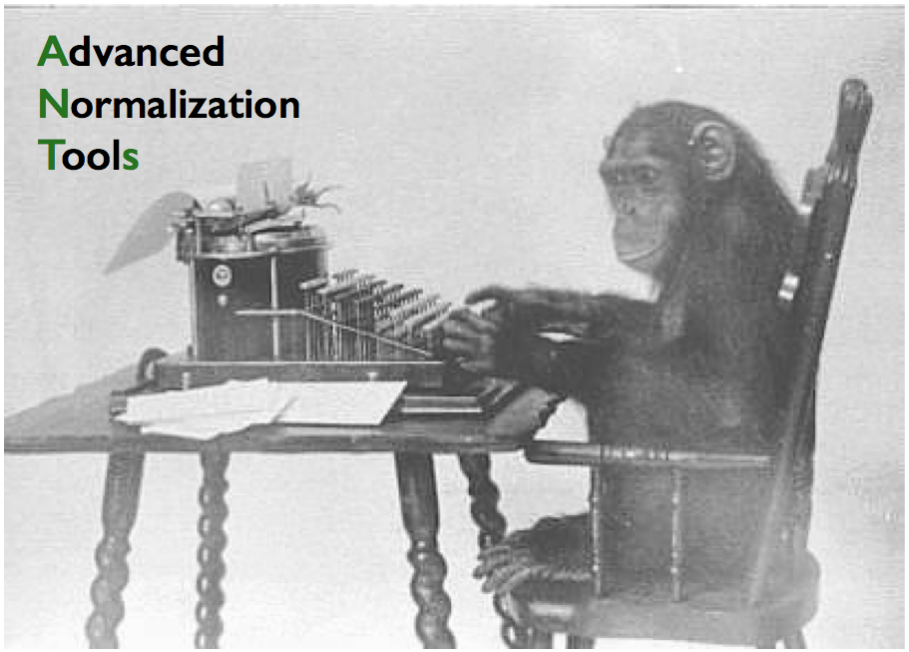
“Dr. Tustison (UVA) presentation”

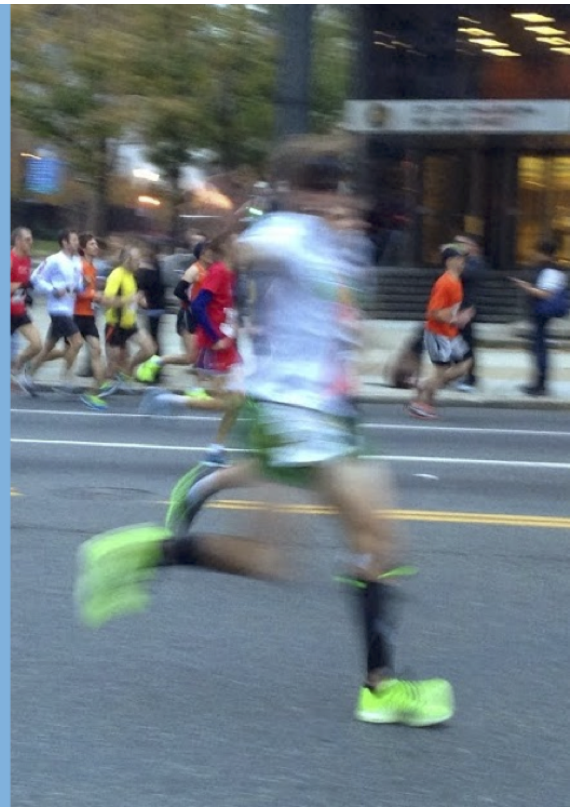
Nick Tustison

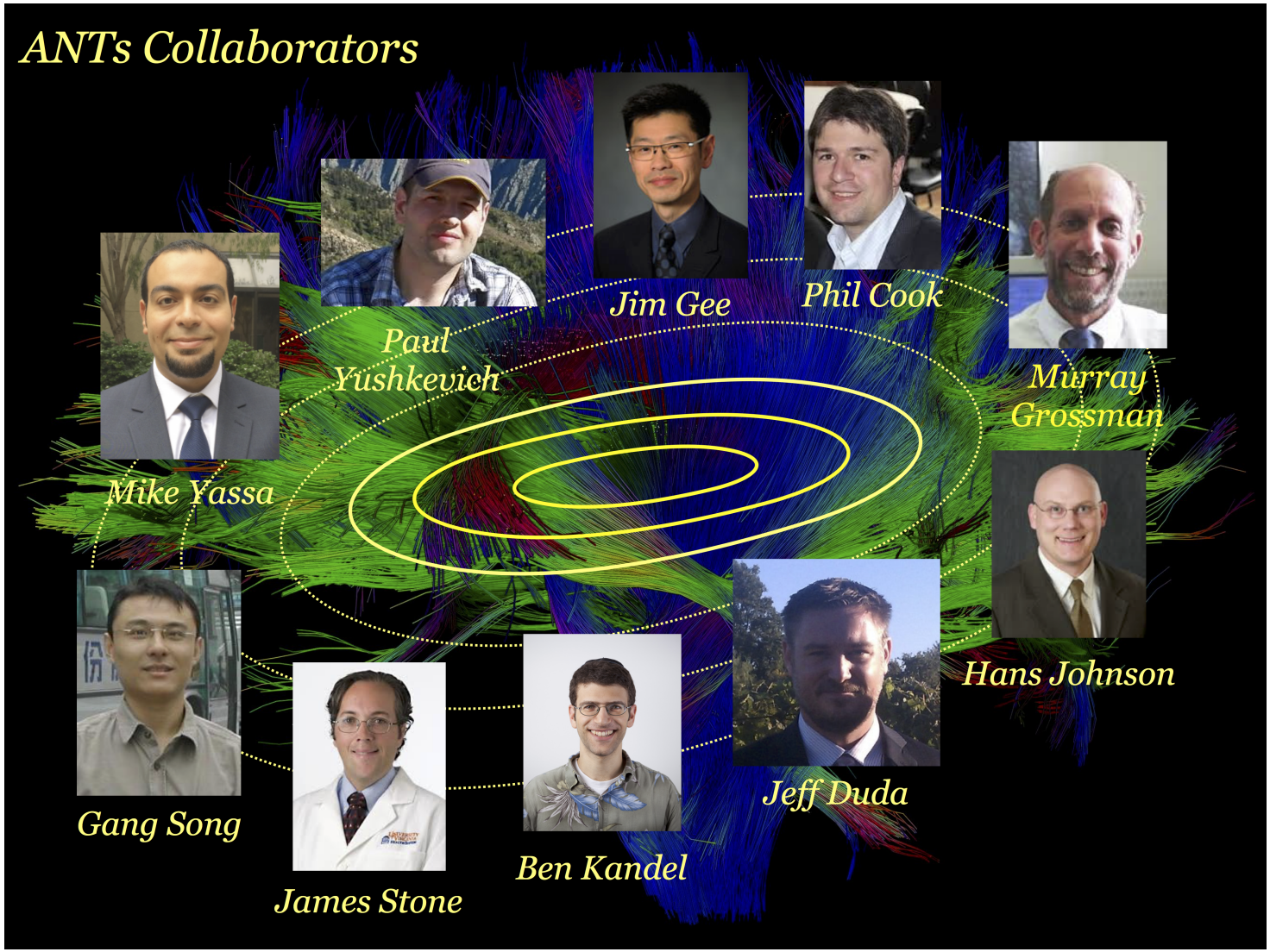
University of Virginia



Developers and collaborators

Founders: Brian and Nick





+ neurodebian, slicer, brainsfit, nipype, itk and more . . .

Why would you care?

Software for medical image analysis

- FSL
- SPM
- FreeSurfer
- MIPAV
- AFNI
- Slicer, Elastix, SimpleITK, ANTs $\longleftrightarrow$ Insight Toolkit
- Many more at idoimaging.com

International competitions

- Klein 2009: MRI brain registration
- EMPIRE 2010: CT lung registration
- Multi-Atlas Label Challenge 2012: MRI brain registration and segmentation
- SATA Challenge 2013: MRI cardiac and canine hind leg registration
- BRATS 2013: Multi-modal MRI brain segmentation
- STACOM 2014 MoCo Challenge: MRI cardiac motion estimation

Major ANTs utilities

Donoho?

"Papers are just advertisements for the science."

Beyond original SyN

frontiers in NEUROINFORMATICS

ORIGINAL RESEARCH ARTICLE
published: 28 April 2014
doi: 10.3389/fninf.2014.00044

The Insight ToolKit image registration framework

Brian B. Avants[1]*, Nicholas J. Tustison[2], Michael Stauffer[1], Gang Song[1], Baohua Wu[1] and James C. Gee[1]

[1] *Penn Image Computing and Science Laboratory, Department of Radiology, University of Pennsylvania, Philadelphia, PA, USA*
[2] *Department of Radiology and Medical Imaging, University of Virginia, Charlottesville, VA, USA*

frontiers in NEUROINFORMATICS

METHODS ARTICLE
published: 23 December 2013
doi: 10.3389/fninf.2013.00039

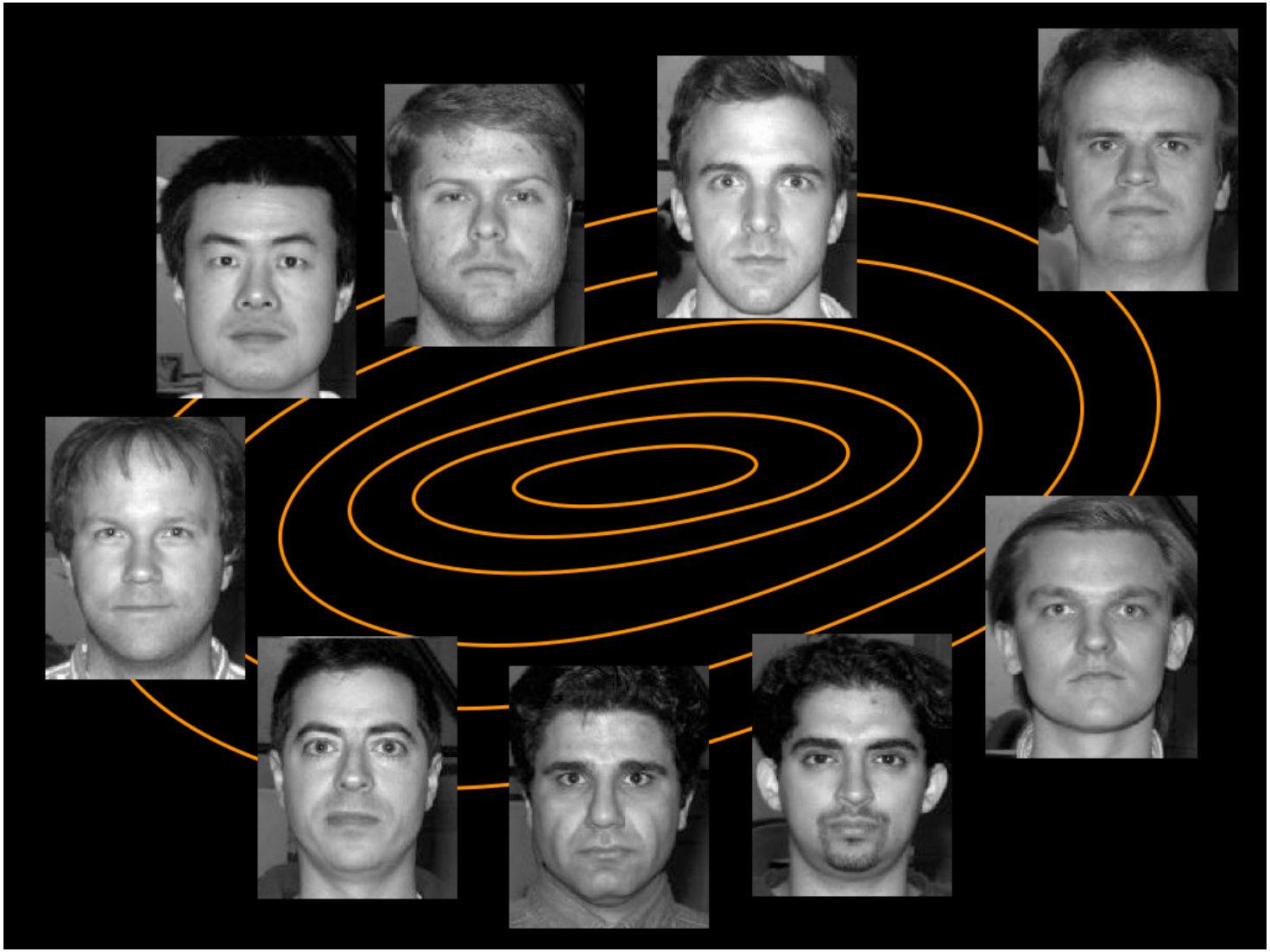
Explicit B-spline regularization in diffeomorphic image registration

