FreeSurfer Introduction

MASSACHUSETTS GENERAL HOSPITAL

Course Overview

Day 1

- Introduction
- Single Subject Analysis
- Troubleshooting

Day 2

- Group Analysis
- ROI analysis
- Longitudinal

Day 3

- Multimodal
- Diffusion Analysis
- Future Directions

Course Schedule

https://surfer.nmr.mgh.harvard.edu/fswiki/FsTutorial/CphAug2016CourseSchedule
https://fscph.nru.dk/programme.html

FreeSurfer Course, August 10-12

Wednesday, August 10th - Introduction / Single Subject Analysis /Troubleshooting

Time	Title	Type	Lecturer
9:00 - 9:30	**optional** - ● Unix Tutorial for FreeSurfer Users	talk/tutorial	Allison Stevens
9:30 - 9:45	**optional** - ● Intro to FreeSurfer Jargon	talk	Allison Stevens & Lilla Zollei
9:45 - 10:00	**break**		
10:00 - 10:30	● Introduction to Freesurfer	talk	Emily Lindemer
10:30 - 11:30	● Analyzing the Individual Subject	talk	Emily Lindemer
11:30 - 11:45	Freeview demonstration	demo	Allison Stevens
11:45 - 12:15	Interaction with Individual Subject Data Tutorial	tutorial	staff
12:15 - 1:15	**Lunch**	--	--
1:15 - 1:45	Interaction with Individual Subject Data Tutorial	tutorial	staff
1:45 - 2:30	● FreeSurfer Troubleshooting	talk	Allison Stevens
2:30 - 2:45	Freeview Troubleshooting demonstration	demo	Allison Stevens
2:45 - 3:05	**break**		
3:05 - 4:05	Troubleshooting Tutorial	tutorial	staff
4:05 - 5:05	● Quality Checking a Recon	demo	Allison Stevens
5:05 - 5:45	NRU - A high resolution in vivo atlas of the human brain's serotonin system		

Thursday, August 11th - Group Analysis / ROI Analysis / Longitudinal

Time	Title	Type	Lecturer
9:00 - 9:30	● Surface-based Analysis: Intersubject Smoothing & Registration	talk	Lilla Zollei
9:30 - 10:20	● Group Analysis	talk	Emily Lindemer
10:20 - 10:40	**break**		
10:40 - 11:20	Group Analysis Tutorial	tutorial	staff
11:20 - 11:40	● Multiple Comparisons	talk	Emily Lindemer
11:40 - 12:00	QDEC demonstration	demo	Martin Reuter
12:00 - 1:00	**Lunch**	--	--
1:00 - 1:20	● Multiple Comparisons Tutorial	tutorial	staff
1:20 - 2:00	QDEC Tutorial	tutorial	staff
2:00 - 2:30	● ROI Analysis	talk	Martin Reuter
2:30 - 2:50	**break**		
2:50 - 3:20	ROI Analysis Tutorial	tutorial	staff
3:20 - 3:50	● Longitudinal FreeSurfer see also: *LongitudinalProcessing*	talk	Martin Reuter
3:50 - 4:30	Longitudinal Tutorial	tutorial	staff
4:30 - 5:30	NRU - PLS applied to PET data in SAD	--	--

Friday, August 12th - Multimodal / Diffusion / Future Directions

Time	Title	Type	Lecturer
9:00 - 10:00	● Multi-Modal Integration, Part1[● http://surfer.nmr.mgh.harvard.edu/pub/docs/fs.multimodal-integration.Part2.ppt|Multi-Modal Integration, Part2]]	talk	Martin Reuter
10:00 - 11:00	Multi-Modal Integration Tutorial	tutorial	staff
11:00 - 11:15	**break**		
11:15 - 12:00	● Introduction to Diffusion MRI	talk	Lilla Zollei
12:00 - 1:00	**Lunch**	--	--
1:00 - 1:40	Diffusion Tutorial	tutorial	staff

Lectures and Practicals

- General format: talk followed by tutorial (both are on the wiki course page, but please don't download tutorial data or FreeSurfer– it can kill the network)

Wednesday, August 10th - Introduction / Single Subject Analysis /Troubleshooting

Time	Title	Type	Lecturer
9:00 - 9:30	**optional -** Unix Tutorial for FreeSurfer Users	talk/tutorial	Allison Stevens
9:30 - 9:45	**optional -** Intro to FreeSurfer Jargon	talk	Allison Stevens & Lilla Zollei
9:45 - 10:00	**break**		
10:00 - 10:30	Introduction to Freesurfer	talk	Emily Lindemer
10:30 - 11:30	Analyzing the Individual Subject	talk	Emily Lindemer
11:30 - 11:45	Freeview demonstration	demo	Allison Stevens
11:45 - 12:15	Interaction with Individual Subject Data Tutorial	tutorial	staff
12:15 - 1:15	**Lunch**	--	--
1:15 - 1:45	Interaction with Individual Subject Data Tutorial	tutorial	staff
1:45 - 2:30	FreeSurfer Troubleshooting	talk	Allison Stevens
2:30 - 2:45	Freeview Troubleshooting demonstration	demo	Allison Stevens
2:45 - 3:05	**break**		
3:05 - 4:05	Troubleshooting Tutorial	tutorial	staff
4:05 - 5:05	Quality Checking a Recon	demo	Allison Stevens
5:05 - 5:45	NRU - A high resolution in vivo atlas of the human brain's serotonin system		

Search on YouTube for the FreeSurfer channel!

