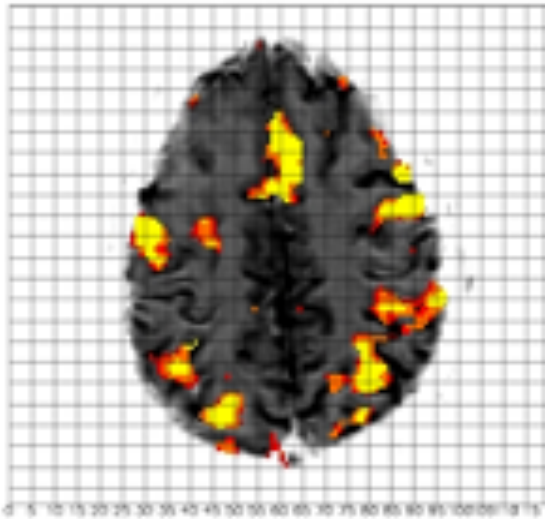
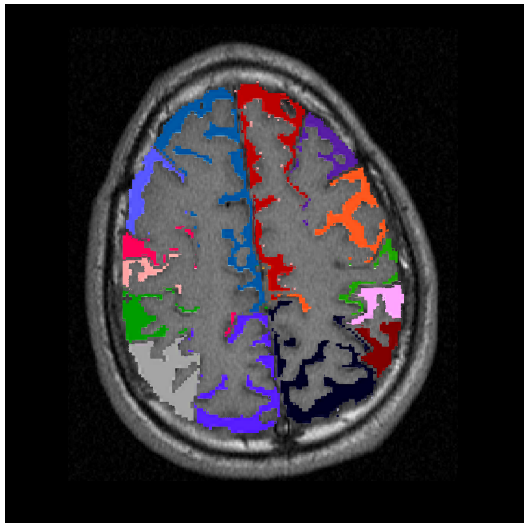


Image data

Structural



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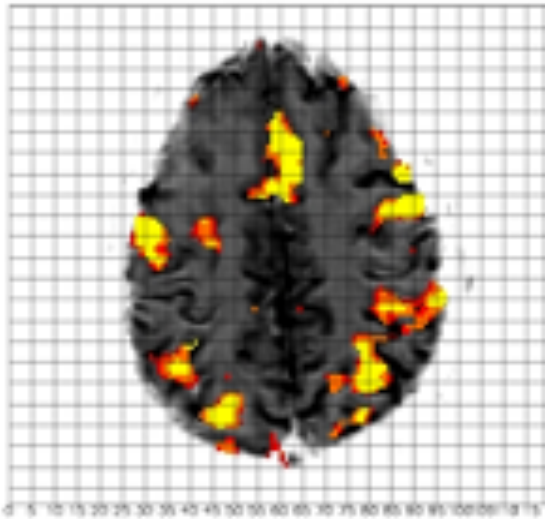

Image data

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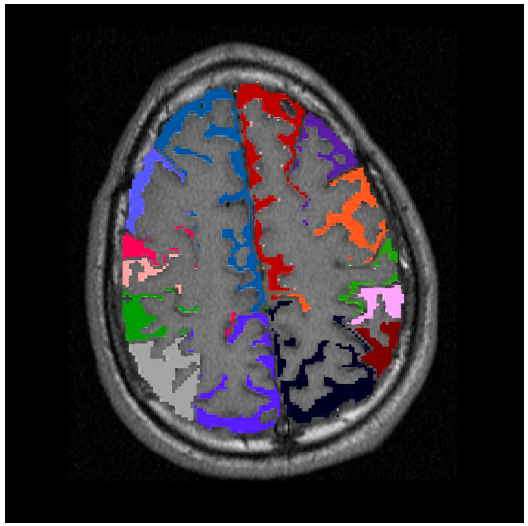
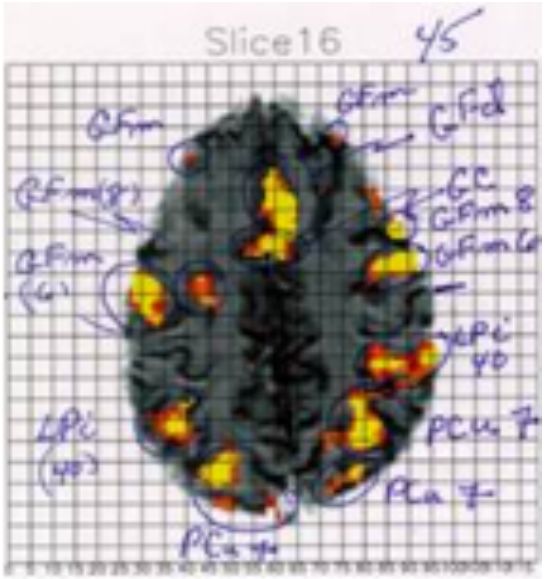
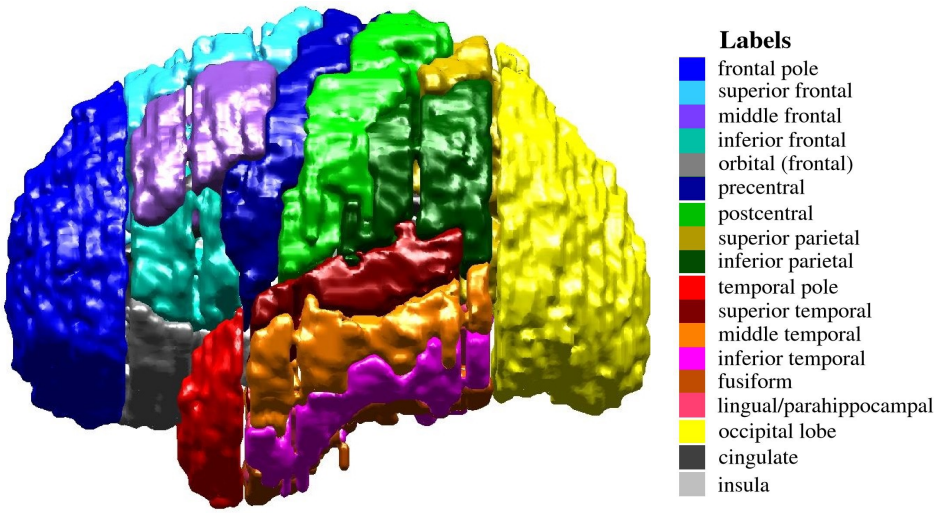


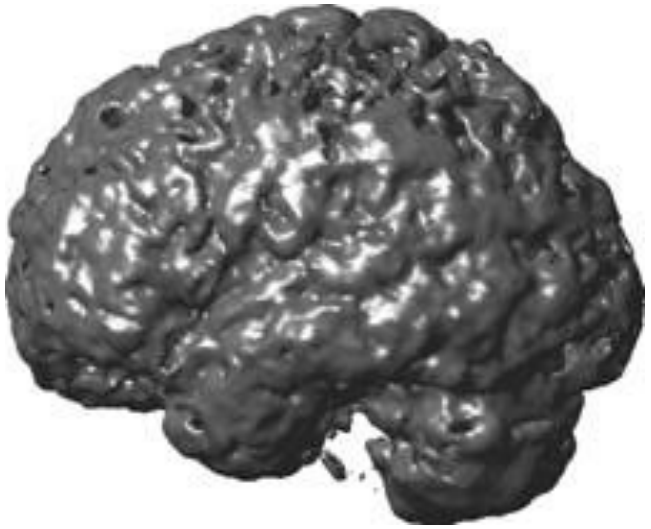
Functional



Tourville/CardViews Atlas

Atlas

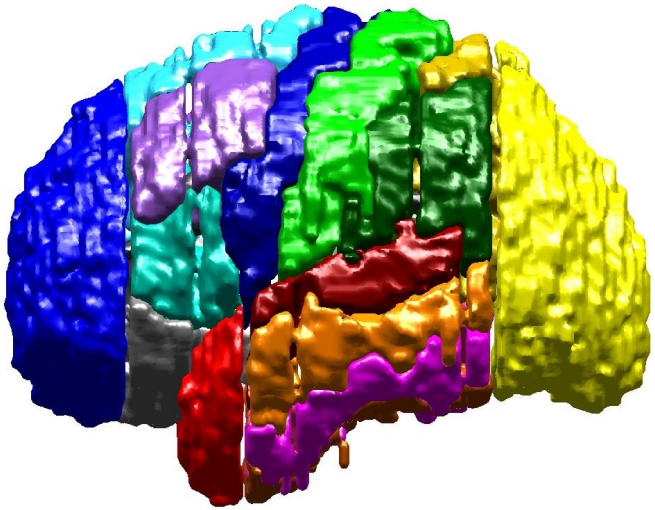


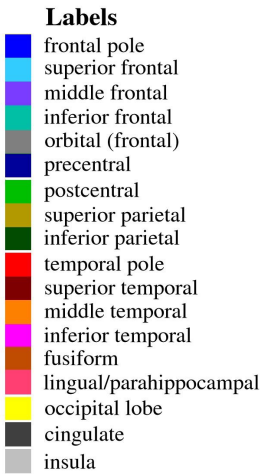


Tourville, J.A., Guenther, F.H. (2003)
Caviness Jr., V.S., Meyer, J., Makris, N., Kennedy, D.N. (1996)

The correspondence problem

Atlas





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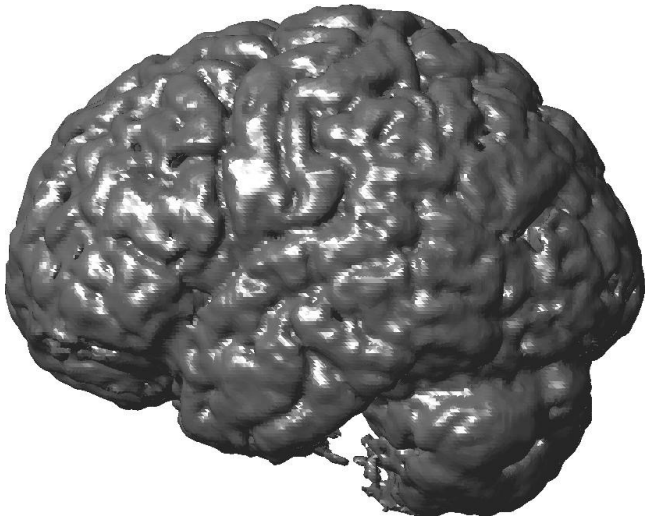
Subject