Nicholas J. Tustison[1]* and Brian B. Avants[2]

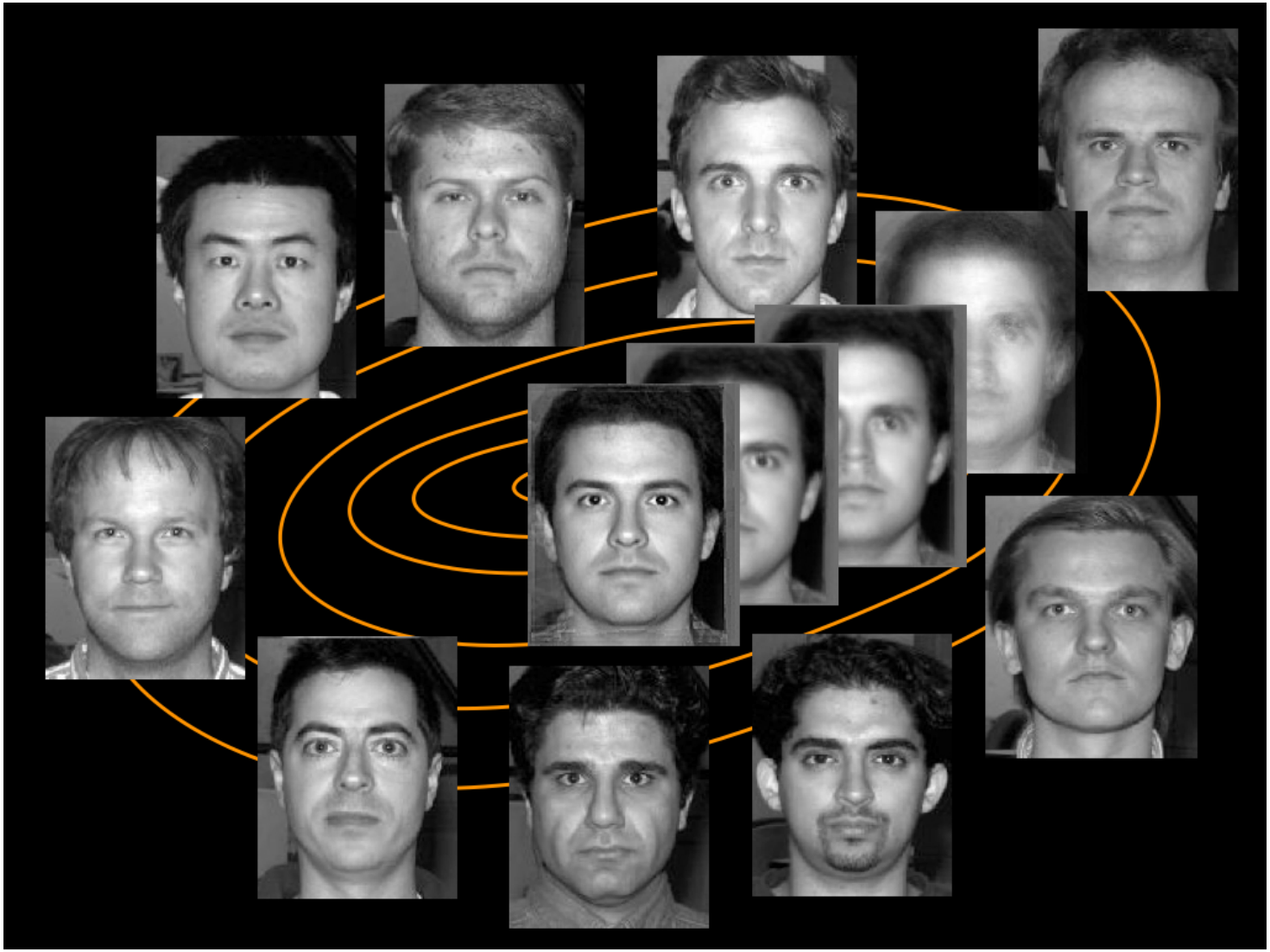
antsRegistration

```
$ antsRegistration --help

COMMAND:
     antsRegistration
          This program is a user-level registration applicatio
          ITKv4-only classes. The user can specify any number
          consists of a transform; an image metric; and iterat
          smoothing sigmas for each level.Note that dimensiona
          output, convergence, shrink-factors and smoothing-si
          mandatory.

OPTIONS:
     --version
          Get Version Information.

     -d, --dimensionality 2/3
```

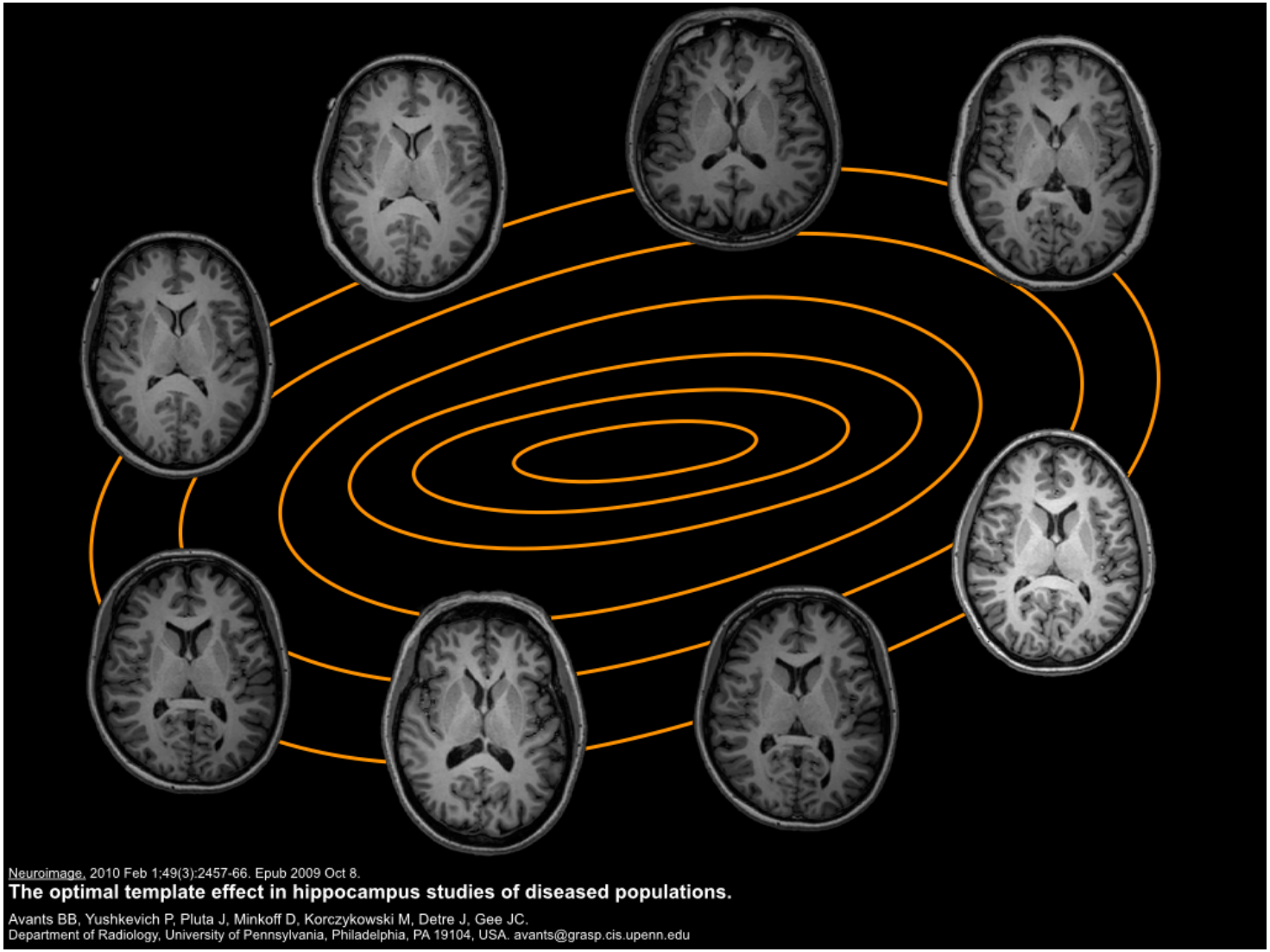
Template building: creating the average Joe



"Attractiveness" $\rightarrow$ mental processing?