Food and such

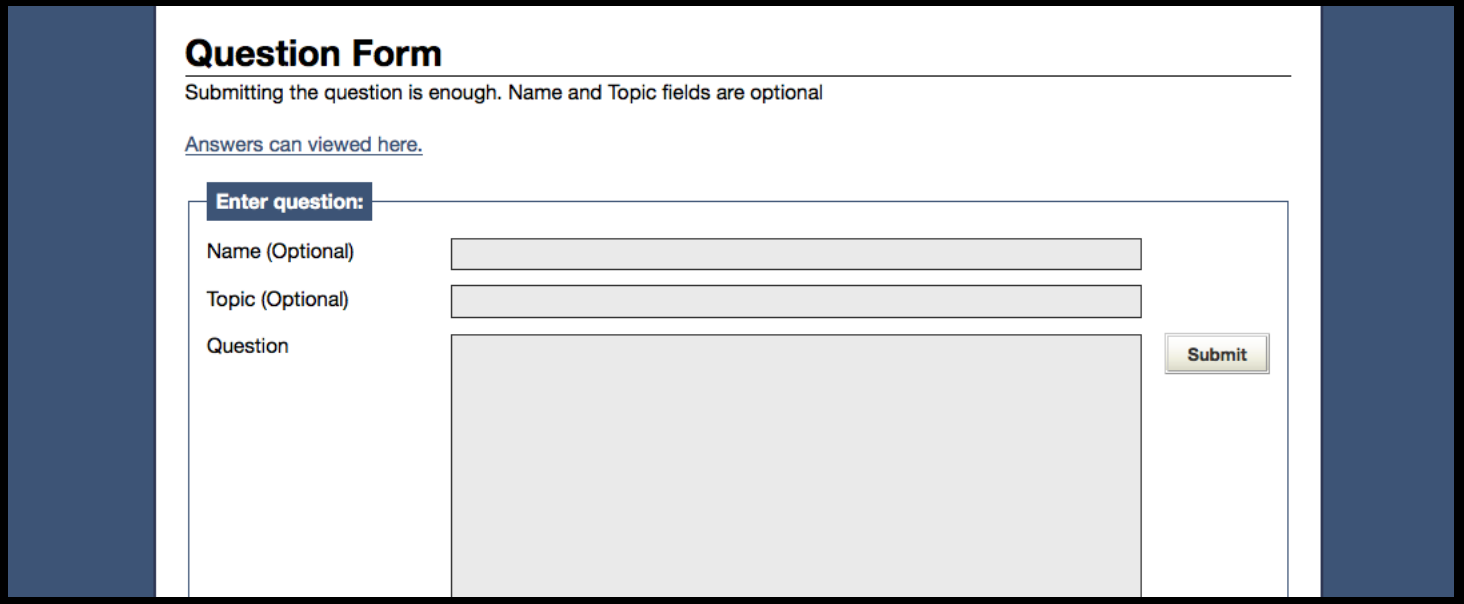
- Lunch – provided every day!
- Snacks during coffee breaks
- **Wednesday evening:** networking event at 18:00 at Noerrebro Bryghus (Ryesgade 3, 2200 København N, http://www.noerrebrobryghus.dk/) Where you can mingle with the *really fun* FreeSurfer lecturers (Food and drinks not provided)
- **Thursday evening:** guided sightseeing tour of Copenhagen by boat (boat fare provided!). Tour starts at 18:30 at Christianshavns Torv (next to the Christianshavn Metro station) and will last ~1 hour. End point of tour will be Papirøen where you can visit Copenhagen Street Food (http://copenhagenstreetfood.dk/en/) and buy yourself dinner

To Caffeinate or not to Caffeinate?

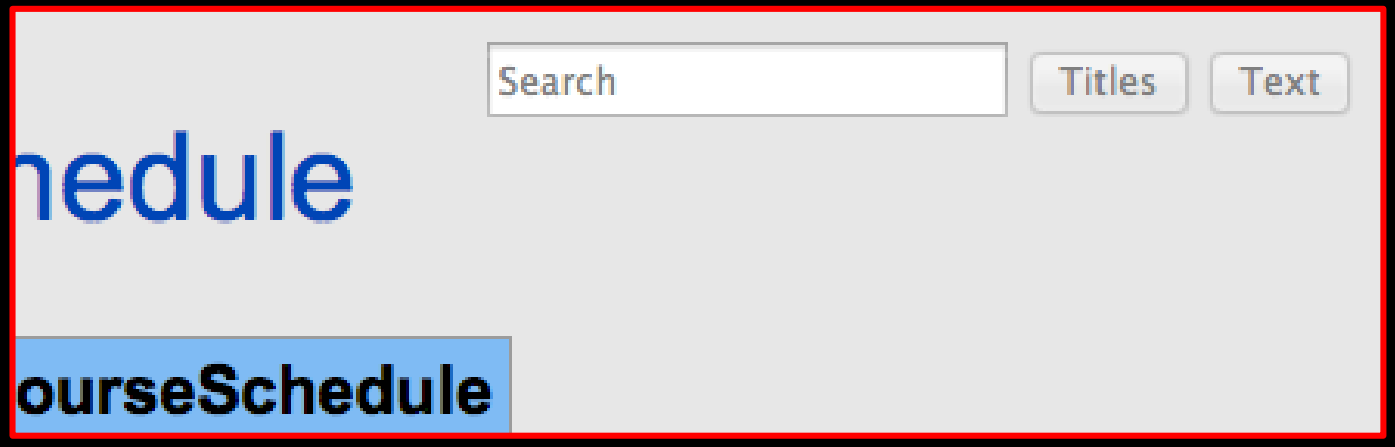
Please don’t spill coffee (or anything else!) on the laptops. If you do, please be prepared to fund a replacement!