Mindboggle

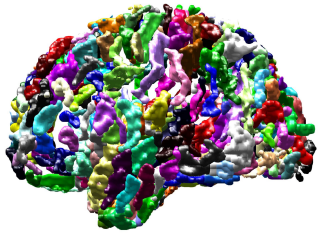
Extract pieces

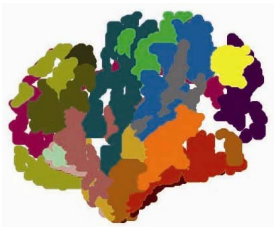
Match pieces

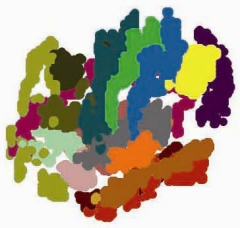
Transform boundaries

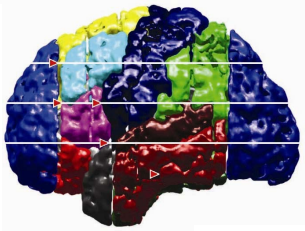
Warp labels

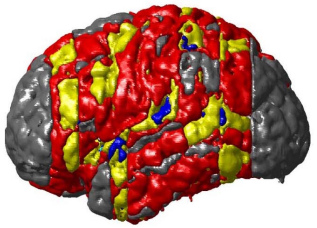
Use multiple atlases



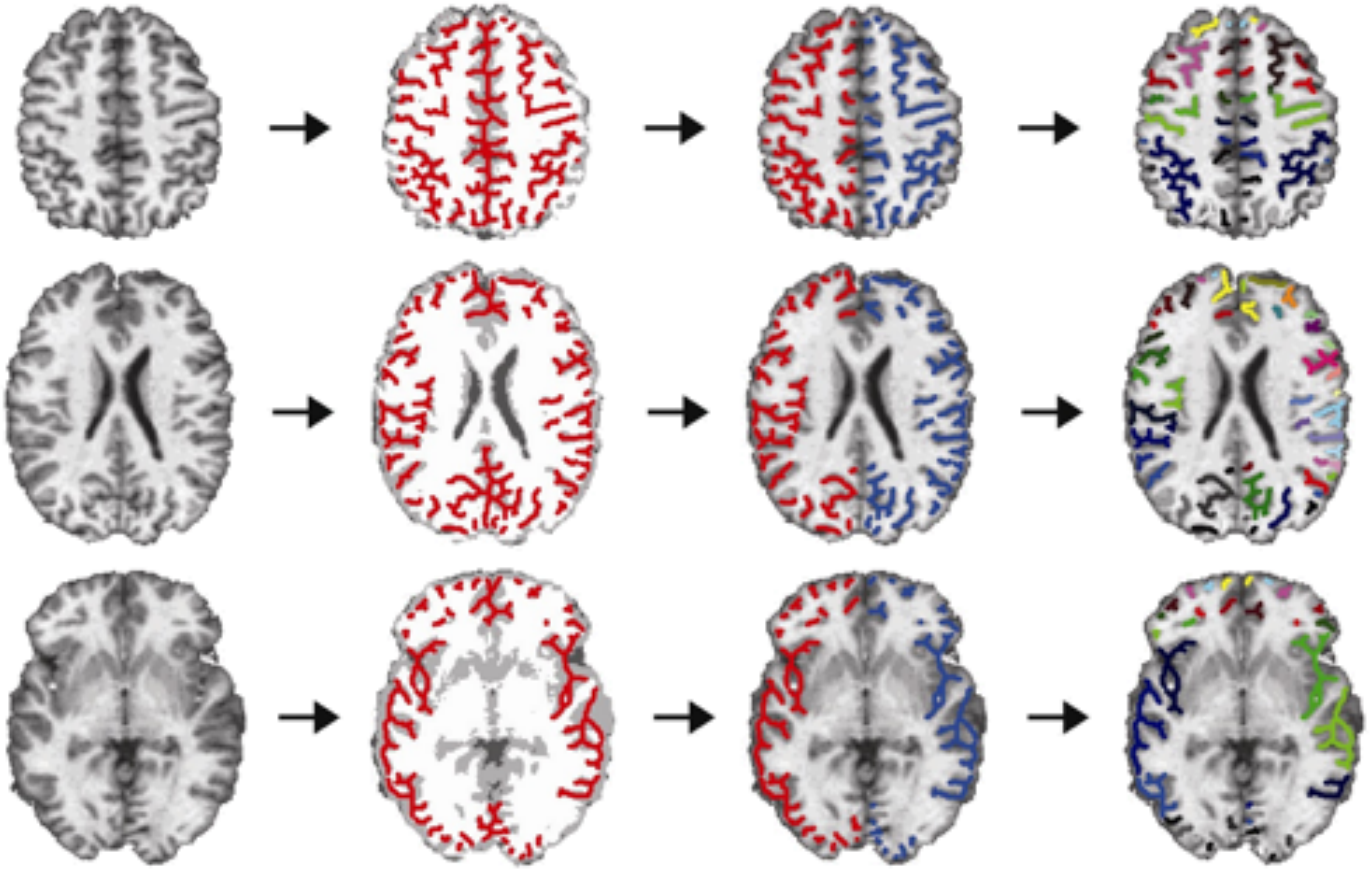




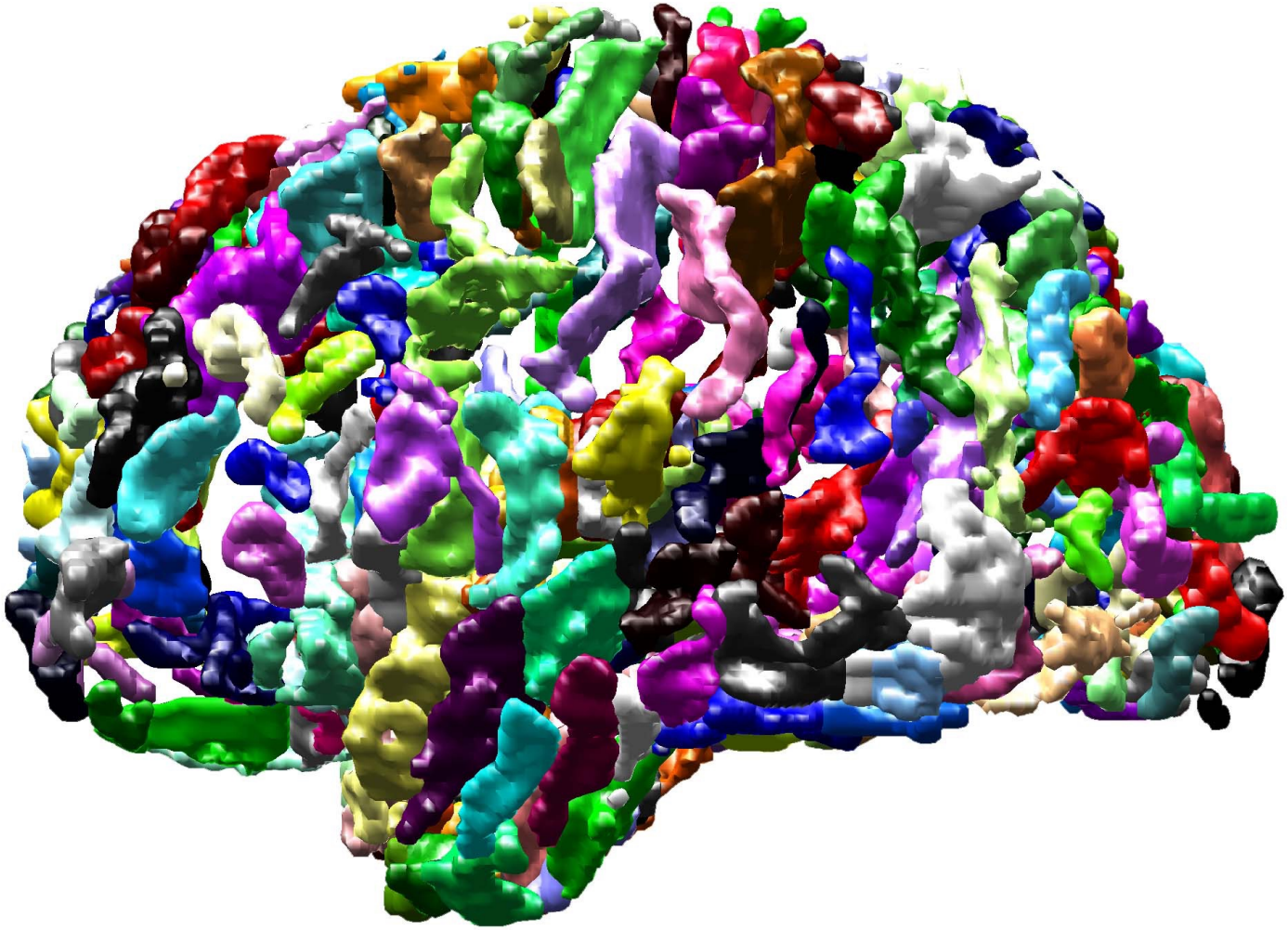




Extract pieces



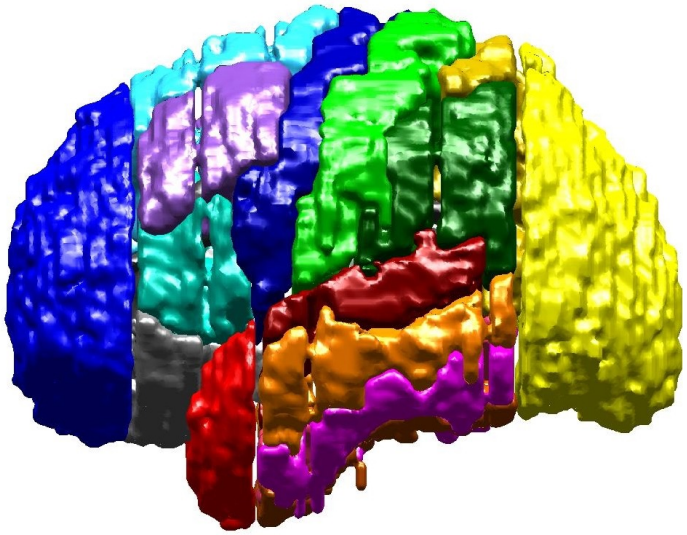
Extract pieces



Match pieces

Atlas

Subject



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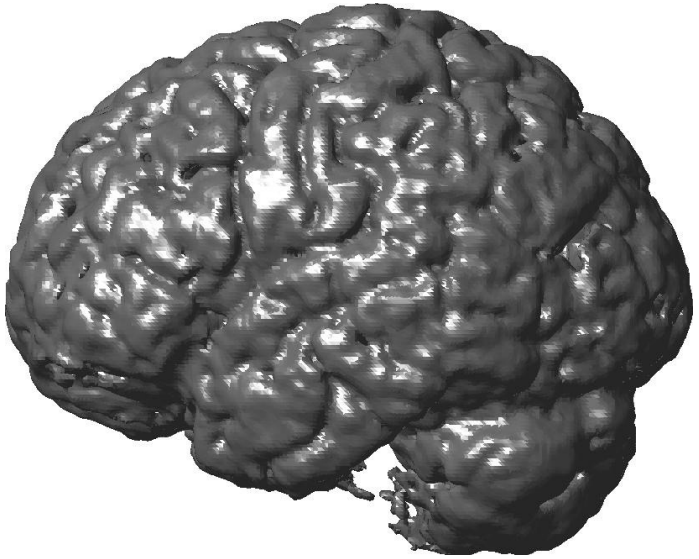

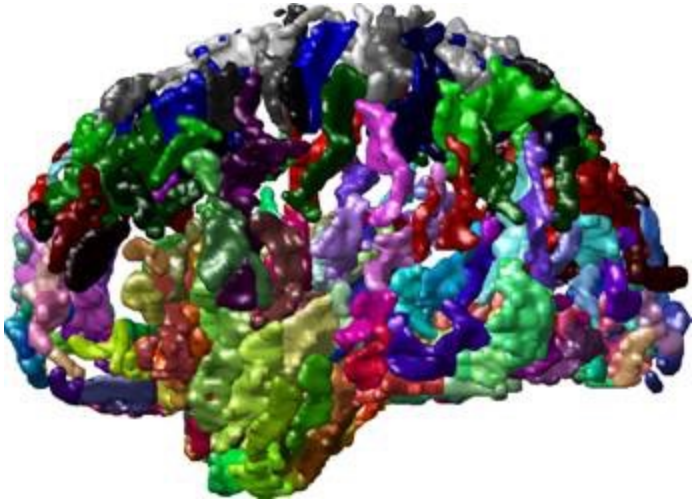

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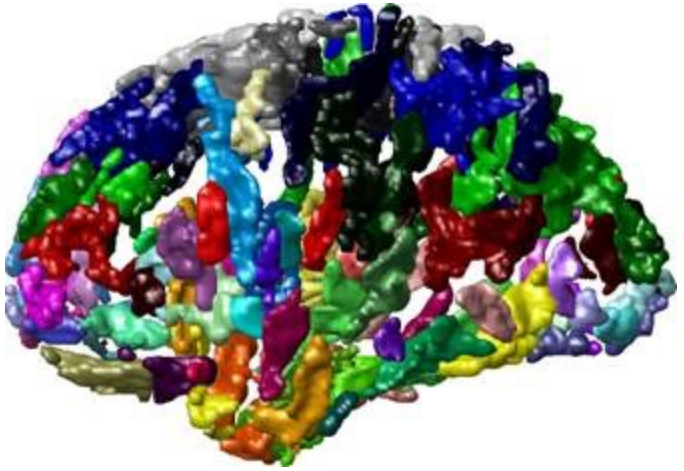