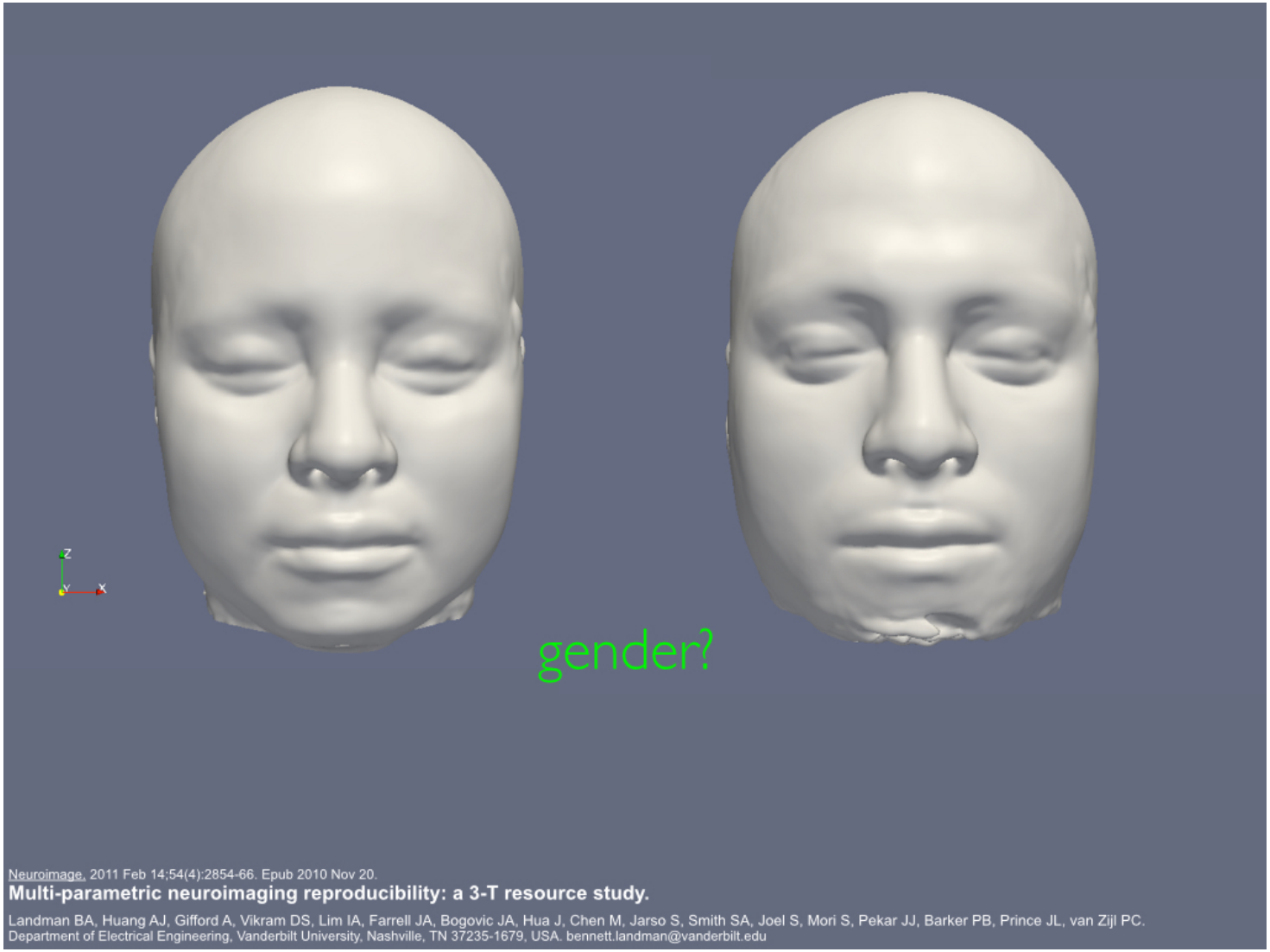


What about brains?



Templates facilitate computation

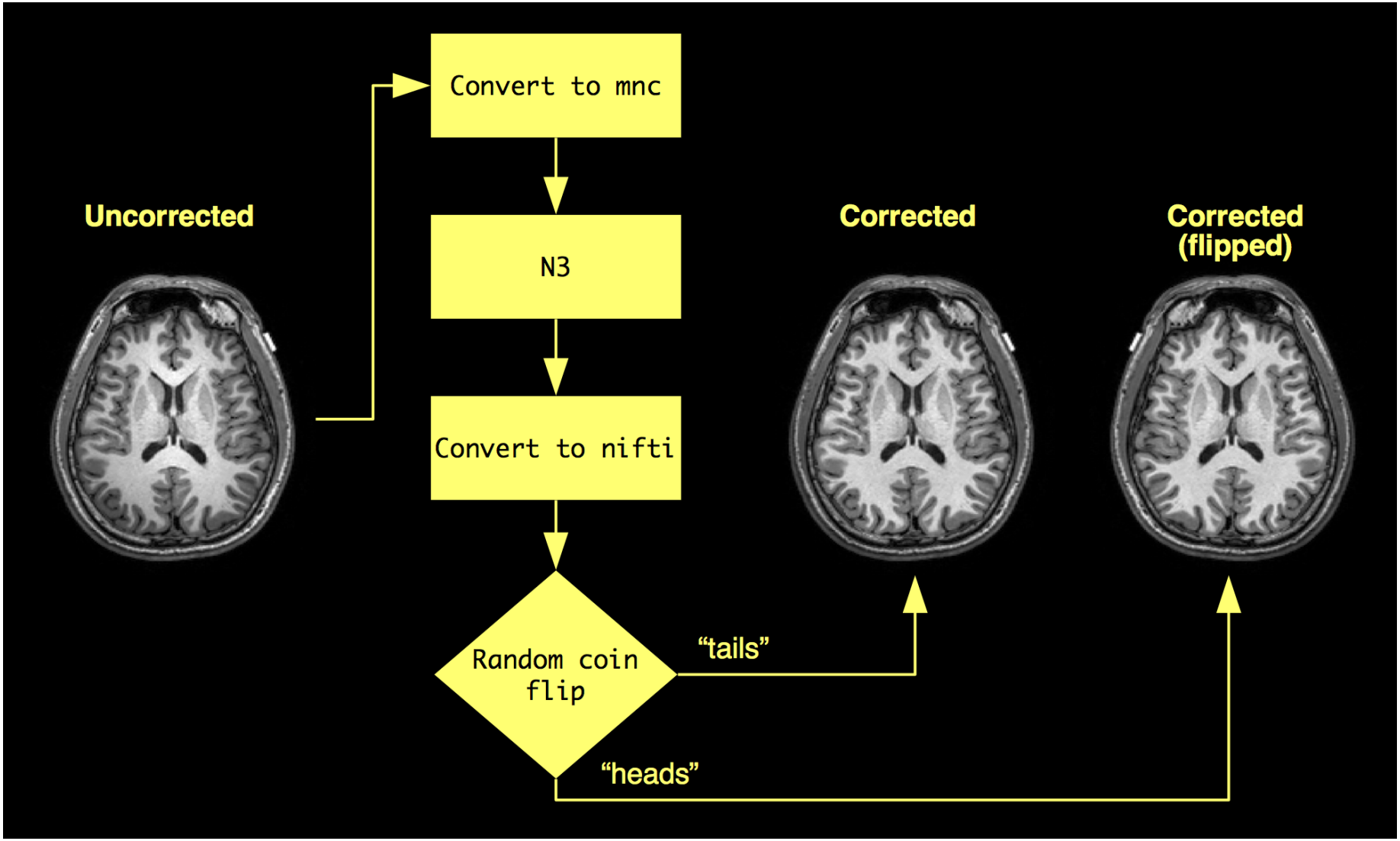
Gender discernibility?



Nonparametric nonuniform intensity normalization (N3)

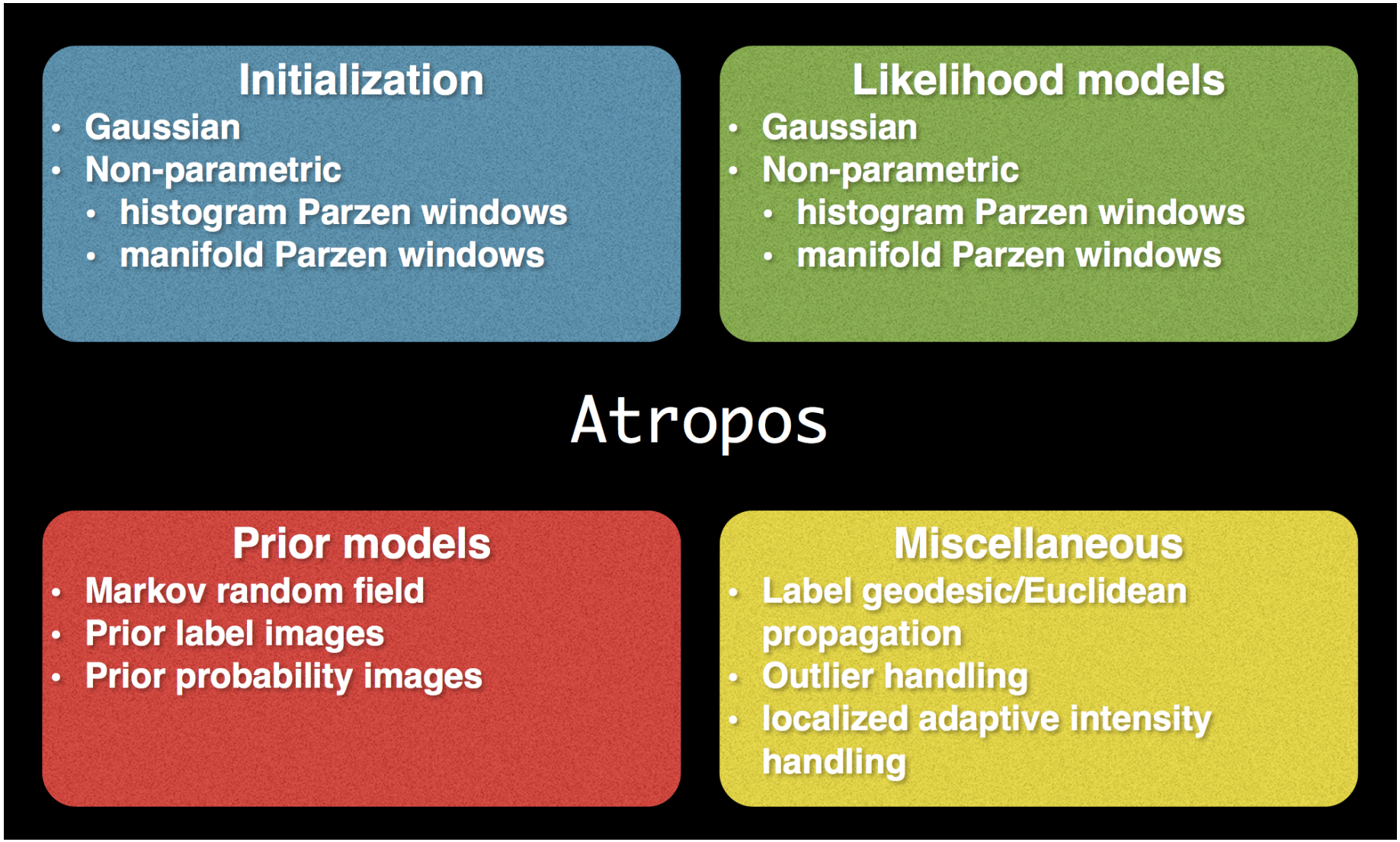
- Developed at the Montreal Neurological Institute (John Sled, 1998)
- Part of the standard preprocessing protocol in large scale projects such as ADNI
- The traditional de facto standard in MRI bias correction
  - good performance
  - *public availability*
- Public availability — set of perl scripts coordinating various C++ programs
- "*Let's incorporate N3 into ANTs!*"