Post Your Questions!

http://surfer.nmr.mgh.harvard.edu/cgi-bin/fsurfer/questions.cgi



Search for Answers



The FreeSurfer Team

The FreeSurfer Team

freesurfer@nmr.mgh.harvard.edu

What is FreeSurfer?

- Neuroimaging analysis software package
  - Open Source
- Detailed characterization of anatomy
  - Cortex – thickness, folding patterns, ROIs
  - Subcortical – structure boundaries
  - Hippocampal subfields
  - Longitudinal analysis – detect changes
- Statistical tools (GLM, LME, …), group comparison
- Multi-modal integration
  - fMRI (task, rest, retinotopy)
  - DWI Tractography
  - PET

What is FreeSurfer?

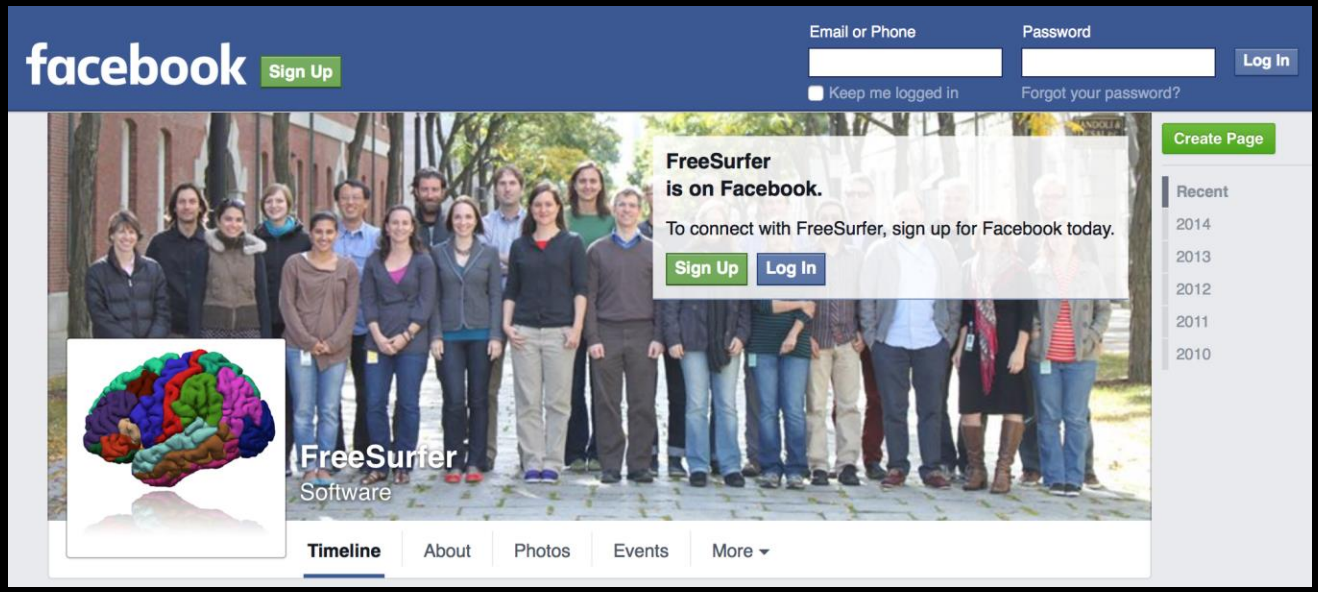
… popular …

Total # licenses distributed to date: 24,107

What is FreeSurfer?