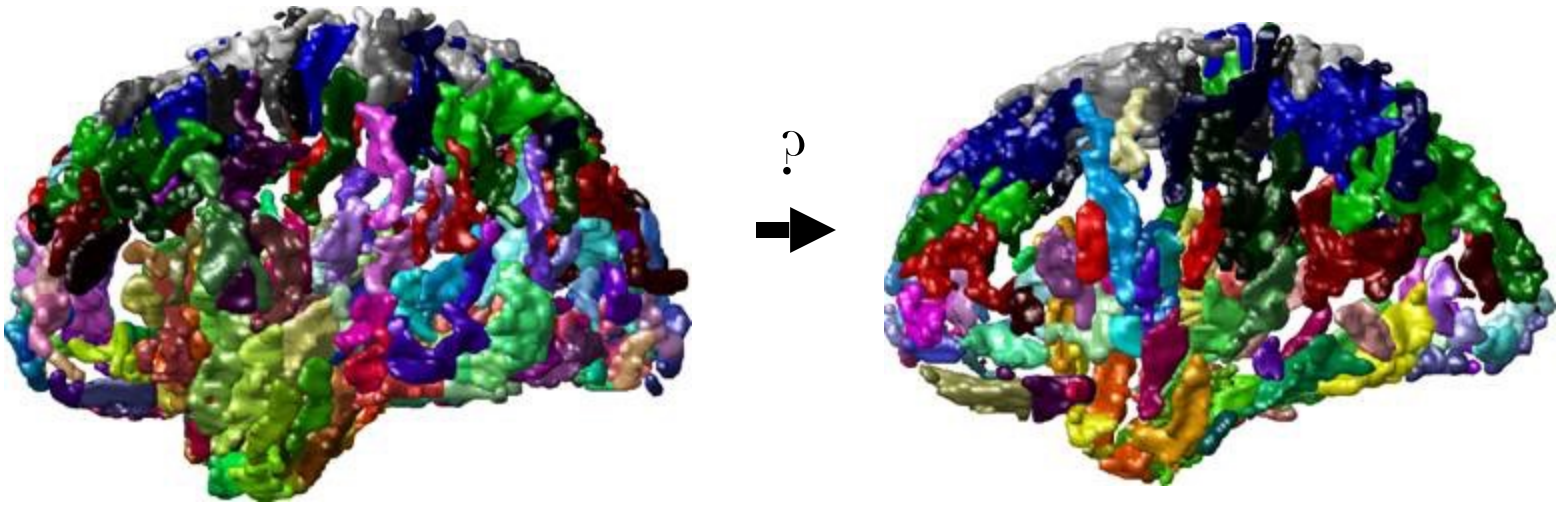
Match pieces

$$\text{Cost} = w_N N + w_V V + w_P P + w_O O$$

$$\begin{Bmatrix} N = \Delta|voxels| \\ V = \Delta|subvolumes| \\ P = \Delta position \\ 0 = (non)overlap \end{Bmatrix}$$

Atlas

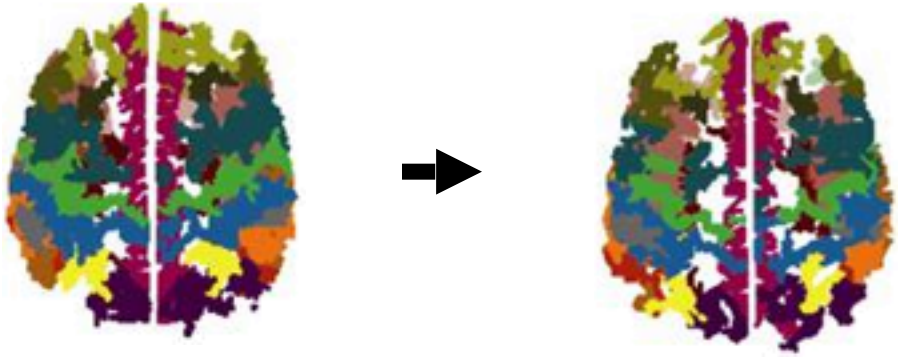
Subject



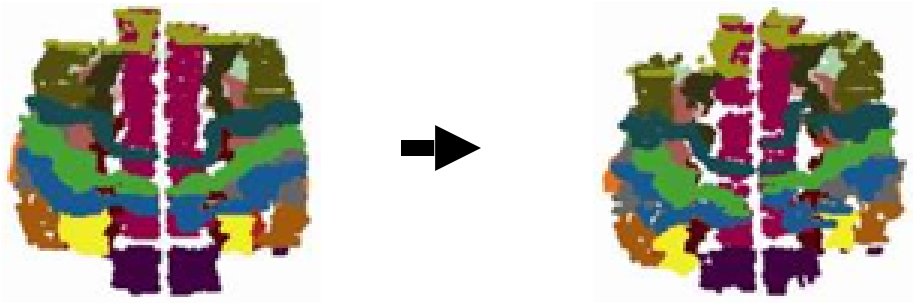
Match pieces

Atlas

Subject

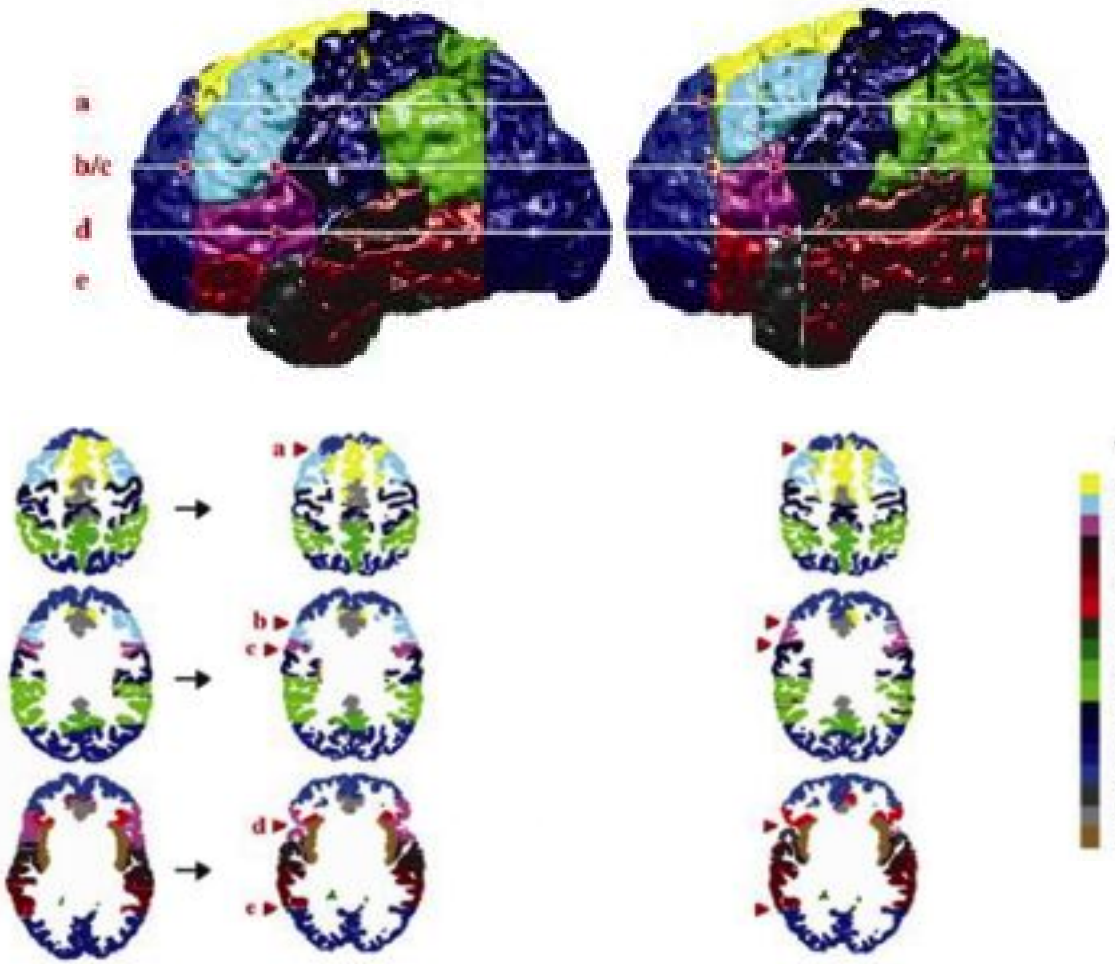


Transform labels

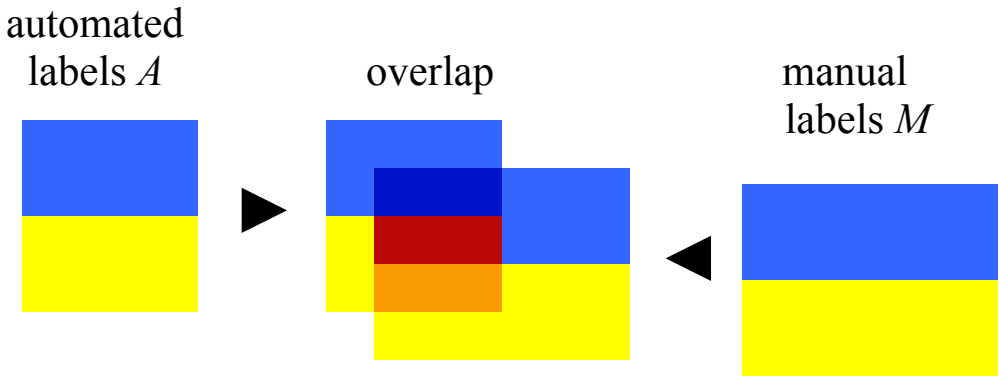


Warp labels

Atlas Mindboggle Subject



Evaluation



Label agreement metrics:

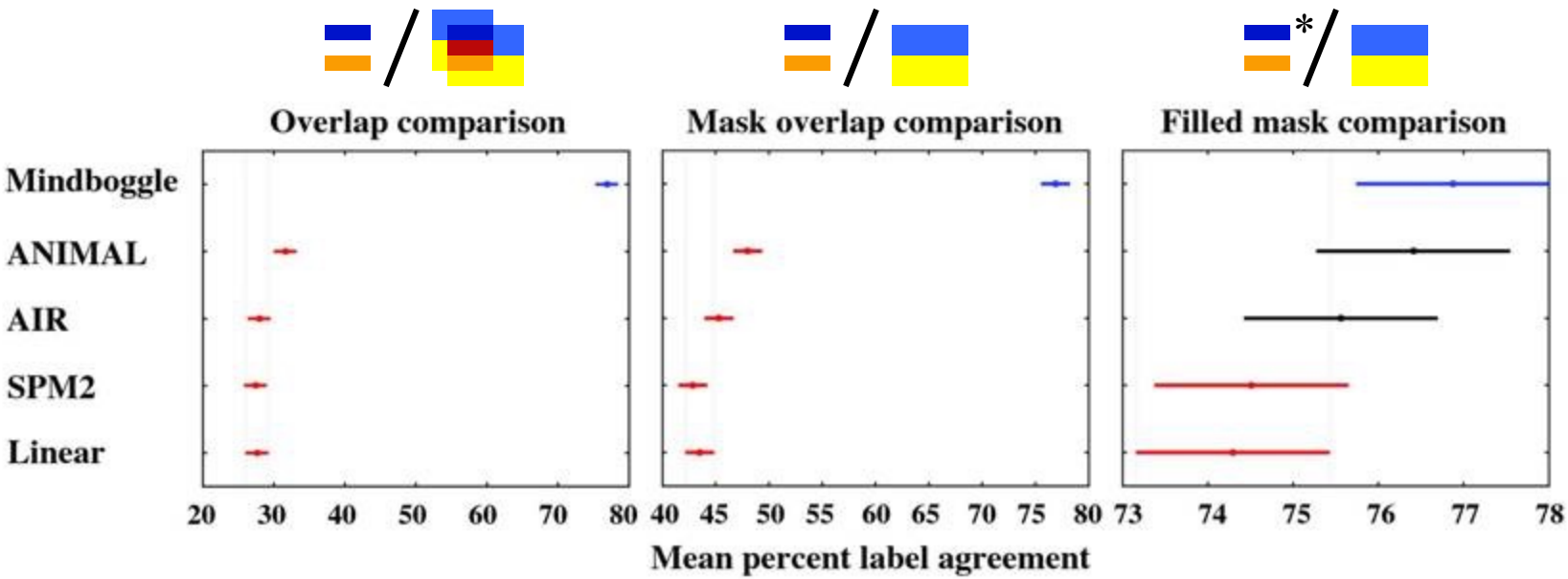
$$V_a = \frac{\text{intersection with the same label}}{V_c = \text{comparison volume}} = \frac{\blacksquare}{?}$$

intersection $= V_a /$ intersection of atlas and subject $= \blacksquare / \blacksquare = \frac{\sum|A_i \cap M_i|}{\sum|A \cap M_i|}$

overlap $= V_a /$ union of atlas and subject $= \blacksquare / \blacksquare = \frac{\sum|A_i \cap M_j|}{\sum|A_i \cup M_i|}$

mask overlap, filled mask overlap $= V_a /$ subject $= \blacksquare / \blacksquare = \frac{\sum|A_i \cap M_i|}{\sum|M_i|}$

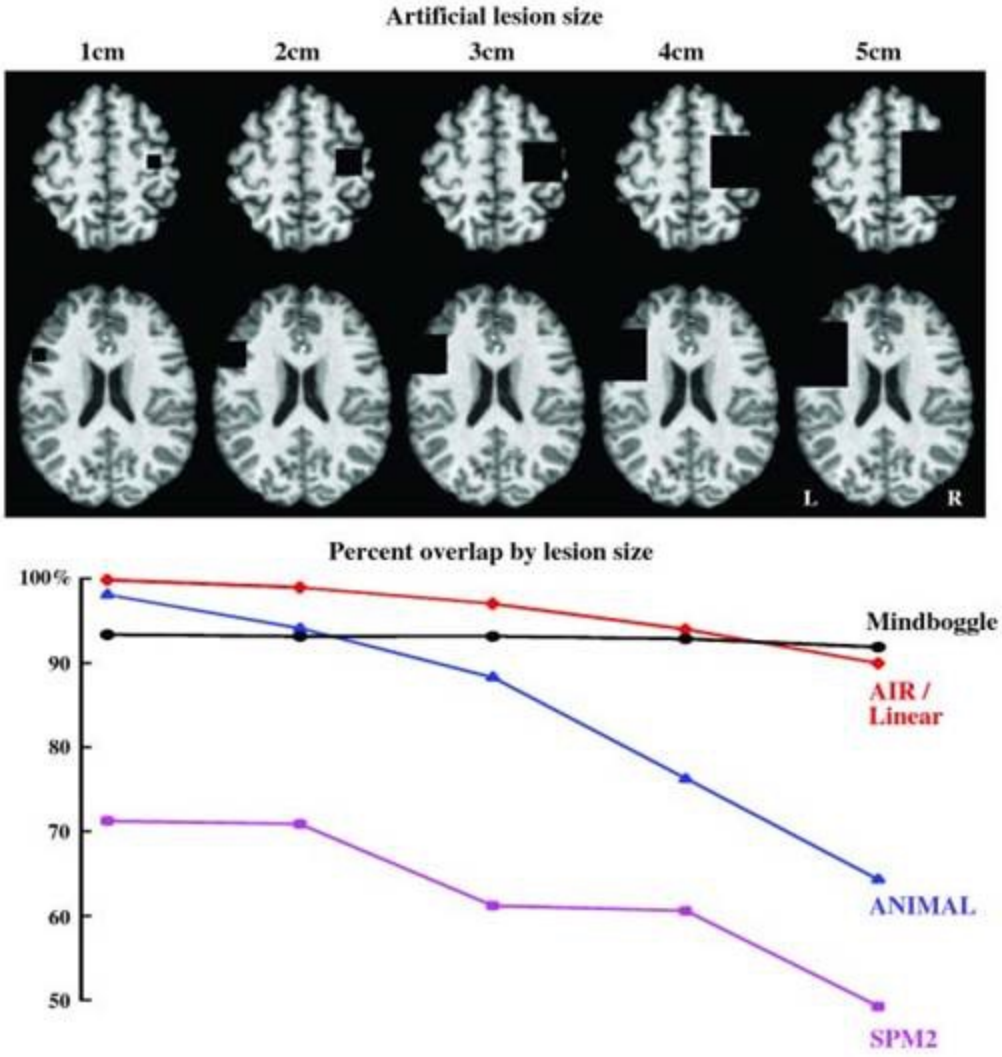
Evaluation



A one-way ANOVA was performed to test if the means are the same for the label agreements obtained by each of the methods.

A multiple comparison test was then performed to determine which pair of means are significantly different (95% confidence interval, based on the Studentized range distribution).

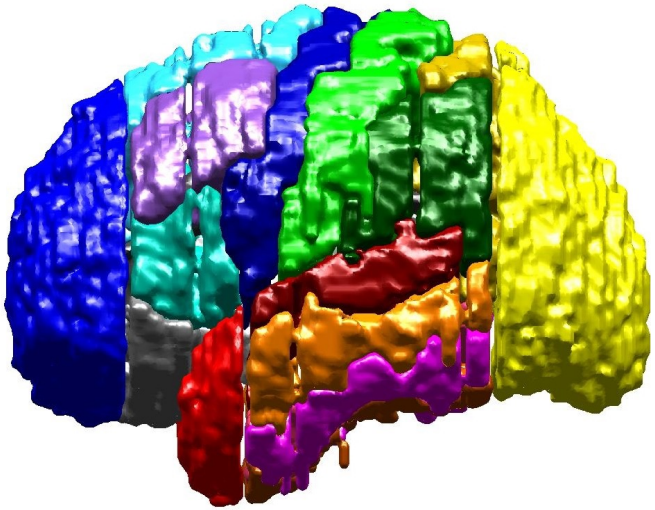
Evaluation

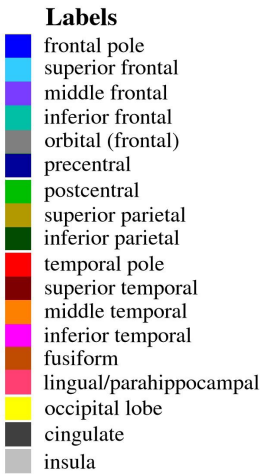


An atlas was used to label an artificially lesioned version of itself.

Single atlas

Atlas





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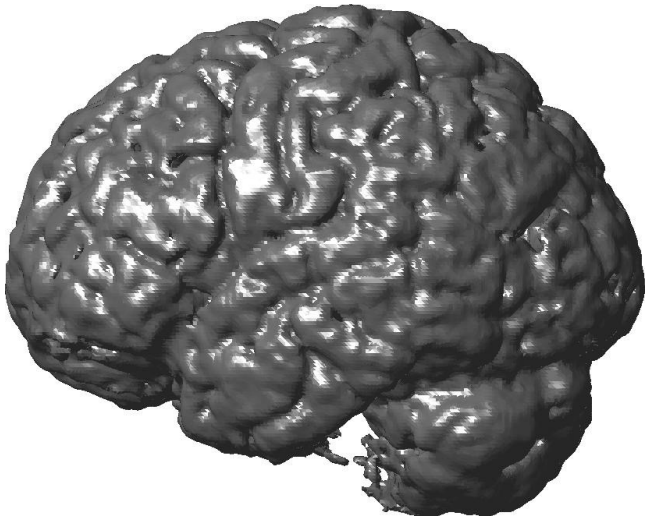
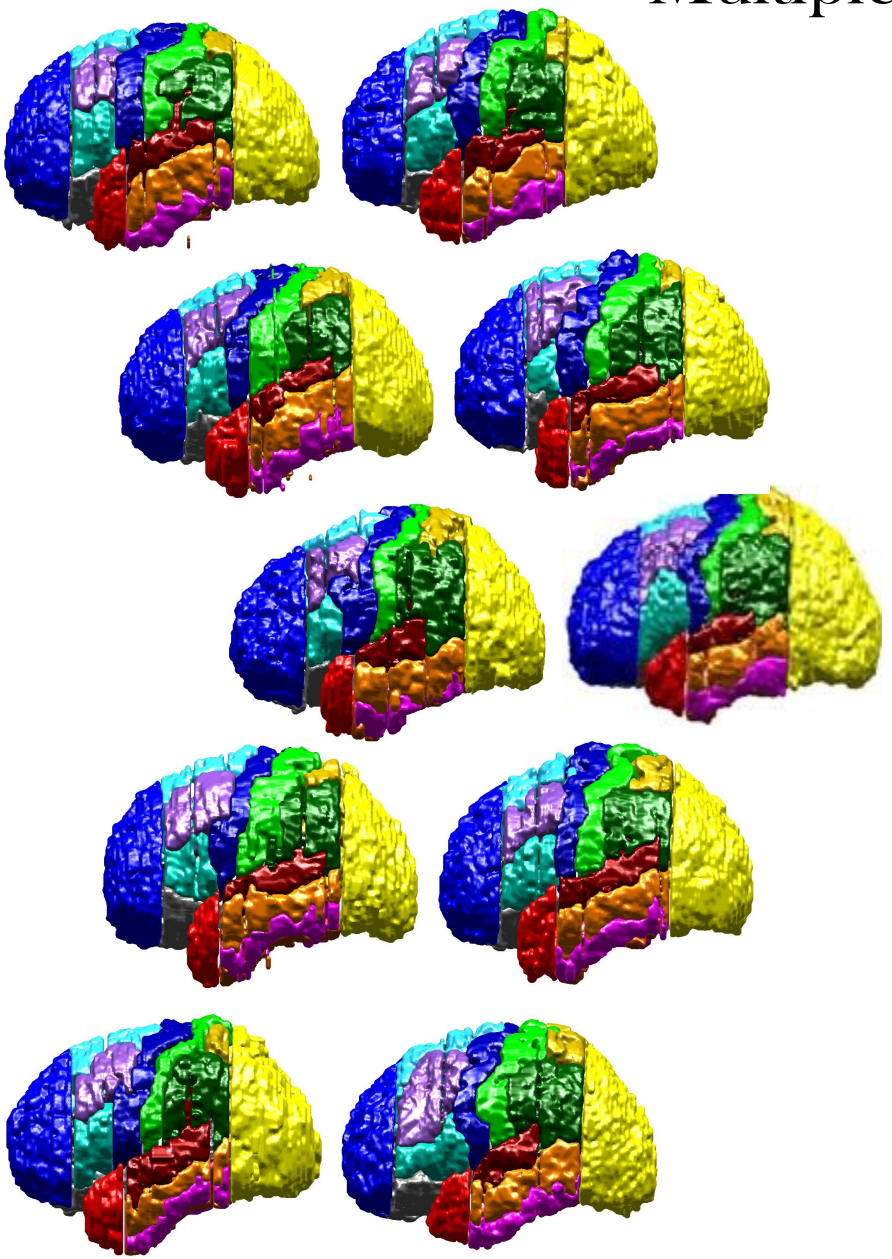
Subject