N3 adoption issues

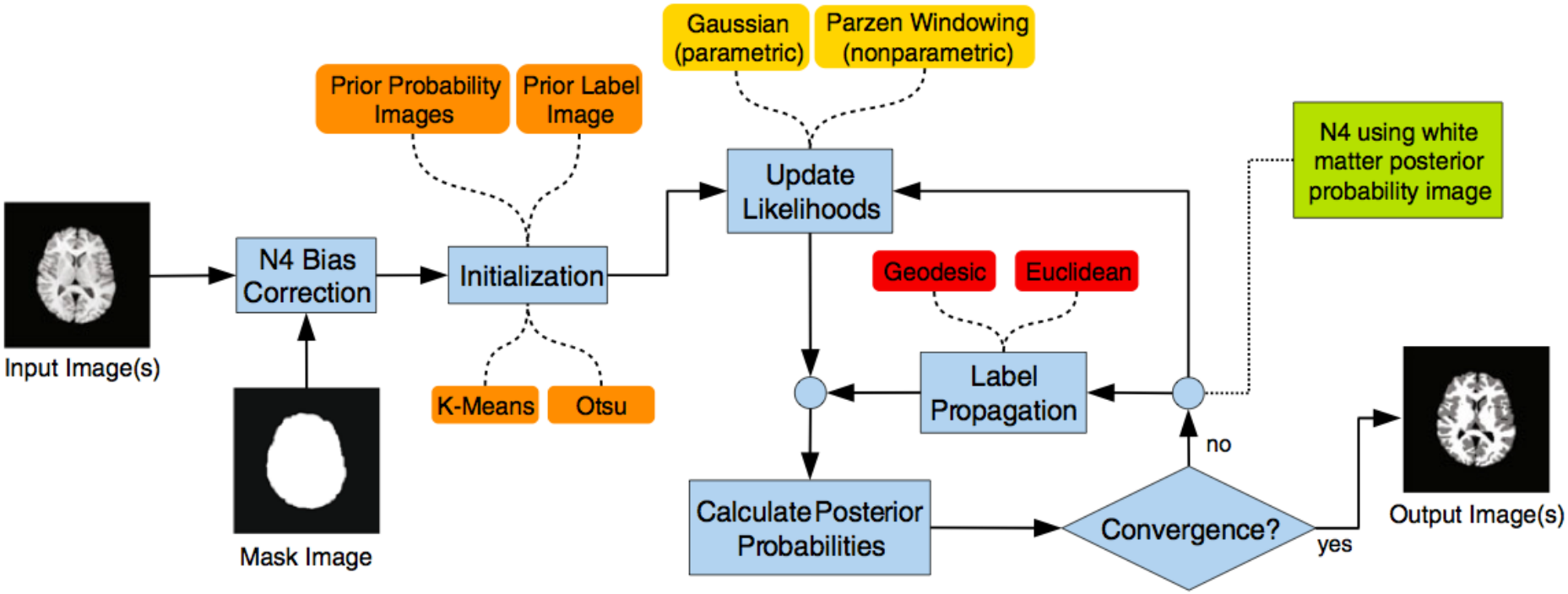


Atropos: flexible code base

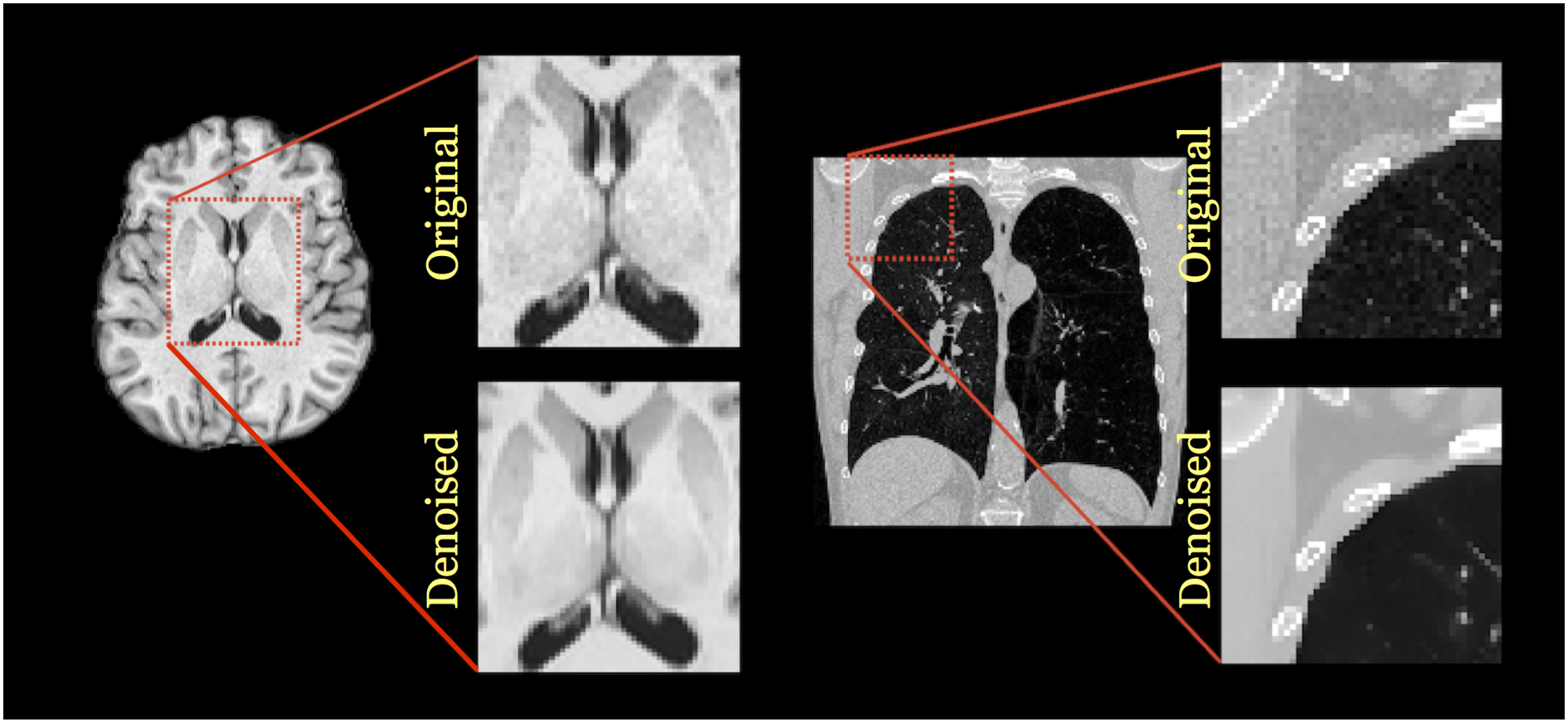
"20+ years of development. *Show me the code!*"



Atropos + N4 → antsAtroposN4.sh

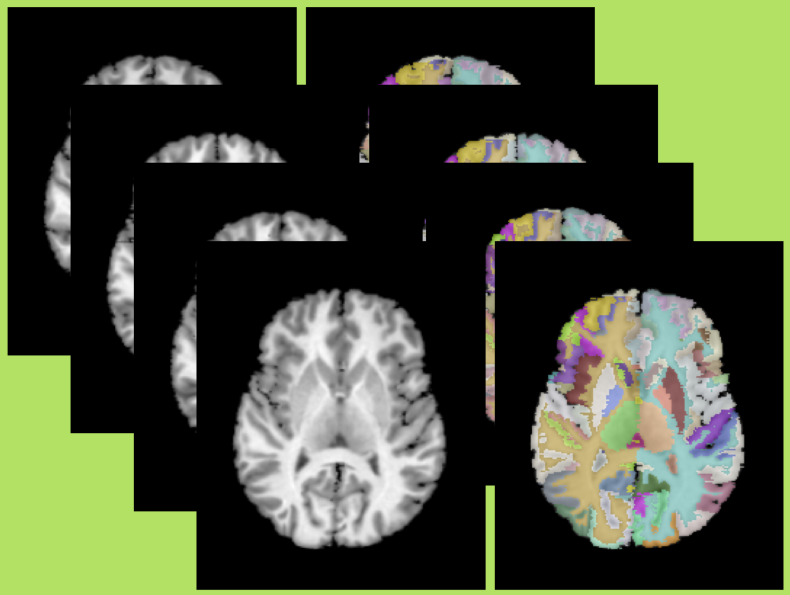


DenoiseImage — contribution from Jose Manjon

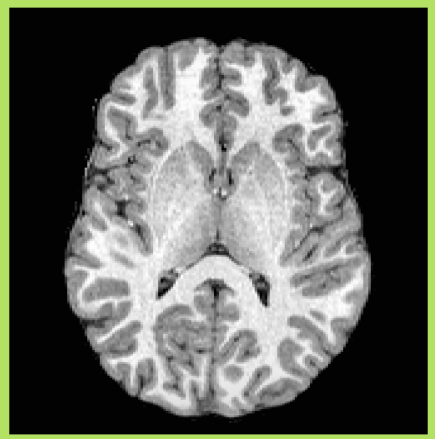


Multi-atlas segmentation

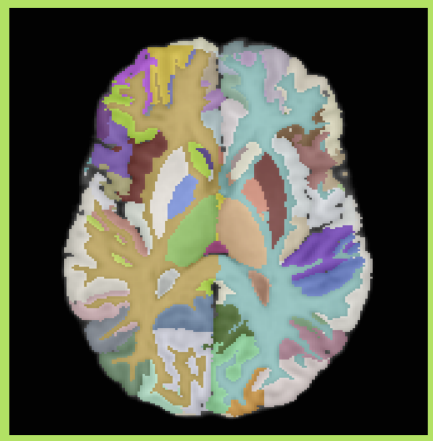
Joint label fusion



Atlases
(grayscale + segmentation)



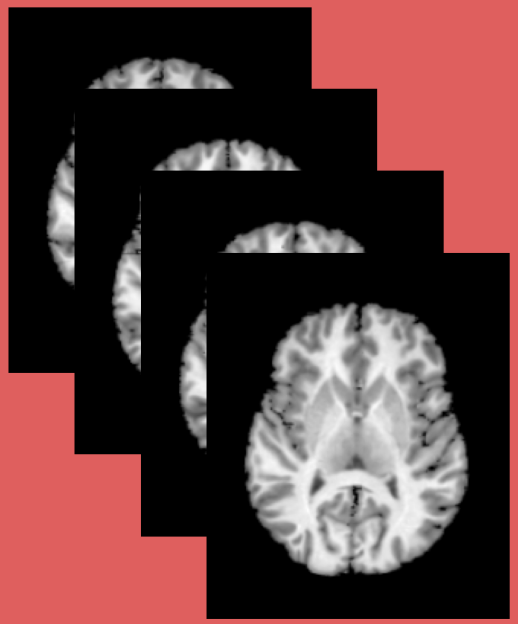
Target image



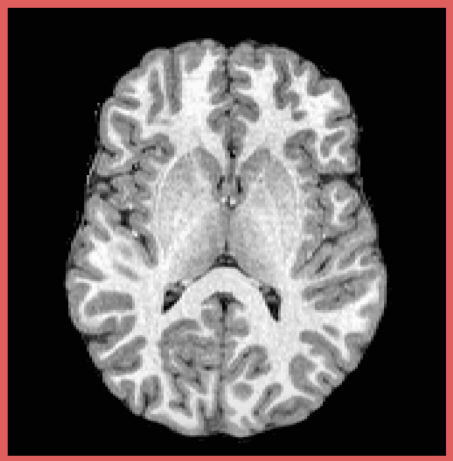
Target segmentation

New work: joint intensity fusion

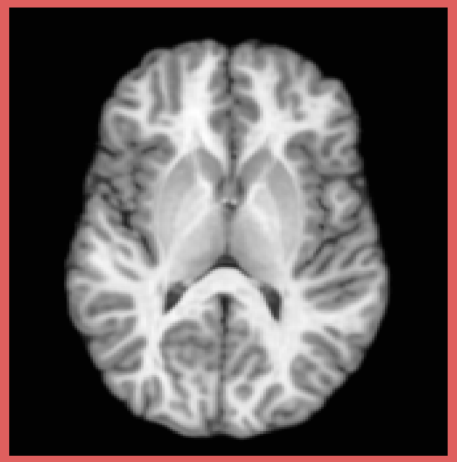
Joint intensity fusion



Atlases
(grayscale only)