… social …

https://www.facebook.com/FreeSurferMRI



Facebook, Twitter, LinkedIn

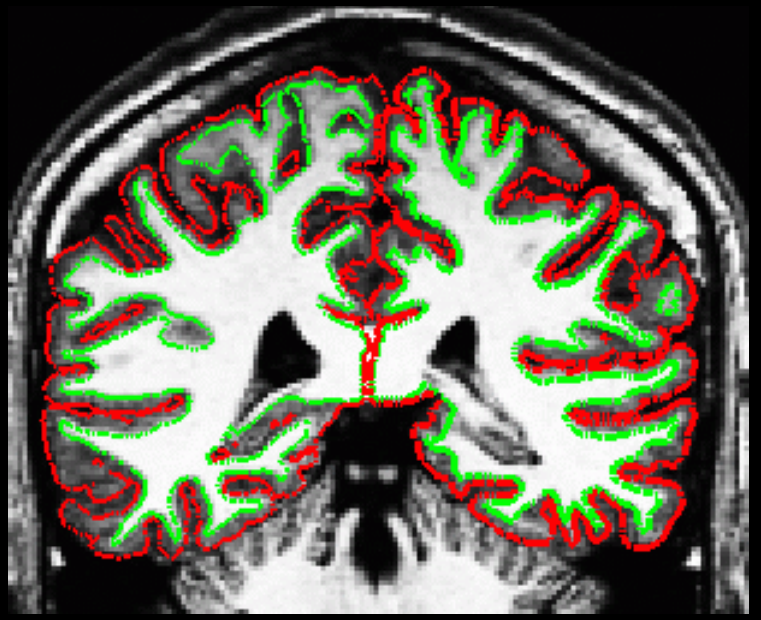
Outline

- Anatomical Analysis
  - Surface-based (Cortex)
  - Volume-based
- Multi-modal integration
  - DWI/Tractography
  - fMRI

Outline

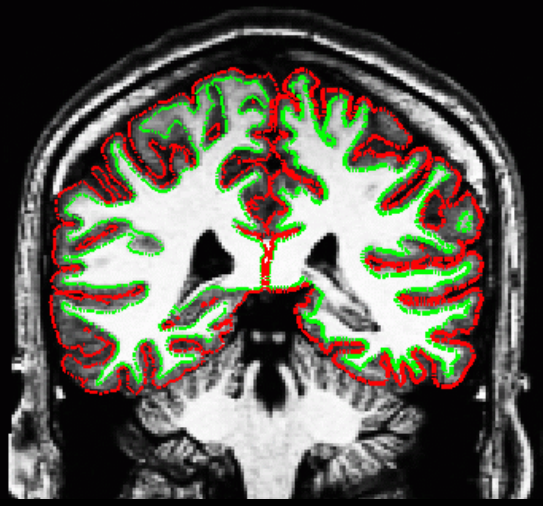
- Anatomical Analysis
  - Surface-based (Cortex)
  - Volume-based
- Multi-modal integration
  - DWI/Tractography
  - fMRI

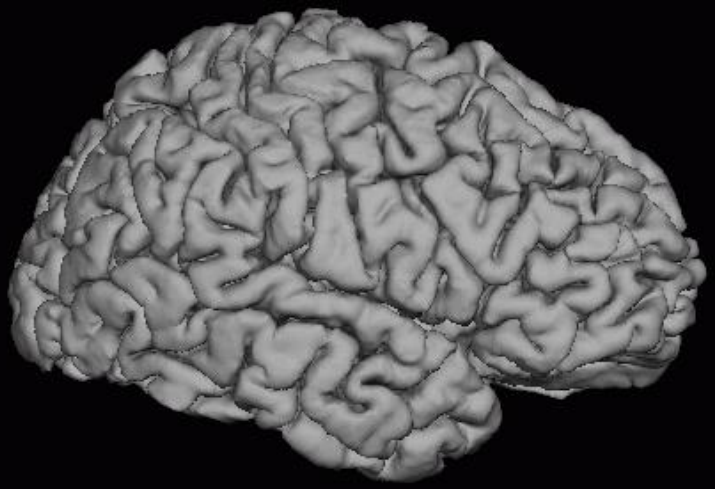
Cortex

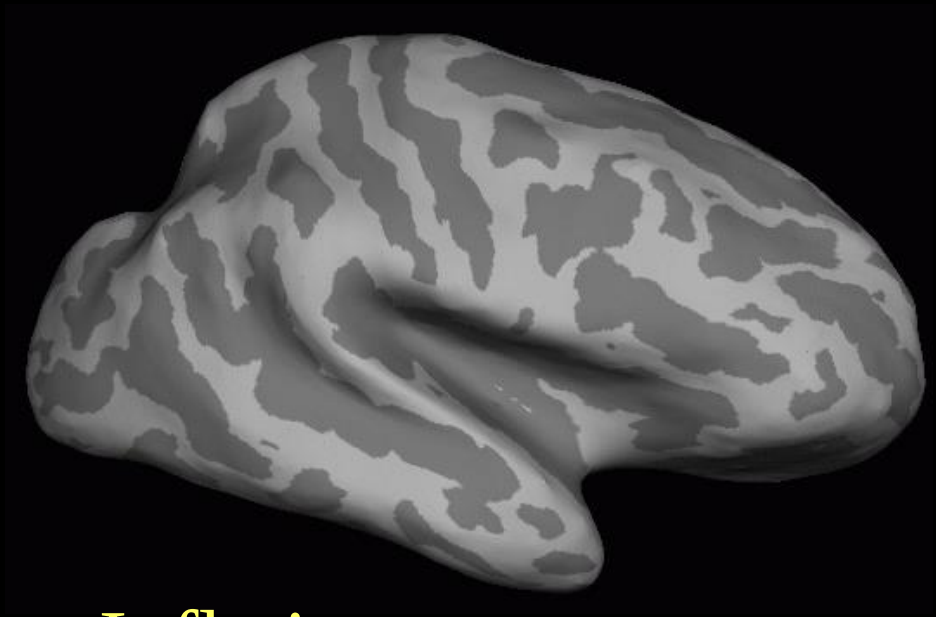


- Outer layer of gray matter
- 1-5mm thick
- Highly folded
- 2 Dimensional, embedded in 3D
- Function follows the surface
  - Visualization
  - Spatial Smoothing
  - Inter-subject Registration