Multiple atlases



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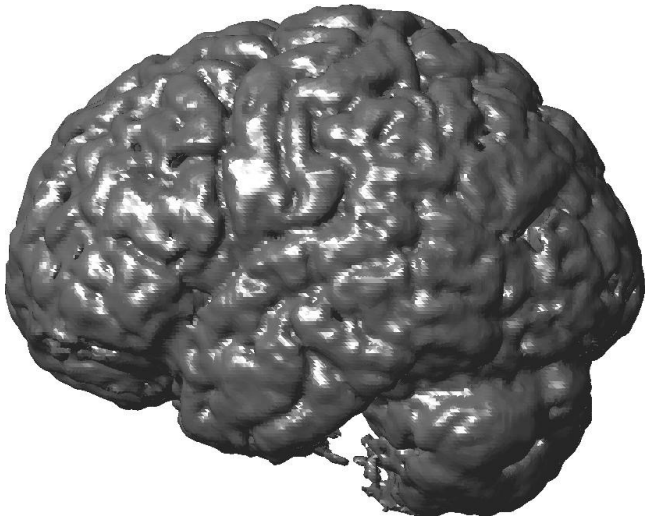
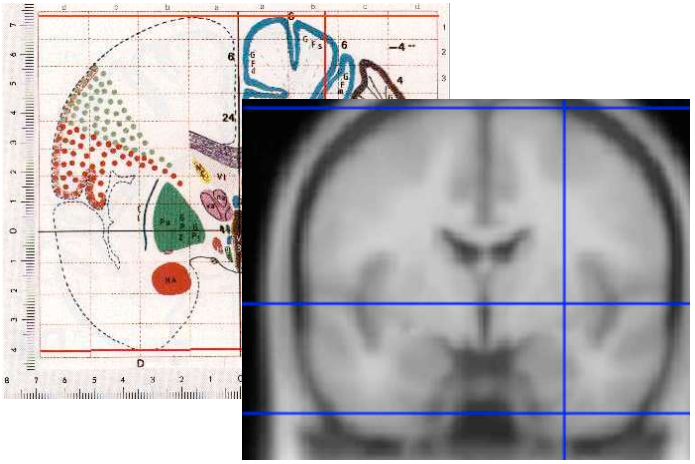
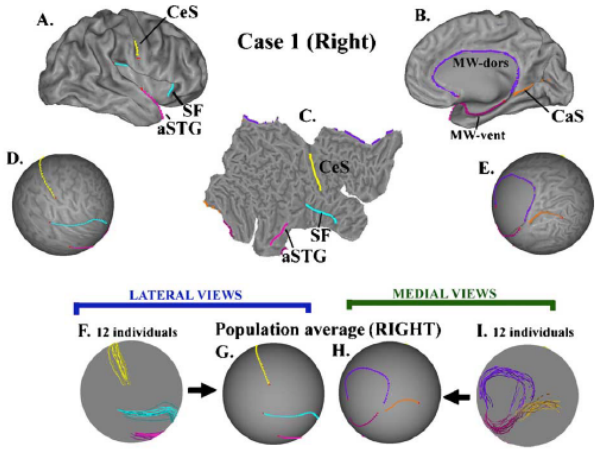
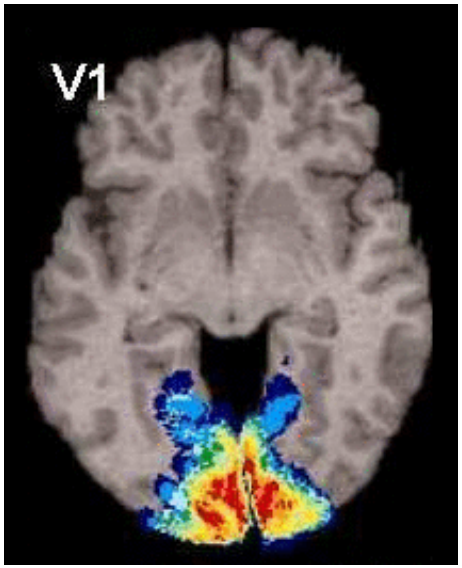
Subject

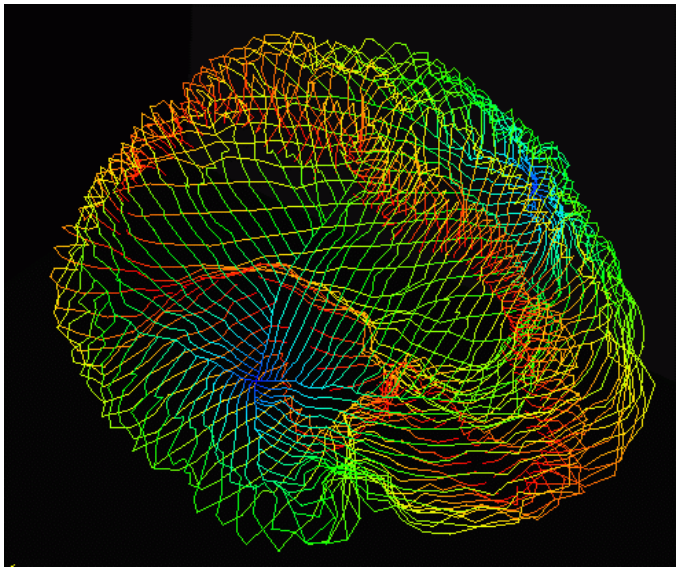


Brain atlases
Multiple





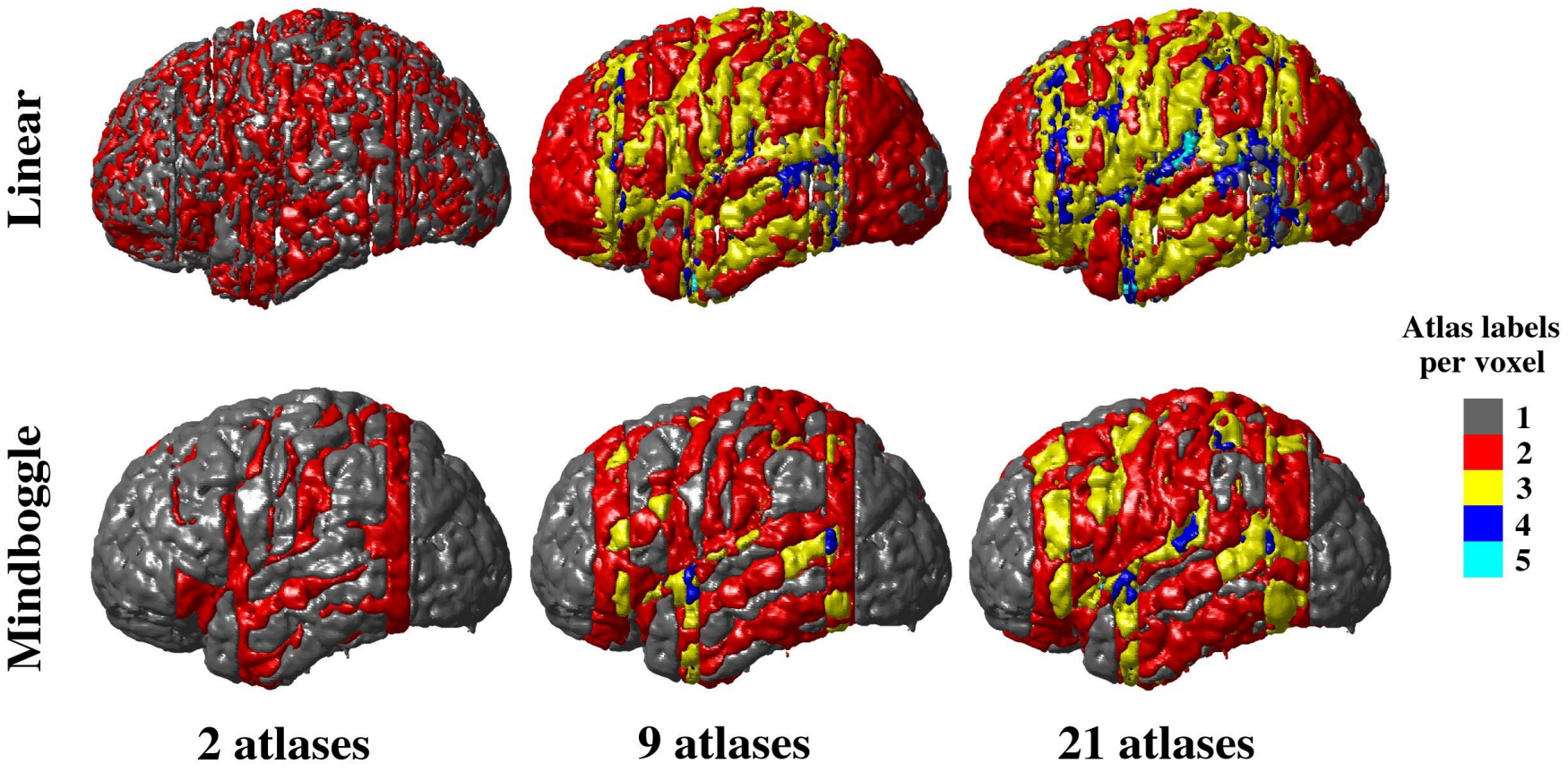




MNI Atlas, van Essen surface-based atlas, LONI deformable atlas , Zilles' probability map, (clockwise from upper left)