Target image



Target fusion image

Possible uses

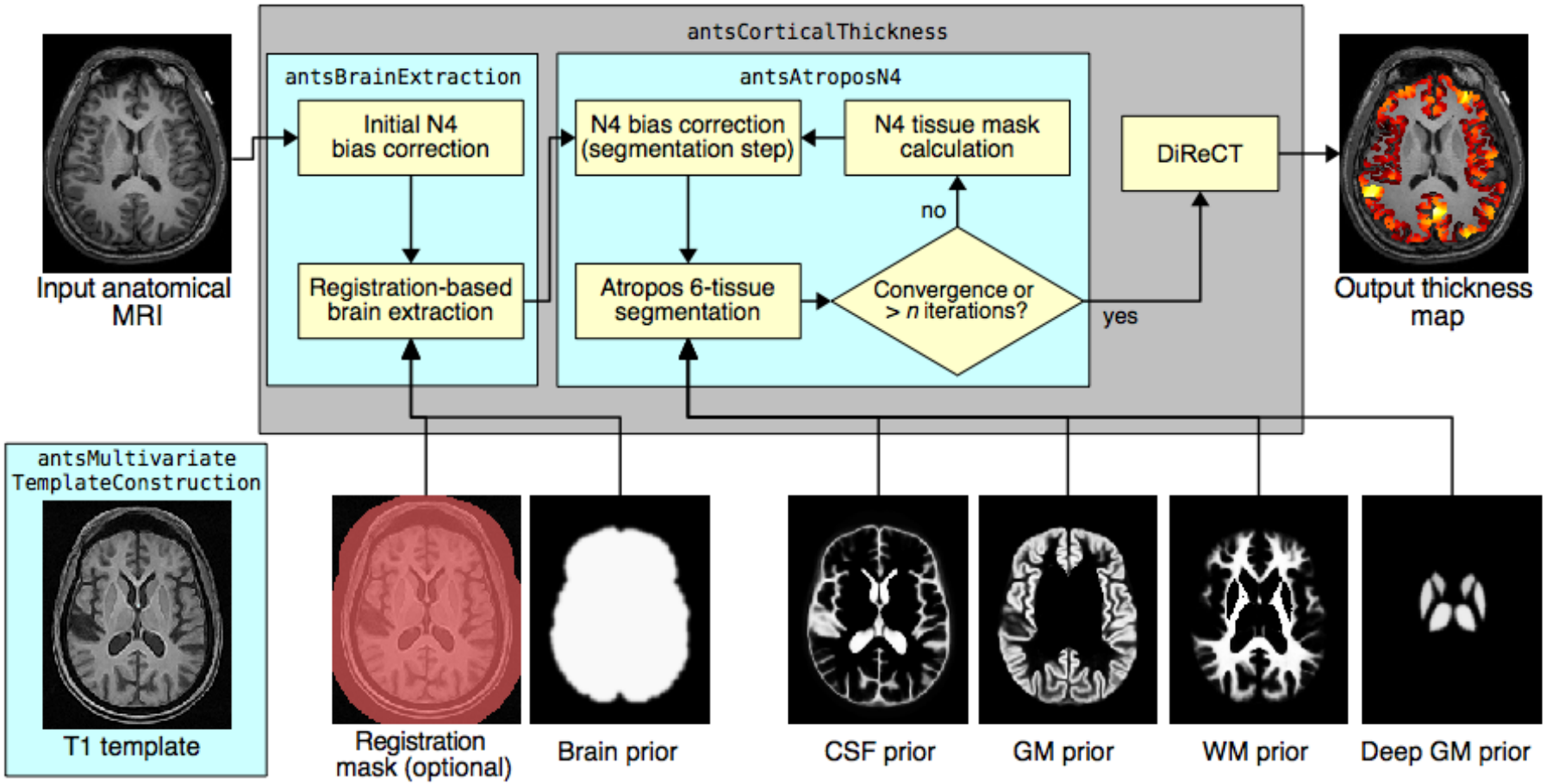
- "Correct" images
  - motion correction
  - "remove" lesions
- Project atlas set intensity signature
- Use in "corrective learning"

Putting it all together—the ANTs cortical thickness pipeline

Cortical thickness studies

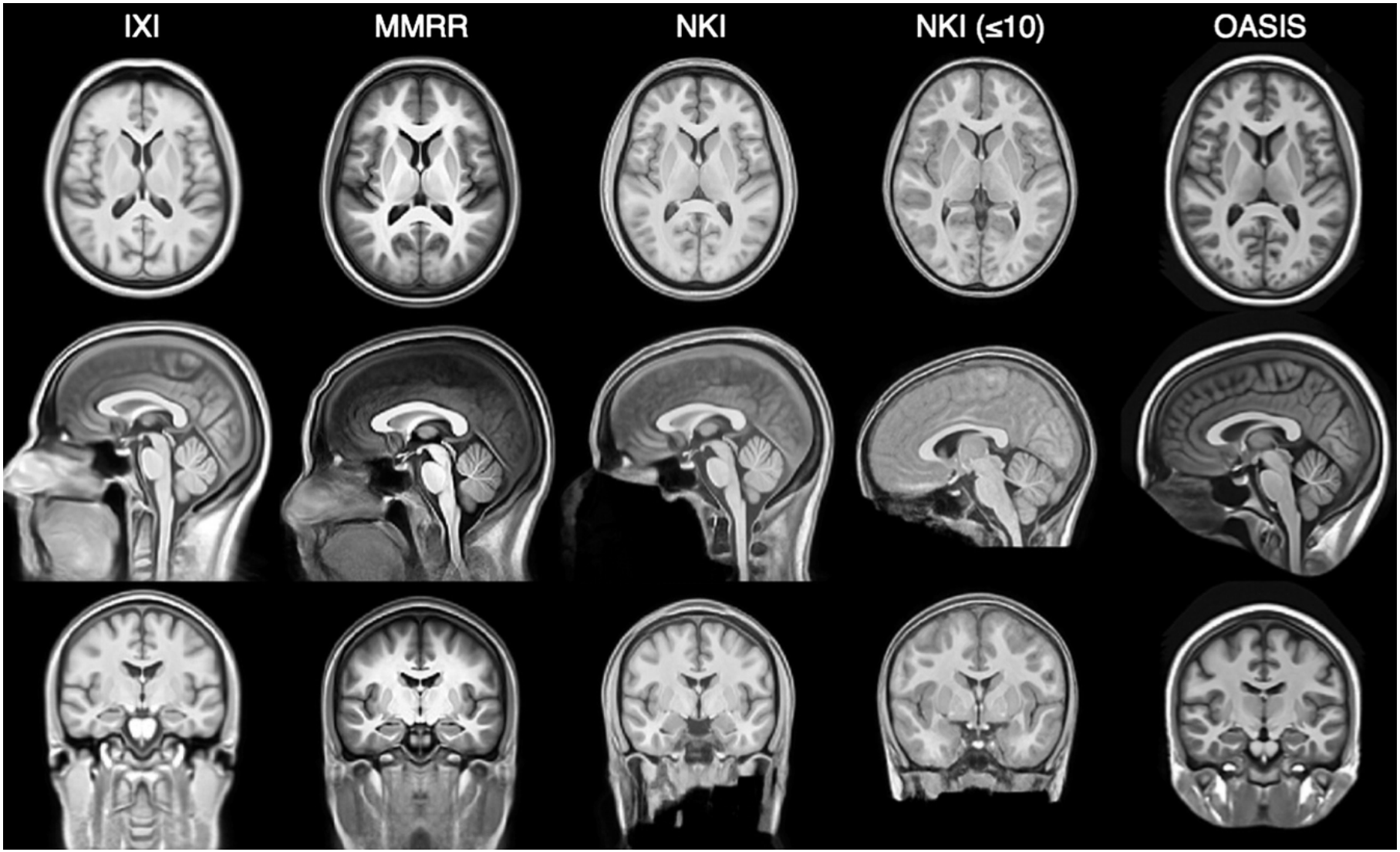
Column1	Column2
Tetris-playing ability	chronic pancreatitis
Huntington's disease	obsessive-compulsive disorder
schizophrenia	ADHD
bipolar disorder	obesity
Alzheimer's disease	heritable depression
frontotemporal dementia	elderly depression
Parkinson's disease	age
Williams syndrome	gender
multiple sclerosis	handedness
autism	intelligence
migraines	athletic ability
chronic smoking	meditative practices
alcoholism	musical ability
cocaine addiction	tendency toward criminality