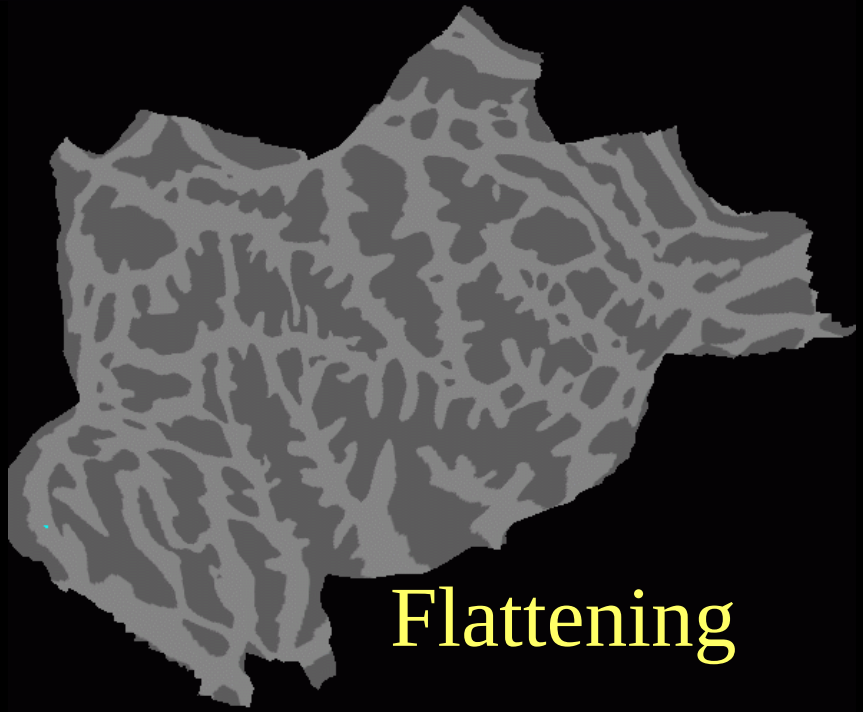
2D Surface in 3D Space





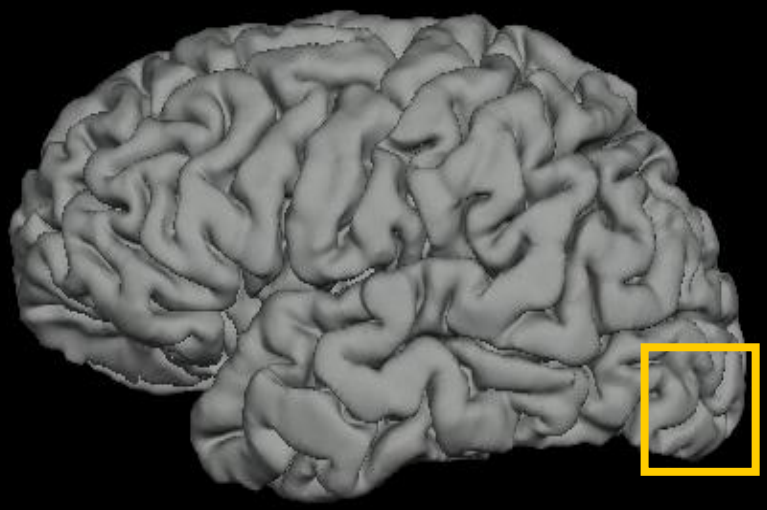


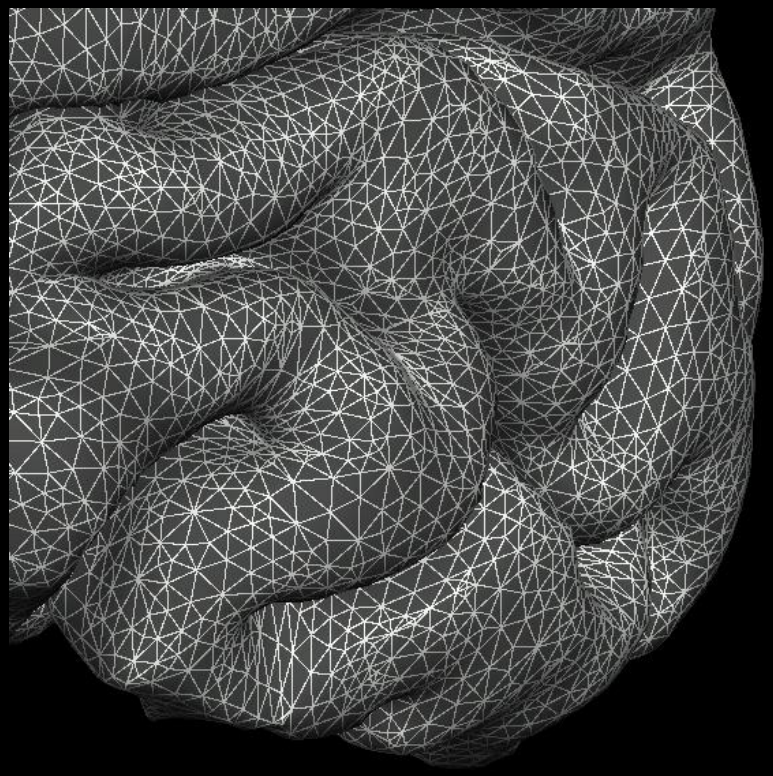
Inflation



Flattening

Surface Model

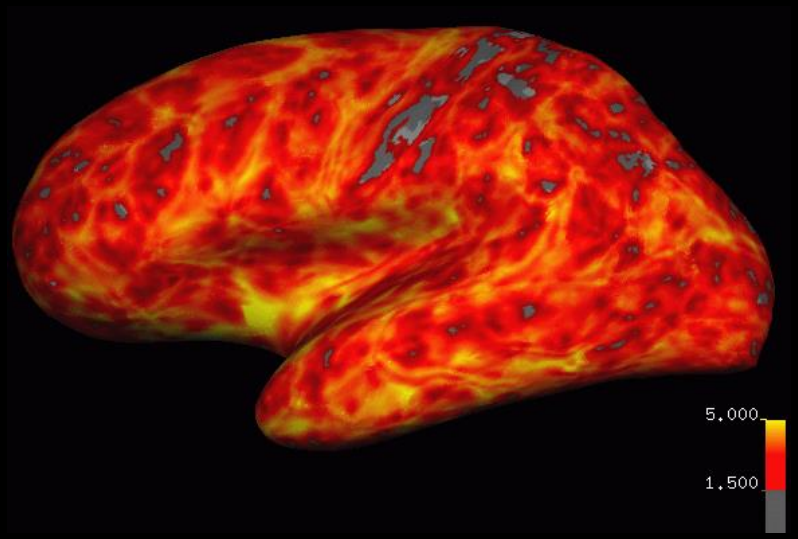