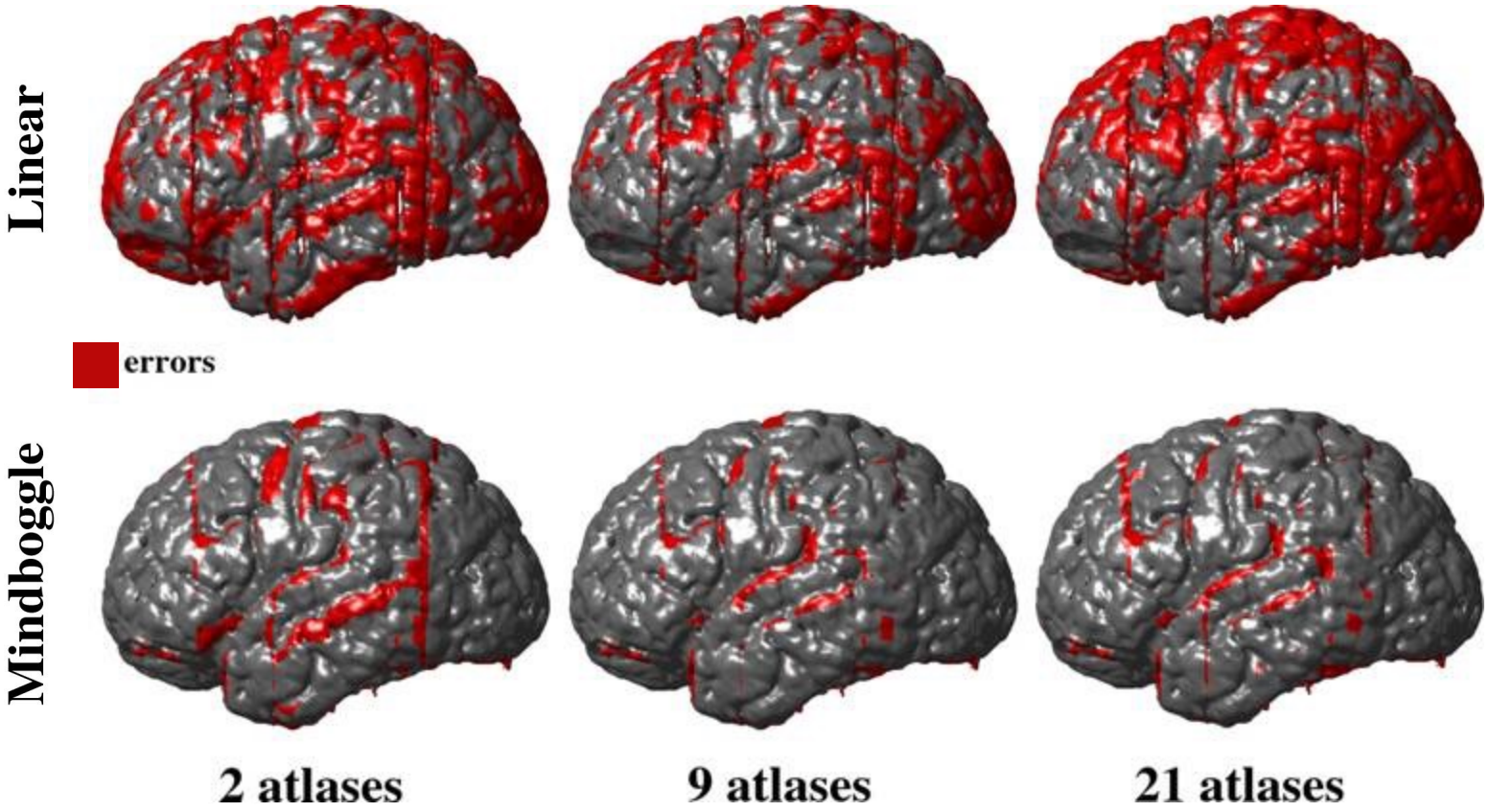
Multiple atlases

Number of labels per voxel



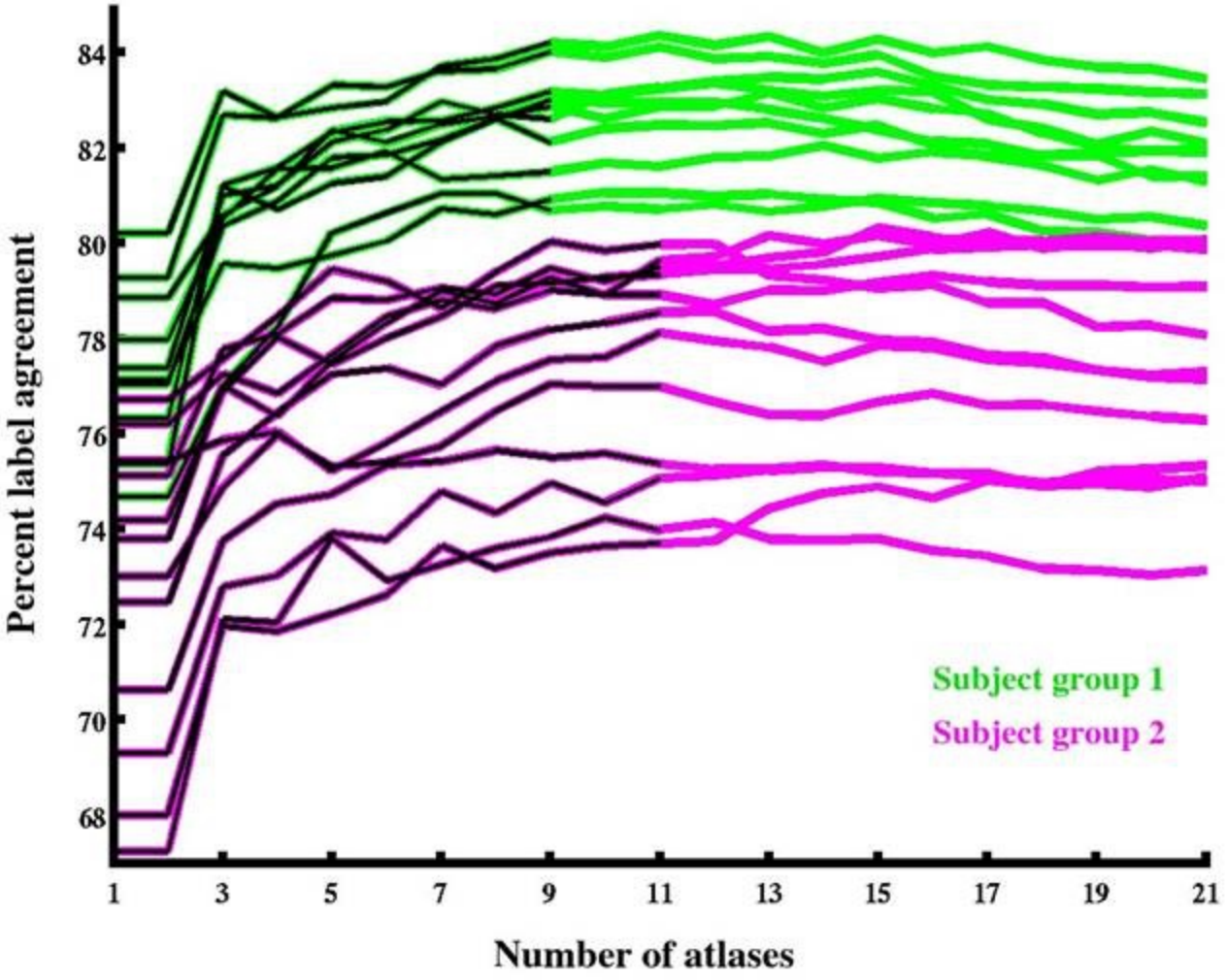
Evaluation

Errors: automated labels ≠ manual labels



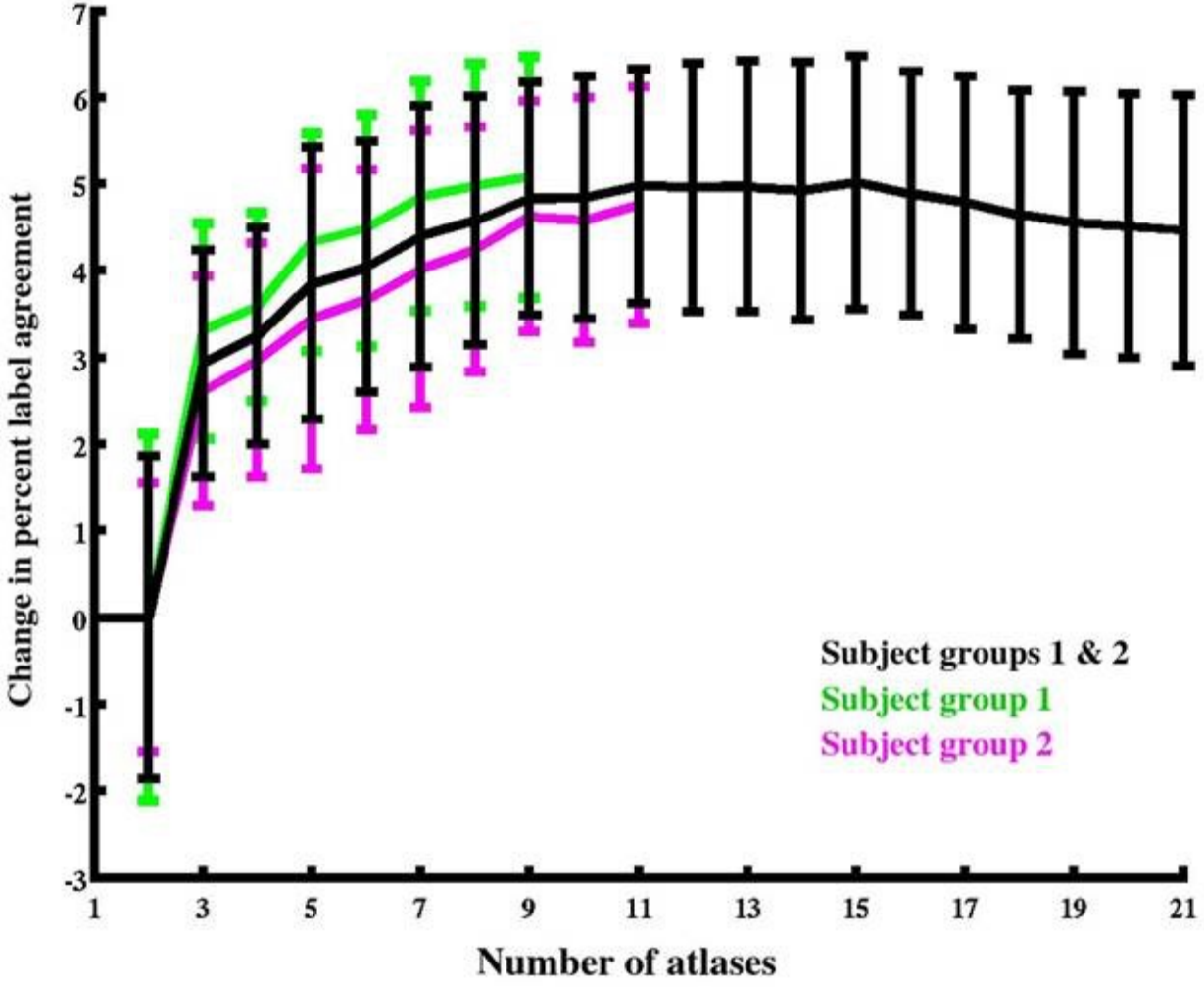
Evaluation

Percent label agreement
by subject, number of atlases



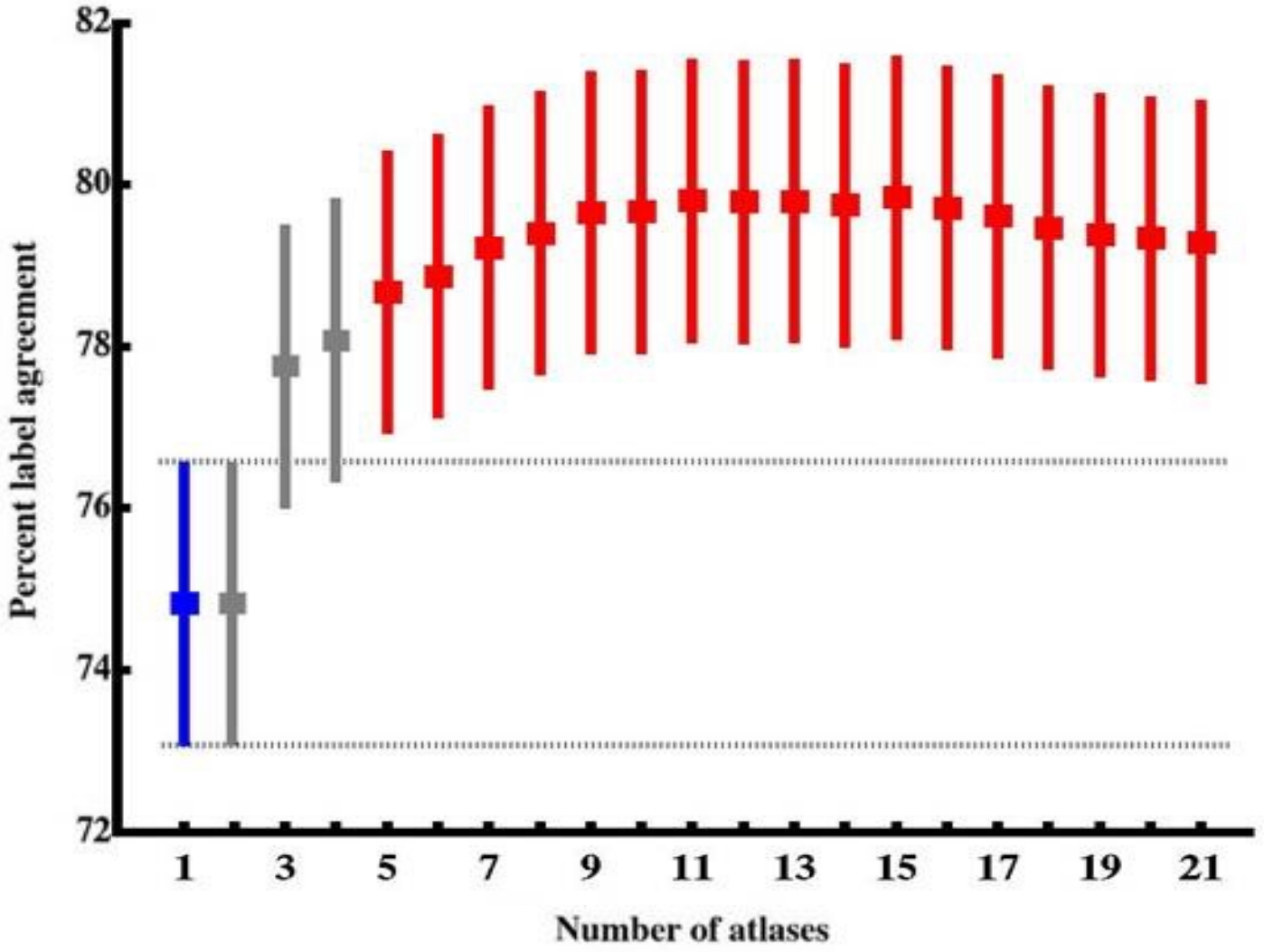
Evaluation

Change in percent label agreement
by subject group, number of atlases



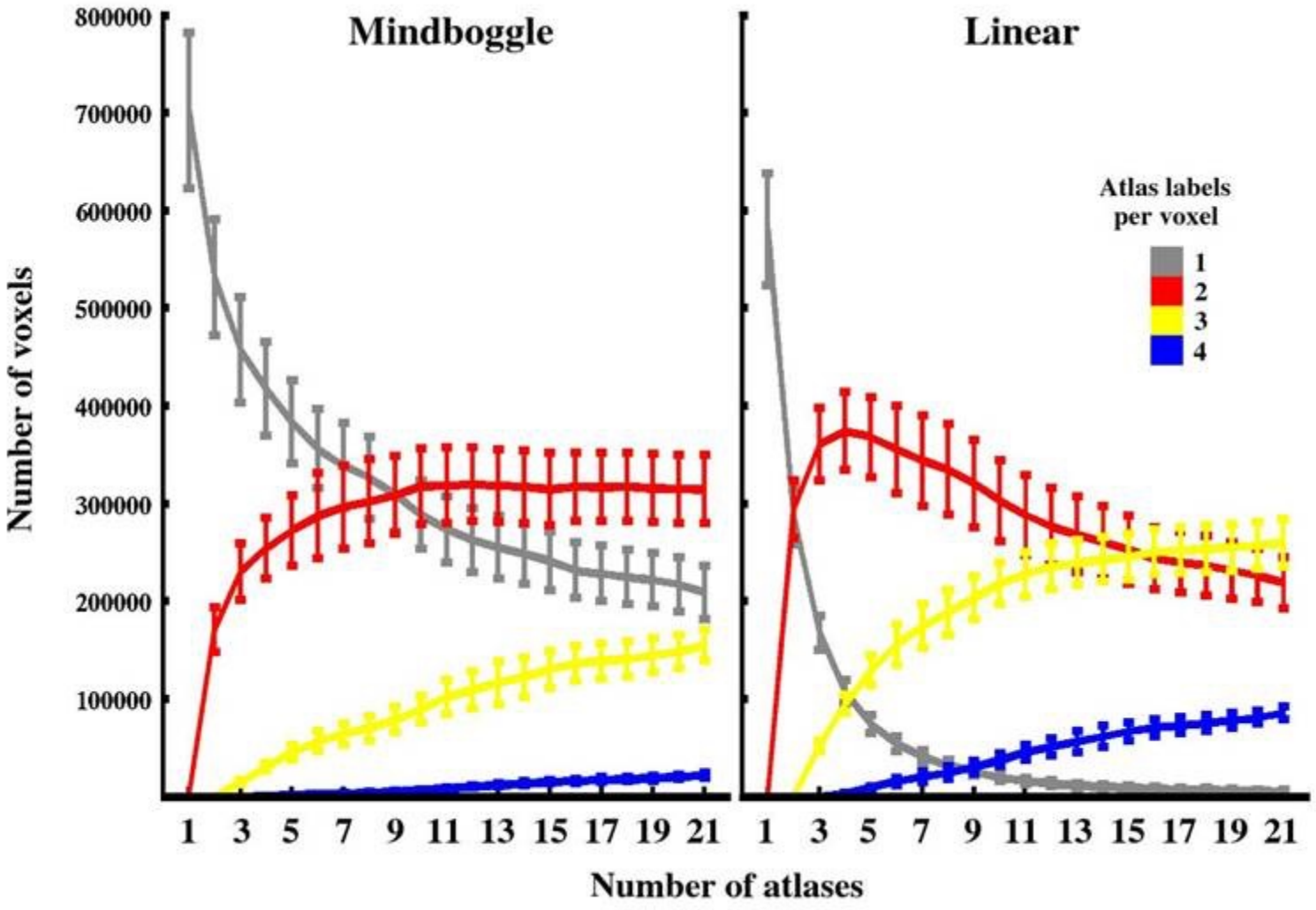
Evaluation

ANOVA, multiple comparison



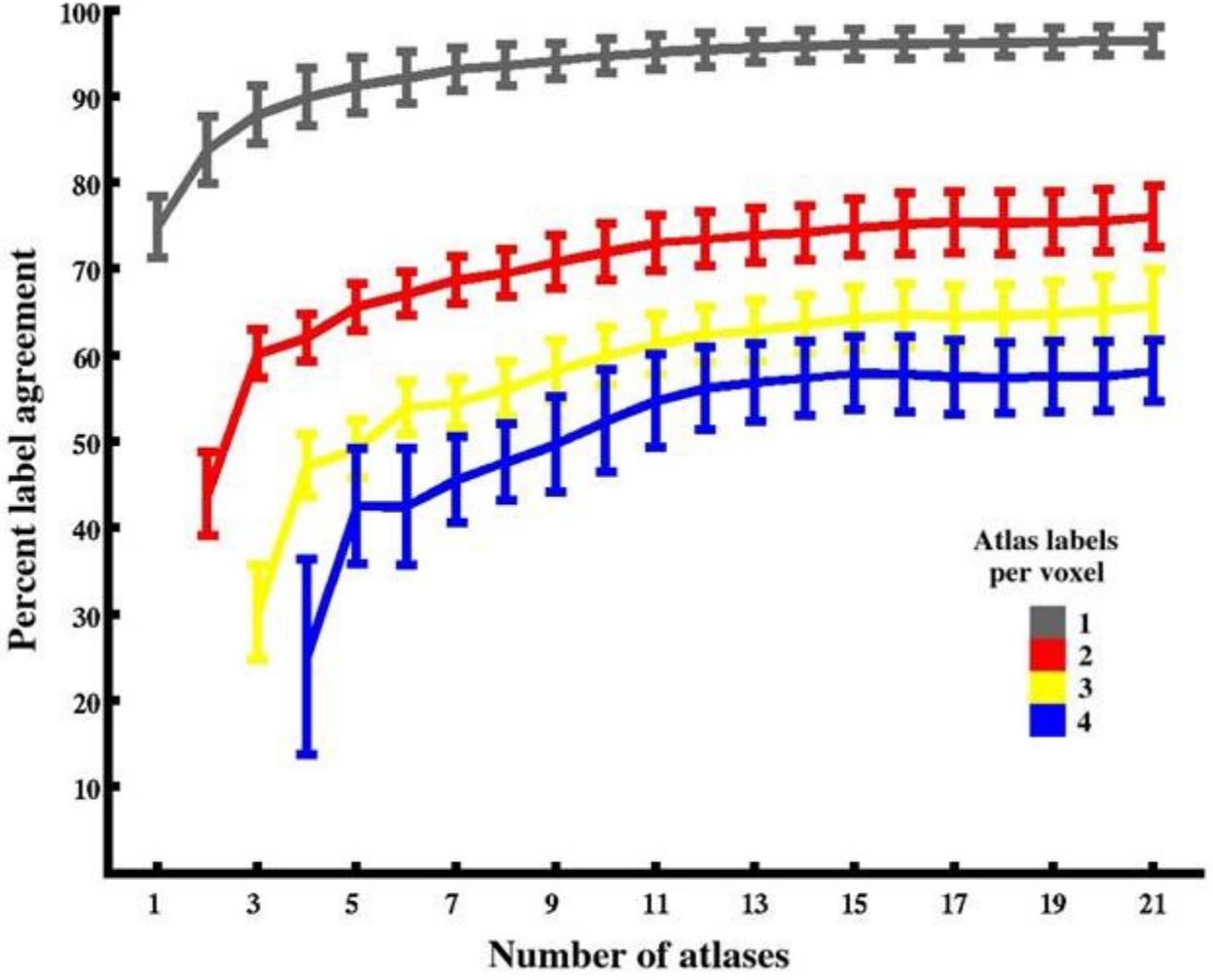
Multiple atlases

Number of labels per voxel: voxel counts



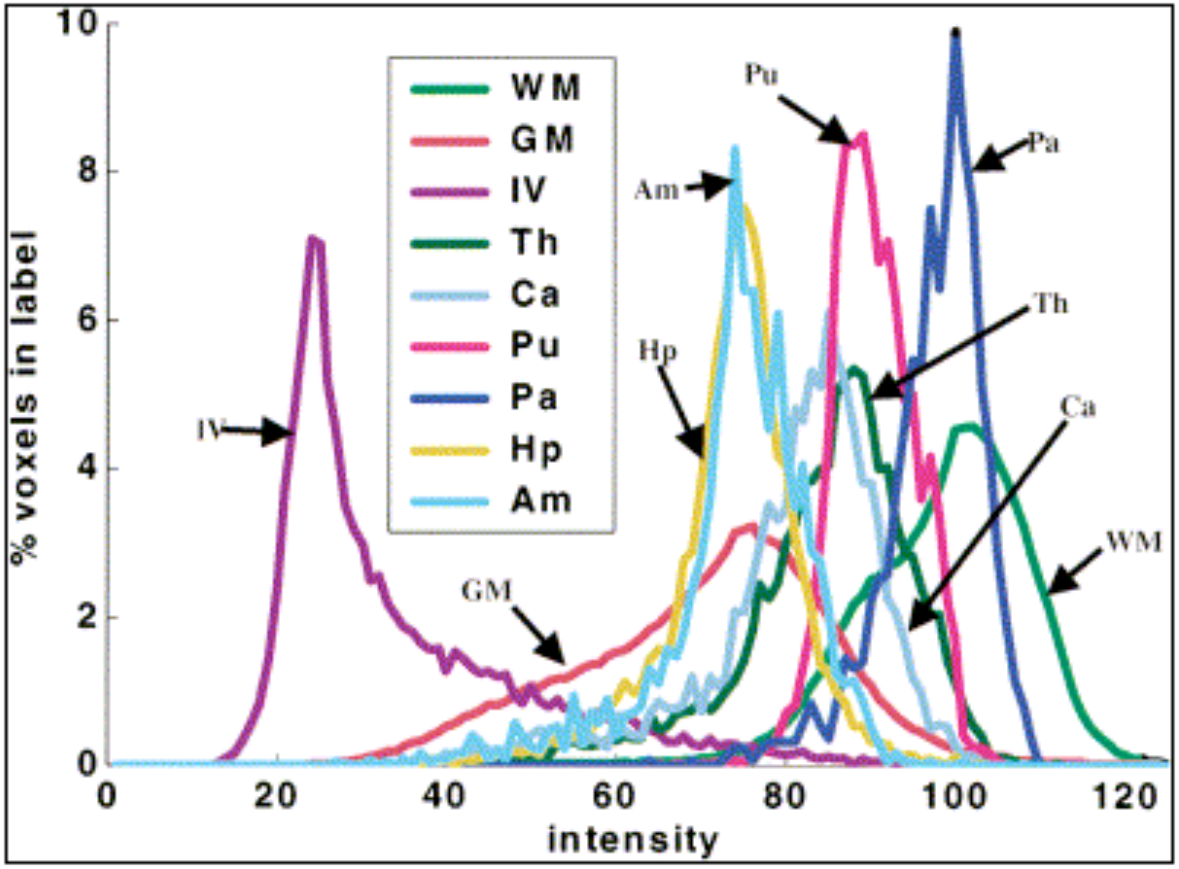
Evaluation

Percent label agreement