The ANTs structural brain mapping workflow

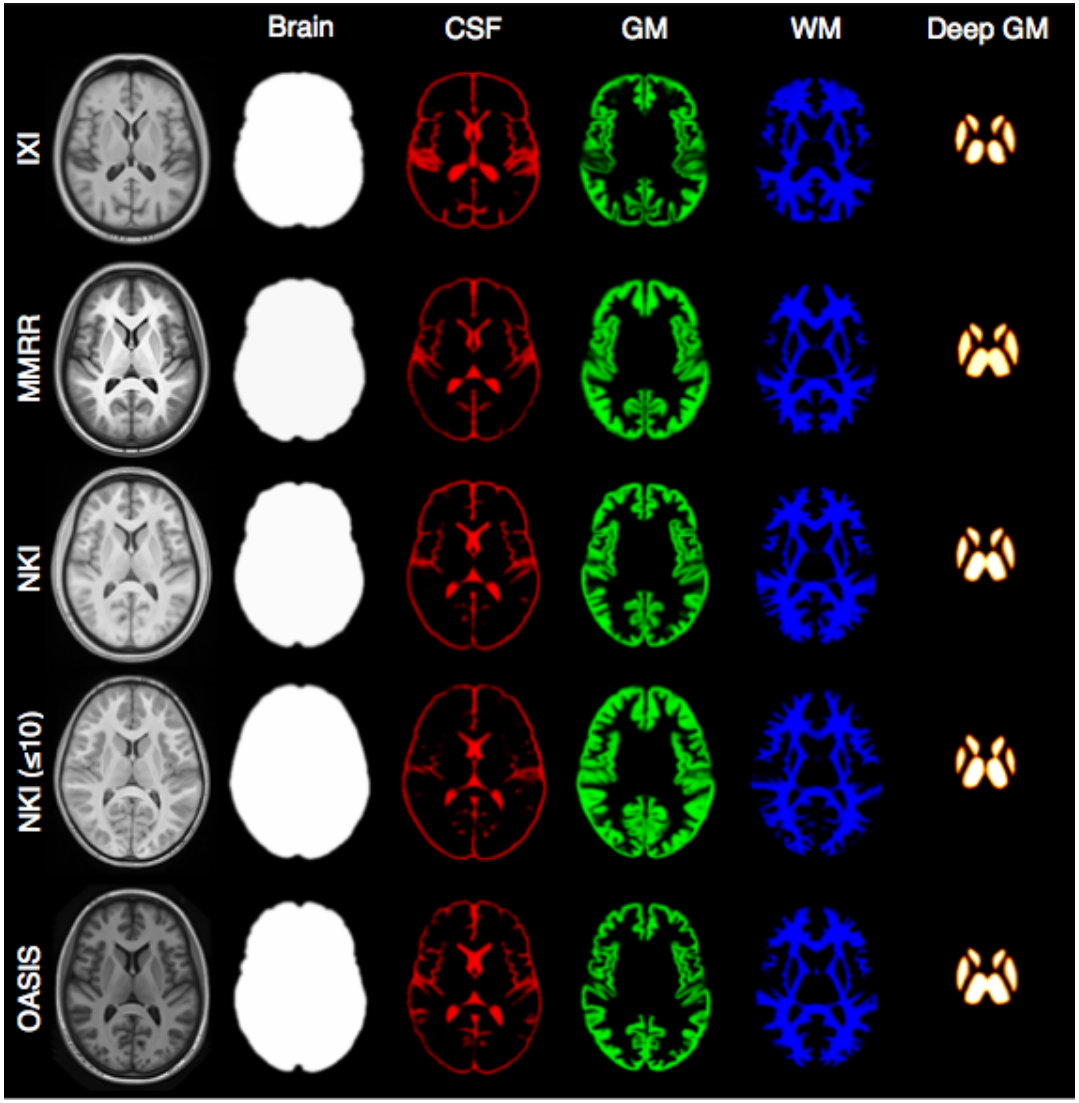


Template building

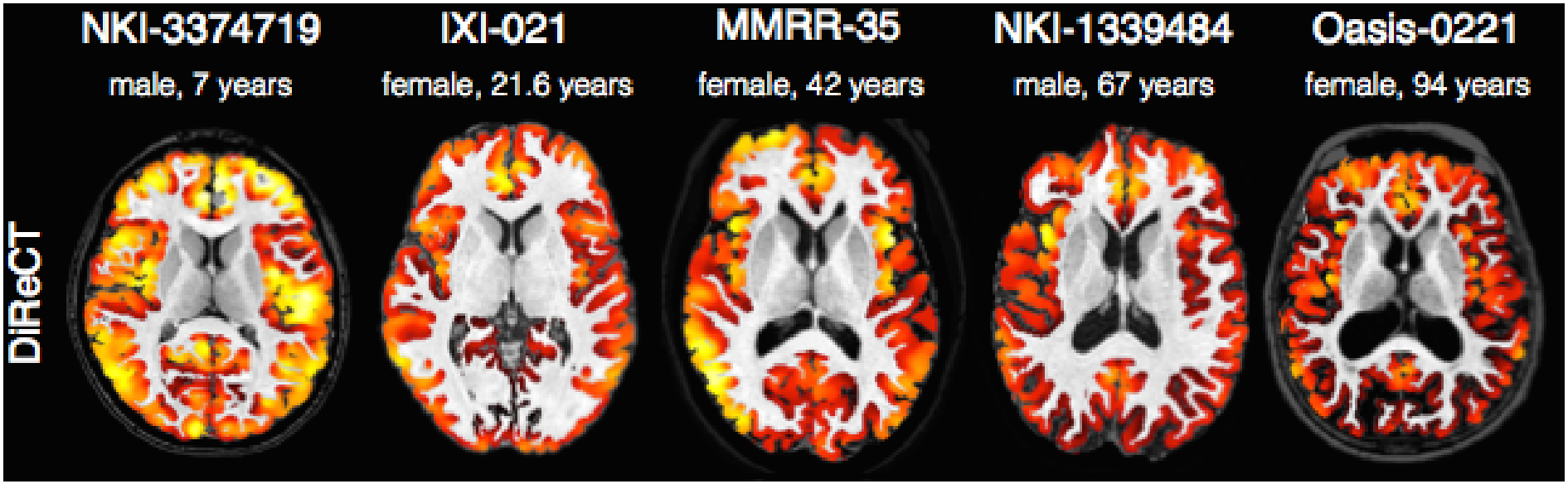
Tailor data to your specific cohort



Template priors



Cortical thickness maps



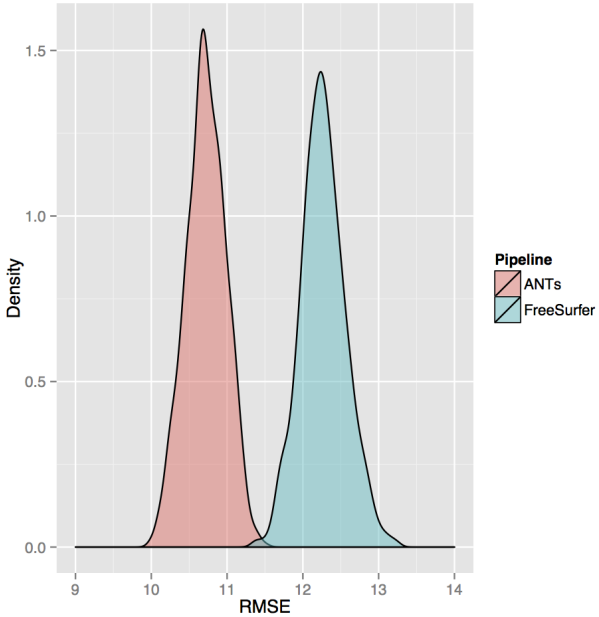
In contrast to FreeSurfer which warps coupled surface meshes to segment the gray matter, *ANTs* diffeomorphically registers the white matter to the combined gray/white matters while simultaneously estimating thickness.

But without ground truth, how does one evaluate the pipeline?

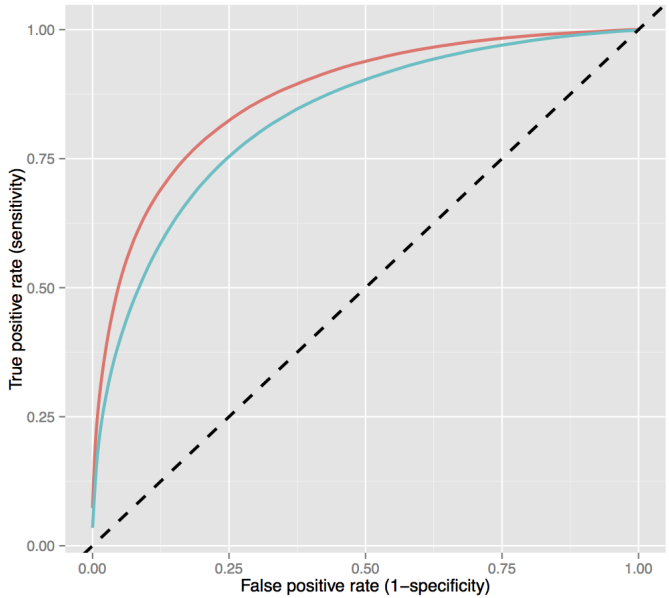
Predict age and gender

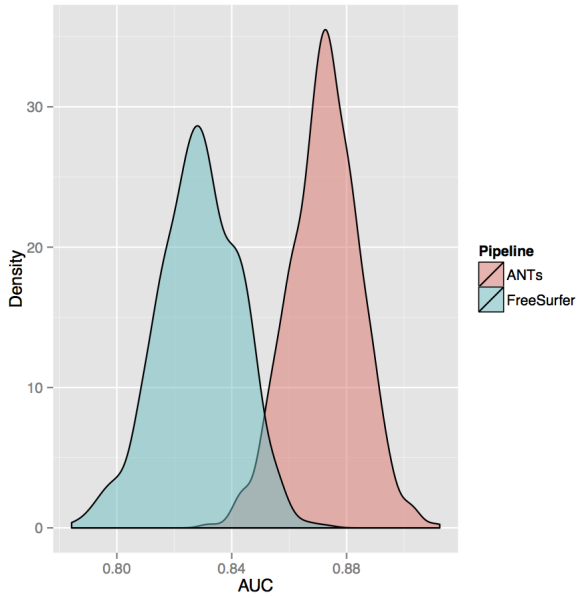
$$AGE \sim VOLUME + GENDER + \sum_{i=1}^{62} T(DKT_i)$$

Prediction from cortical thickness data



Age





Gender

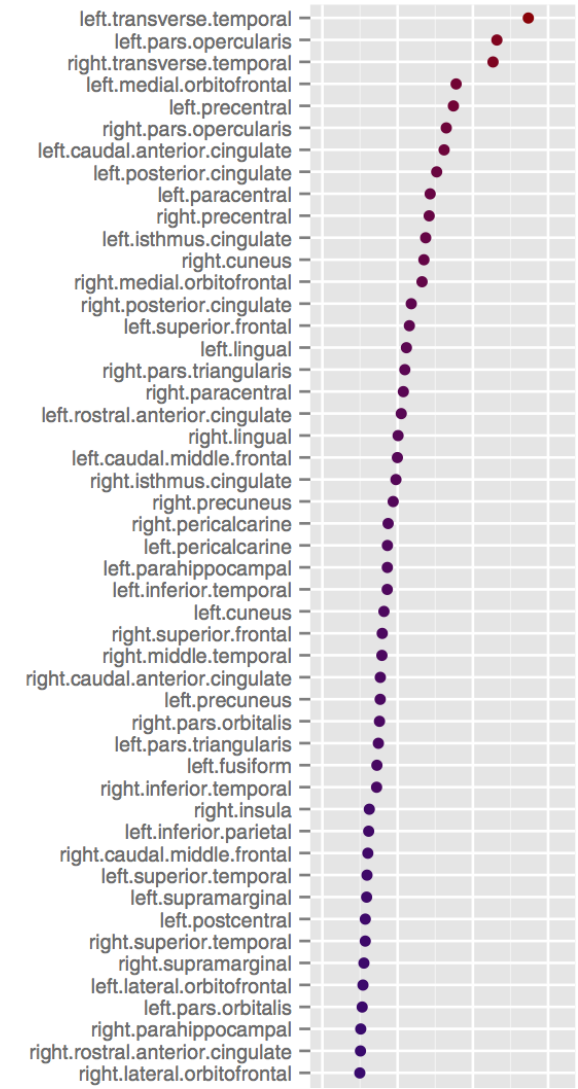
Age prediction per site

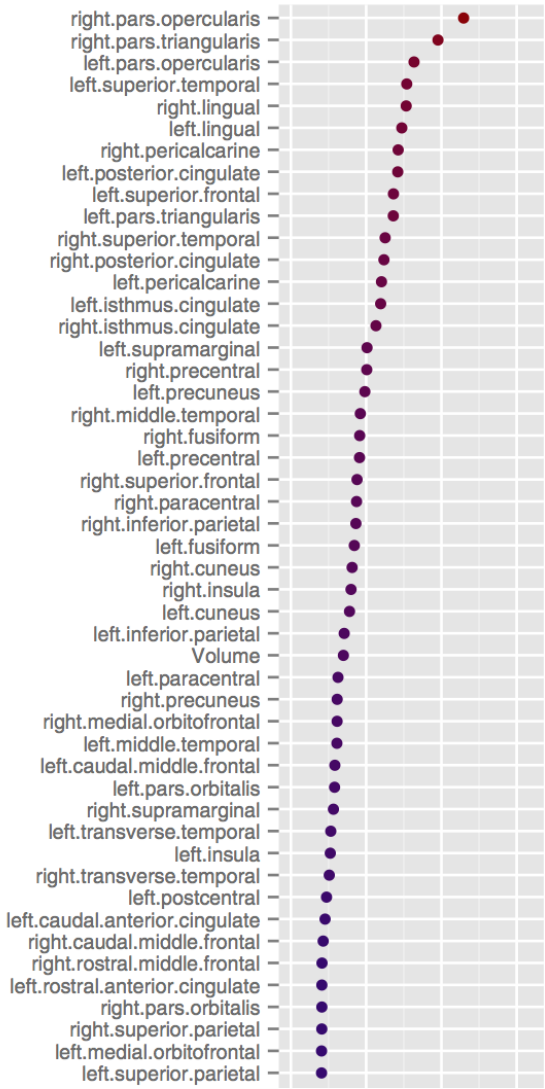
Table 3
Mean RMSE for age prediction in years.