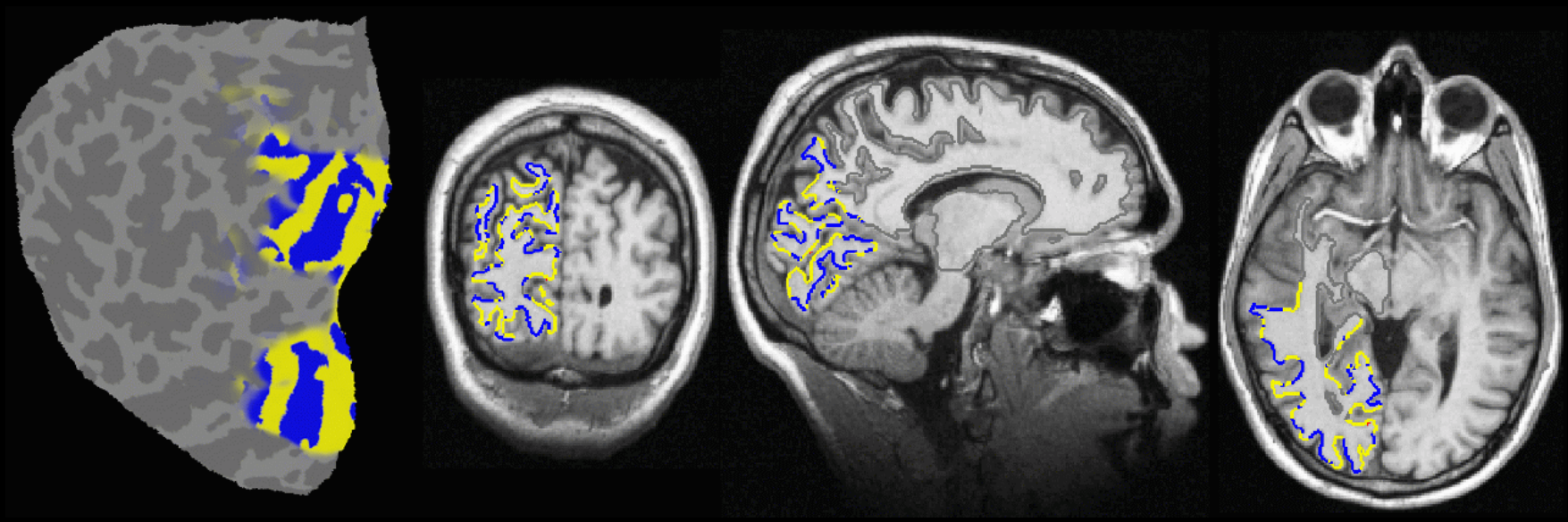
- Triangle Mesh (“Finite Element”)
- Vertex = point of triangles
- Neighborhood
- XYZ at each vertex
- Triangles/Faces ~ 300,000
- Area, Distance
- Curvature, Thickness
- Movable