by number of labels per voxel, number of atlases



Labeling in the future

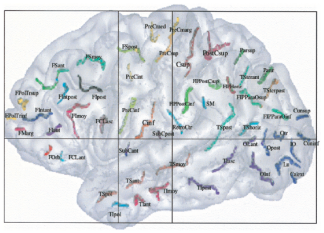
Multispectral imaging

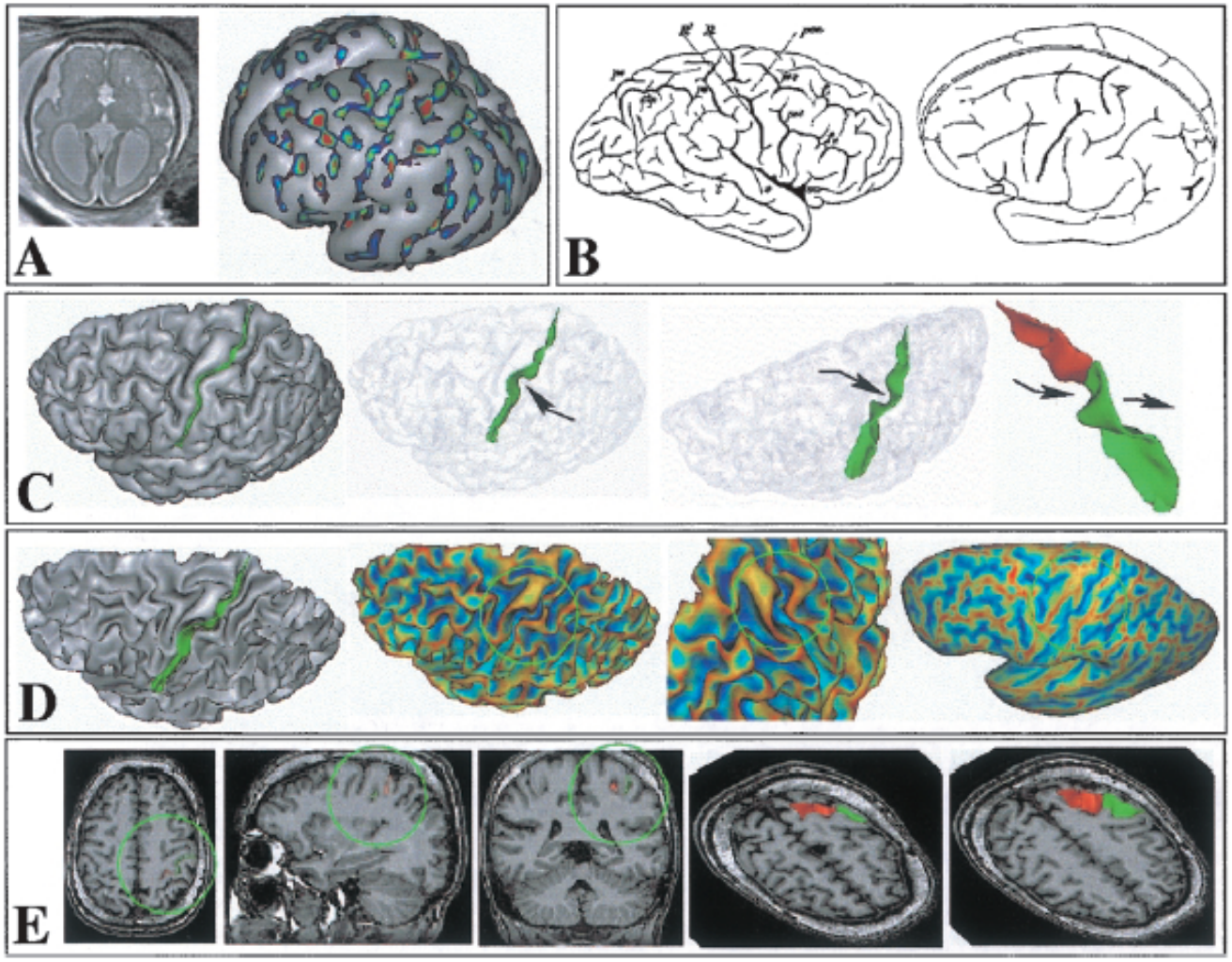


Fischl et.al. Difficulties with multispectral data for parcellation

Labeling in the future

Morphogenesis

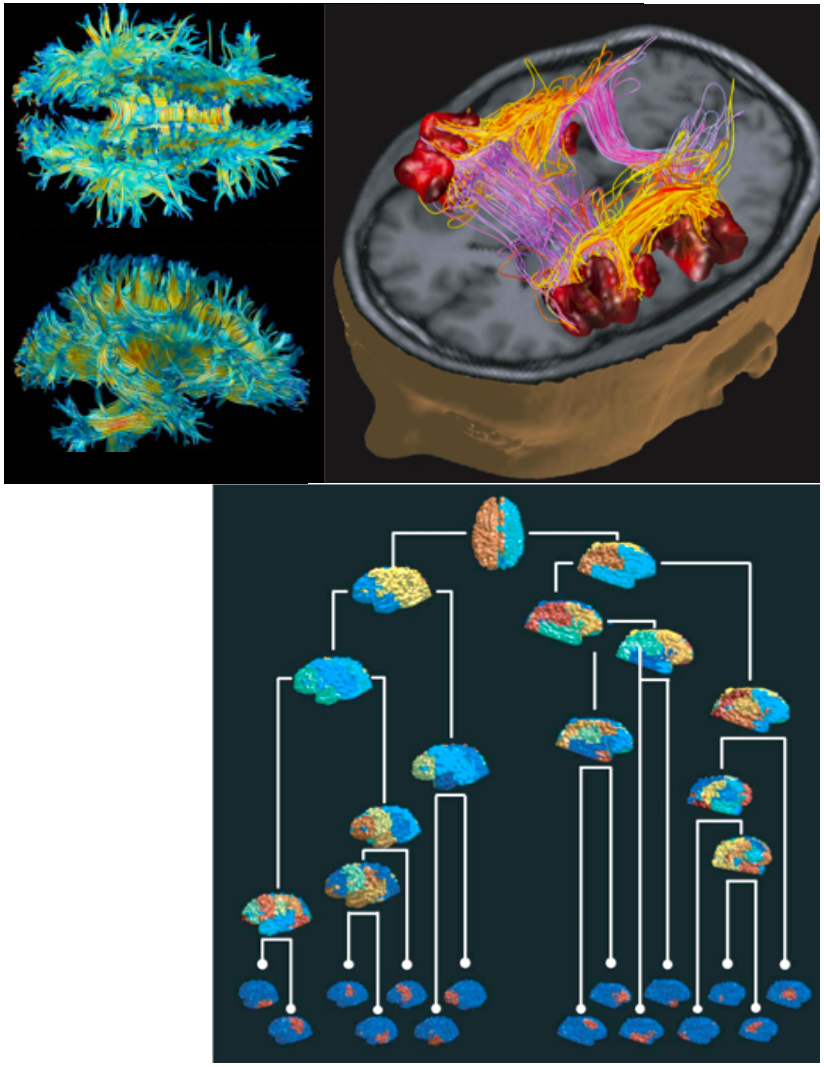




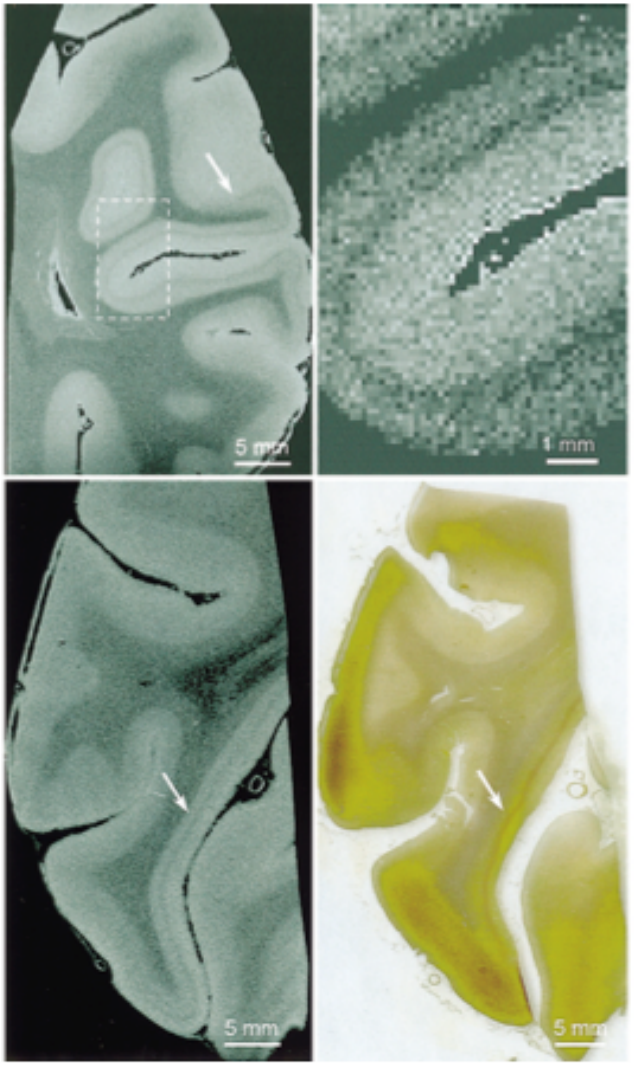
Regis, et.al. Morphological variability and sulcal roots

Labeling in the future

Functional tractography and architectonics



Hagmann (2005) DWI, cortical connectivity tree



Barbier, et.al. (2002)

Mindboggle future directions

Atlas labels	New boundary definitions reflecting: Functional and physiological data Tractography (diffusion-weighted imaging) Microstructural data Multispectral data
Image processing	New methods for extracting sulcus pieces, labeling
Matching structures	Different distance metrics Statistical attributes of sulci Multiscale and ordered comparisons
Combining labels	Alternatives to majority voting rule (weighted matches) Aggregate matching costs to construct a probabilistic atlas
Evaluating results	Treat regions differently with regard to size, variability, etc.
Software distribution	Join the NiPy project
Some applied research	Pattern matching and prediction Morphogenesis Information visualization

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