	Linear model	Random forest
ANTs (combined)	10.7	10.2
FreeSurfer (combined)	12.3	11.9
ANTs (IXI)	9.3	8.6
FreeSurfer (IXI)	12.3	11.7
ANTs (NKI)	NA[a]	10.9
FreeSurfer (NKI)	NA[a]	13.3
ANTs (OASIS)	15.0	12.4
FreeSurfer (OASIS)	15.0	11.4

[a] Fitting error.

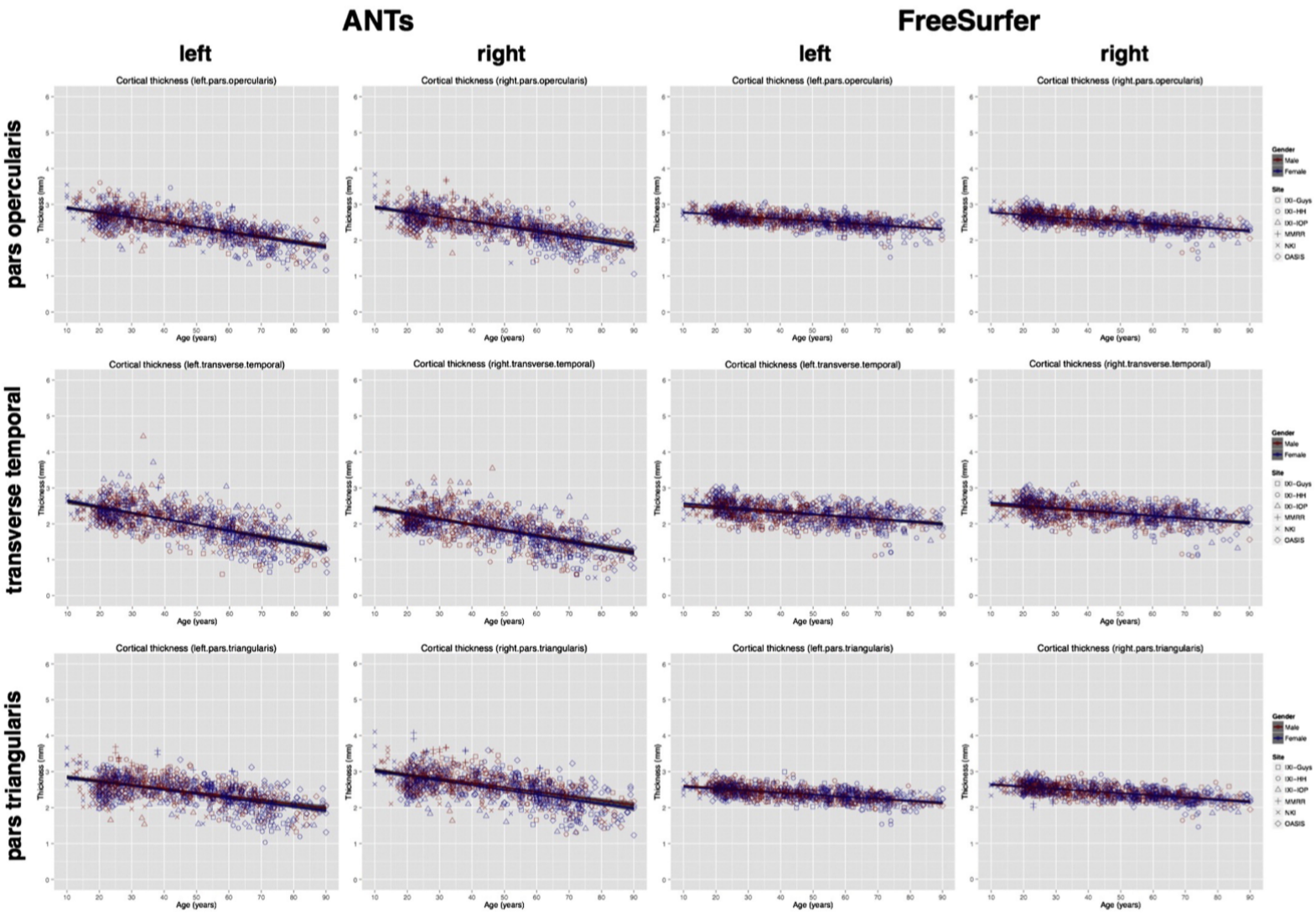
Regional importance comparison





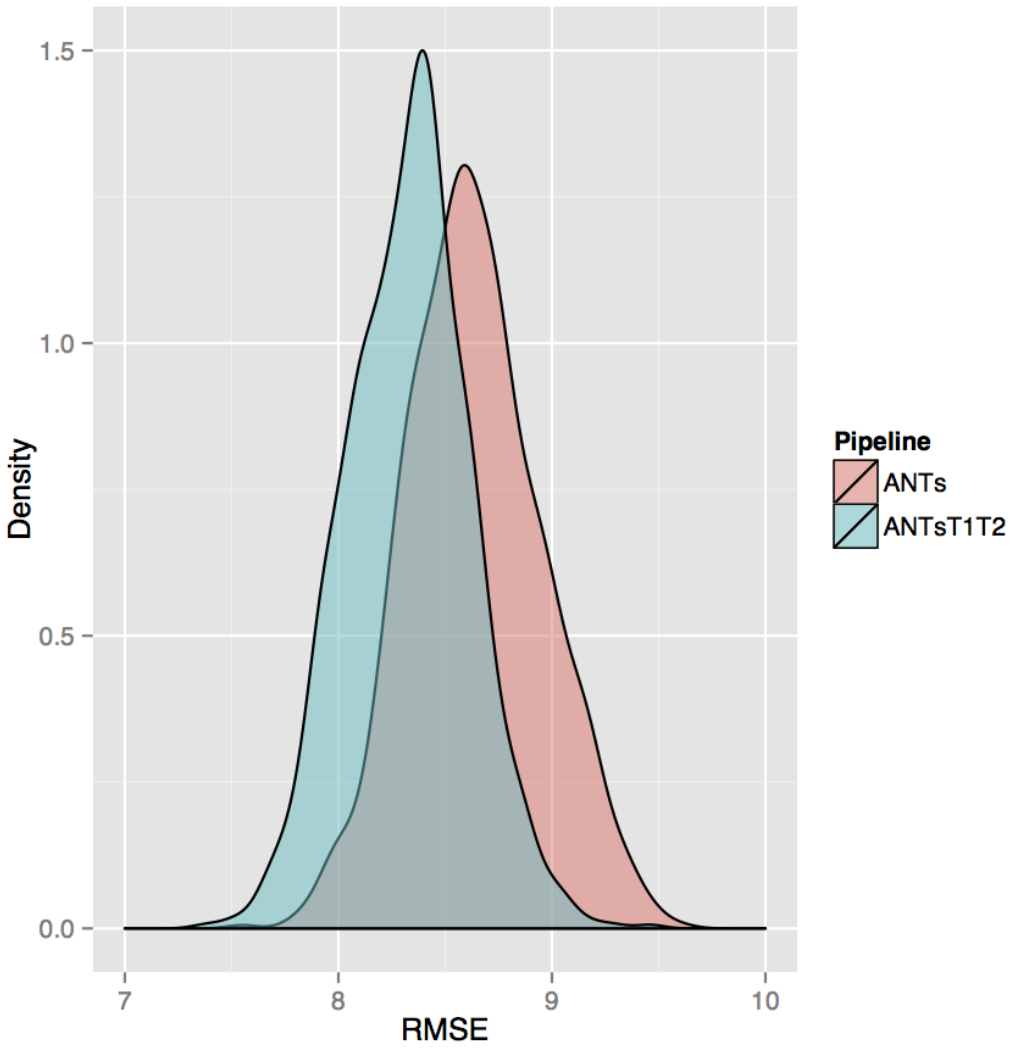
ANTs (left) vs. FreeSurfer (right)

Regional measurements

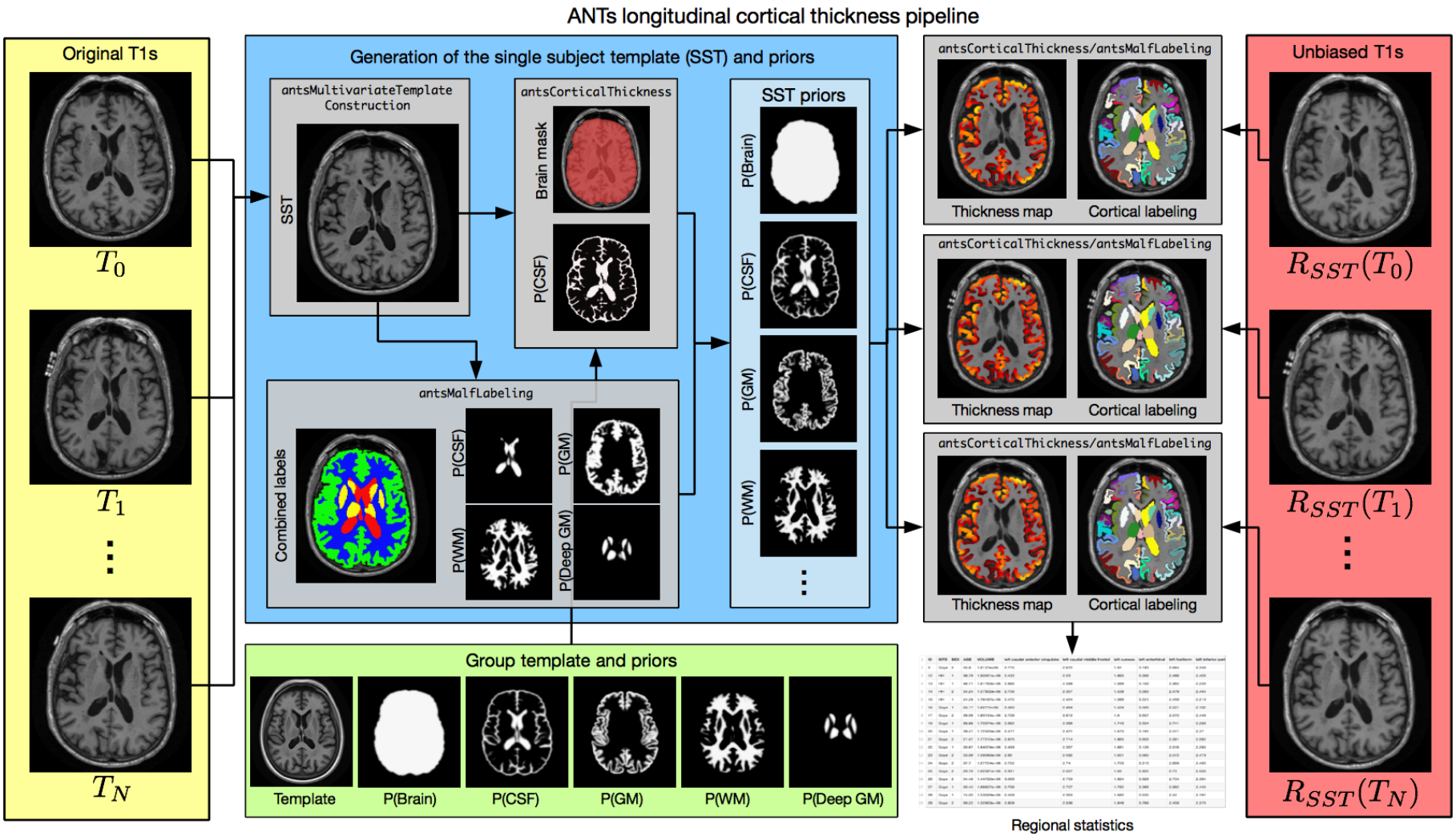


But, wait, there's more!