Cortical Thickness

- Shortest distance between white and pial surfaces.
- 1-5mm in healthy subjects



Function Follows the Surface



- Visual areas mapped using fMRI retinotopy
- Pattern is clear on the surface, but lost in the volume

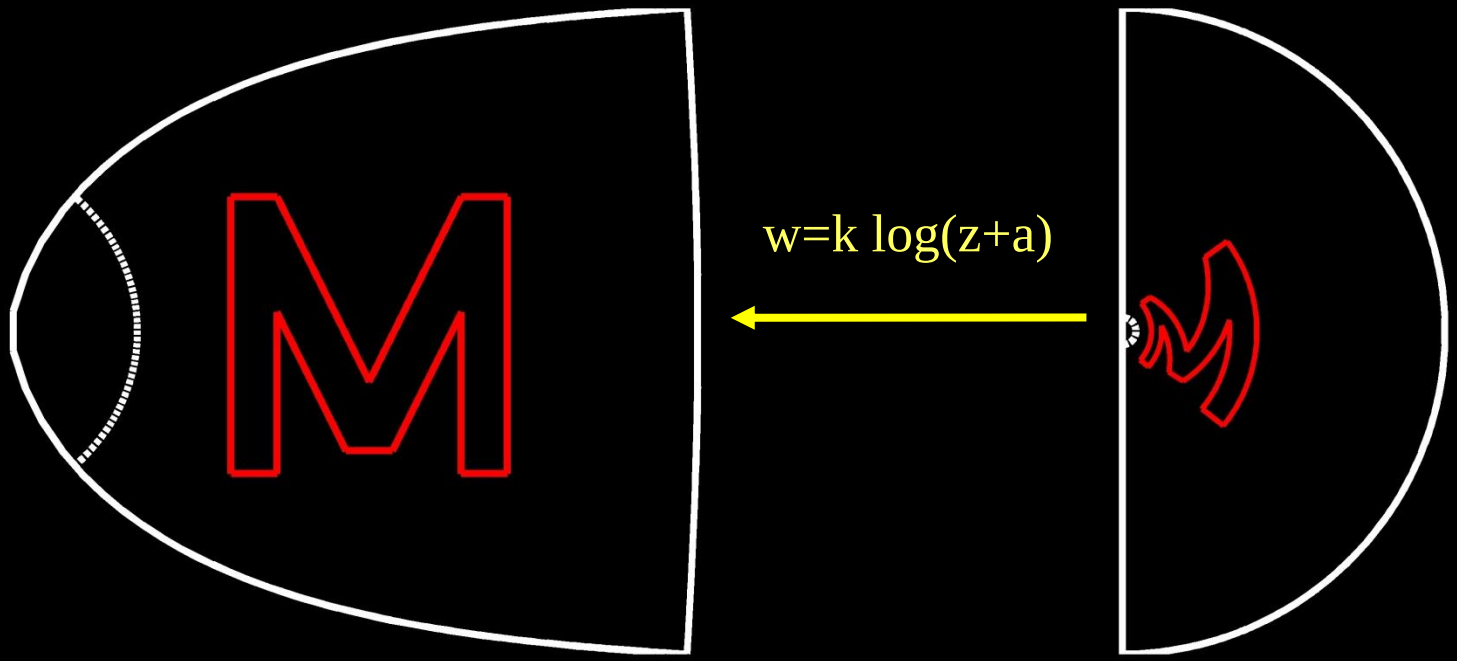
From (Sereno et al, 1995, Science).

What Can One Do With A Surface Model?