ANTs tools are multivariate



Longitudinal processing



Current work and Advanced Normalization Tools in R (ANTsR)

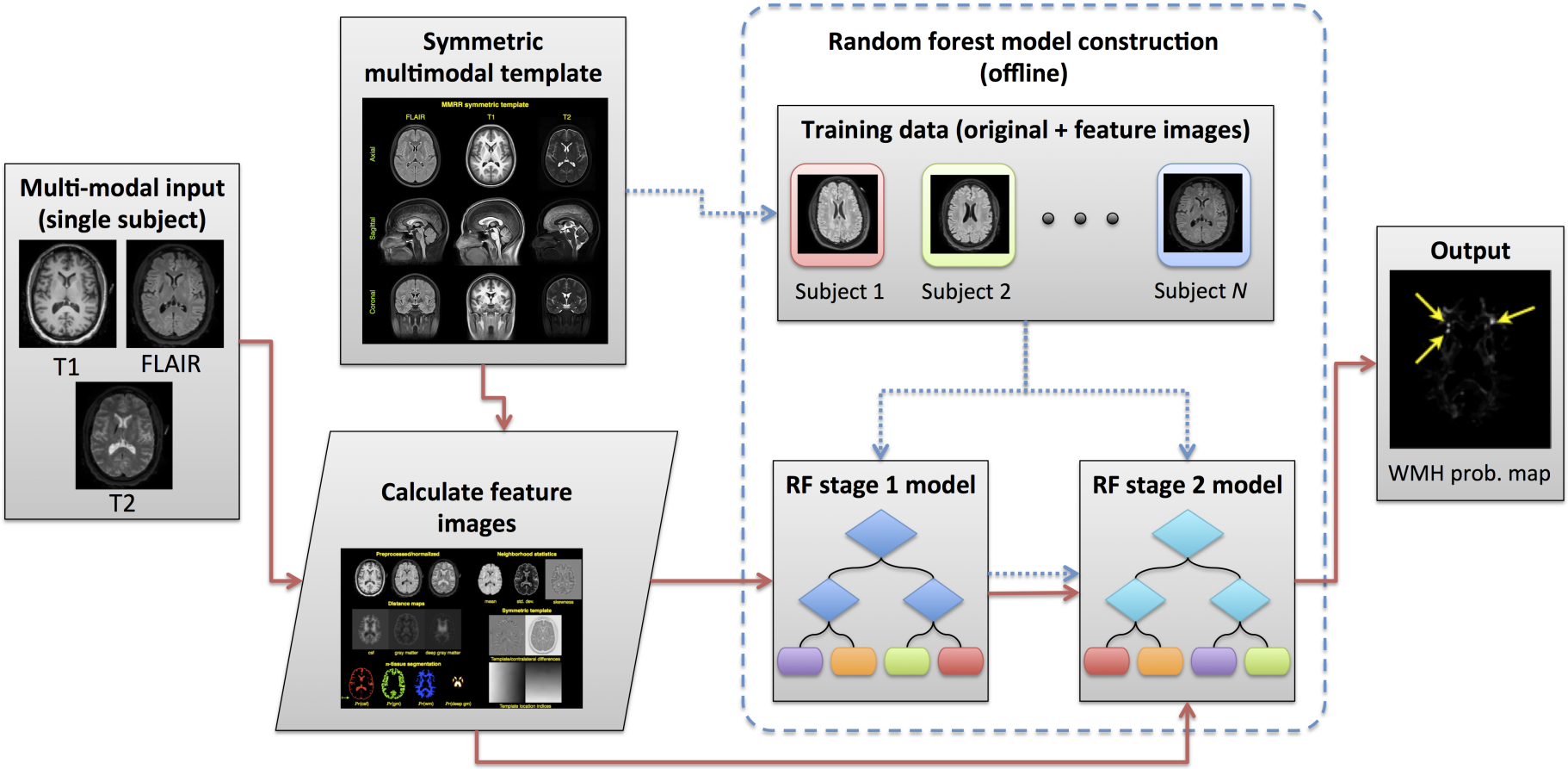
Multimodal Brain Tumor Segmentation (BRATS 2013)

Patient

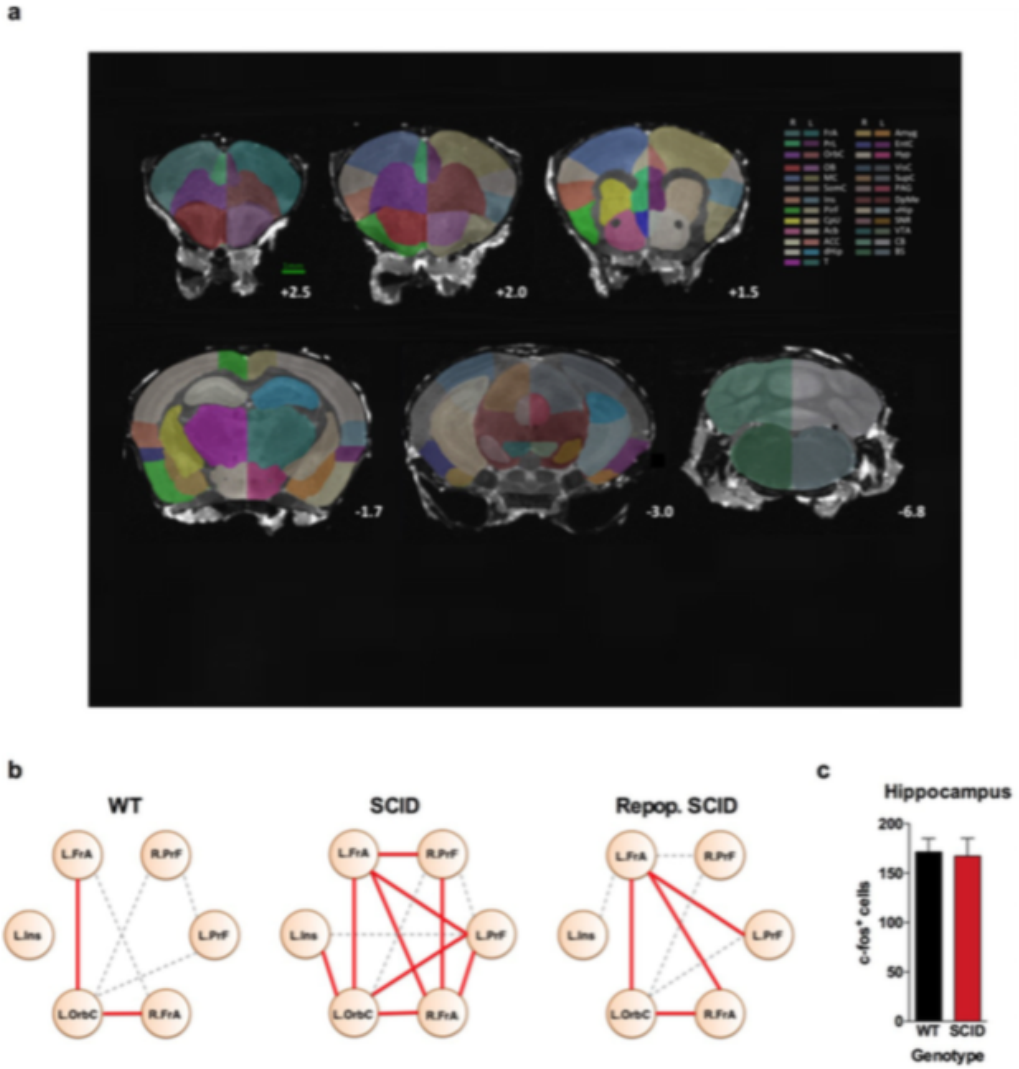
Position	User	Dice			Positive Predictive Value			Sensitivity			Kappa	Complete tumor Rank	Tumor core Rank	Enhancing tumor Rank
		complete	core	enhancing	complete	core	enhancing	complete	core	enhancing				
1	Nick Tustison	0.87 (1)	0.78 (1)	0.74 (1)	0.85 (2)	0.74 (4)	0.69 (4)	0.89 (2)	0.88 (1)	0.83 (1)	0.99 (1)	1.67	2.00	1.89
2	Raphael Meier	0.82 (5)	0.73 (2)	0.69 (3)	0.76 (6)	0.78 (2)	0.71 (1)	0.92 (1)	0.72 (4)	0.73 (3)	0.99 (4)	4.00	2.67	3.00
3	Syed Reza	0.83 (4)	0.72 (3)	0.72 (2)	0.82 (3)	0.81 (1)	0.70 (3)	0.86 (5)	0.69 (6)	0.76 (2)	0.99 (3)	4.00	3.33	3.22
4	Liang Zhao	0.84 (3)	0.70 (4)	0.65 (5)	0.80 (4)	0.67 (5)	0.65 (6)	0.89 (3)	0.79 (3)	0.70 (4)	0.99 (5)	3.33	4.00	4.11
5	Nicolas Cordier	0.84 (2)	0.68 (5)	0.65 (6)	0.88 (1)	0.63 (6)	0.68 (5)	0.81 (6)	0.82 (2)	0.66 (6)	0.99 (2)	3.00	4.33	4.33
6	Joana Festa	0.72 (6)	0.66 (6)	0.67 (4)	0.77 (5)	0.77 (3)	0.70 (2)	0.72 (7)	0.60 (7)	0.70 (5)	0.98 (6)	6.00	5.33	5.00
7	Senan Doyle	0.71 (7)	0.46 (7)	0.52 (7)	0.66 (7)	0.38 (7)	0.58 (7)	0.87 (4)	0.70 (5)	0.55 (7)	0.98 (7)	6.00	6.33	6.44

Tustison, et al., Optimal symmetric multimodal templates and concatenated random forests for supervised brain tumor segmentation (simplified) with *ANTsR*, *Neuroinformatics*.

White matter hyperintensities in TBI



Social behavior and immunity dysfunction in mice



Other ANTsR work

- Pediatric template of brain perfusion
- Automated segmentation of chronic stroke lesions using LINDA: Lesion identification with neighborhood data analysis
- Eigenanatomy
- Corrective learning for segmentation refinement