goal: use model to imposed desired activity pattern on V1

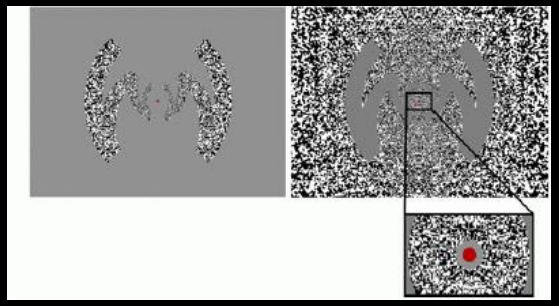
desired shape of activity pattern

required shape of stimulus



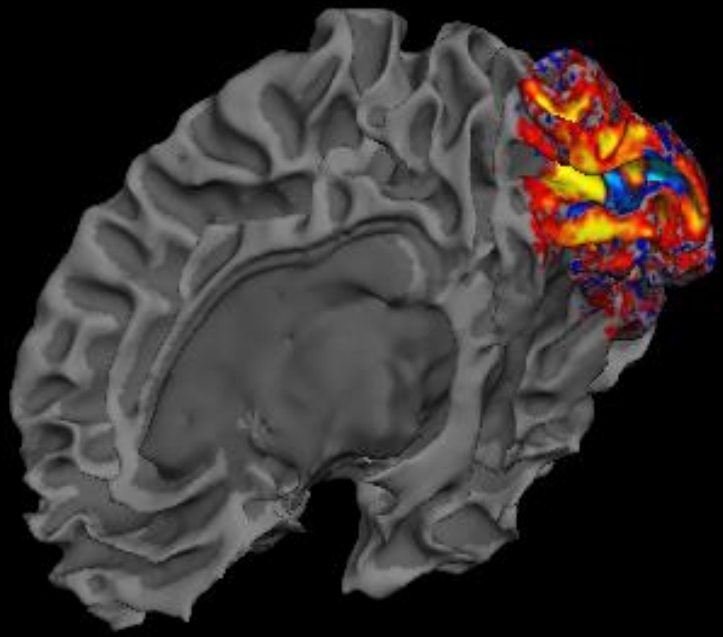
left primary visual cortex

right visual hemifield



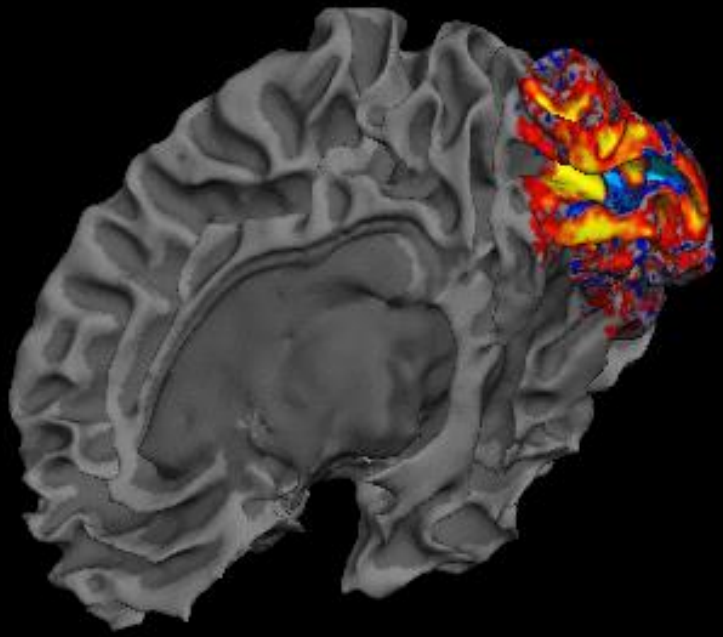
Collaboration with **Jon Polimeni** and Larry Wald.

Tangential Resolution Measured with Surface-based Analysis



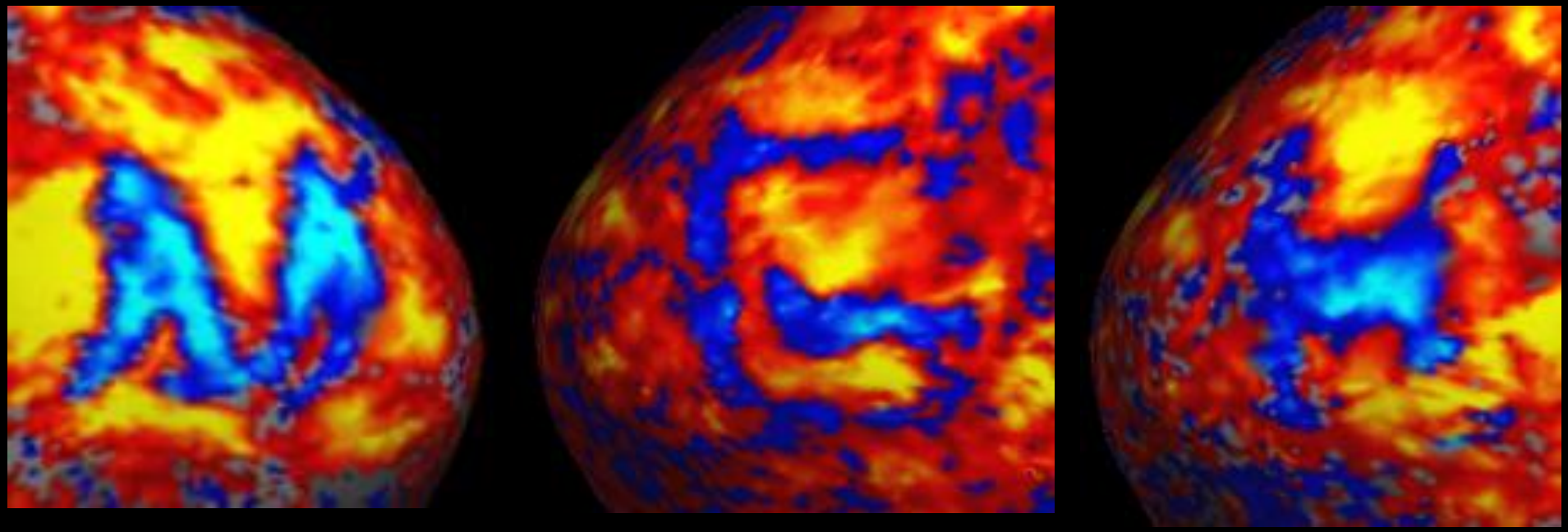
Collaboration with Jon Polimeni and Larry Wald. Polimeni, et al, 2010, NI.

Tangential Resolution Measured with Surface-based Analysis



Collaboration with Jon Polimeni and Larry Wald. Polimeni, et al, 2010, NI.

NeuroMarketing!



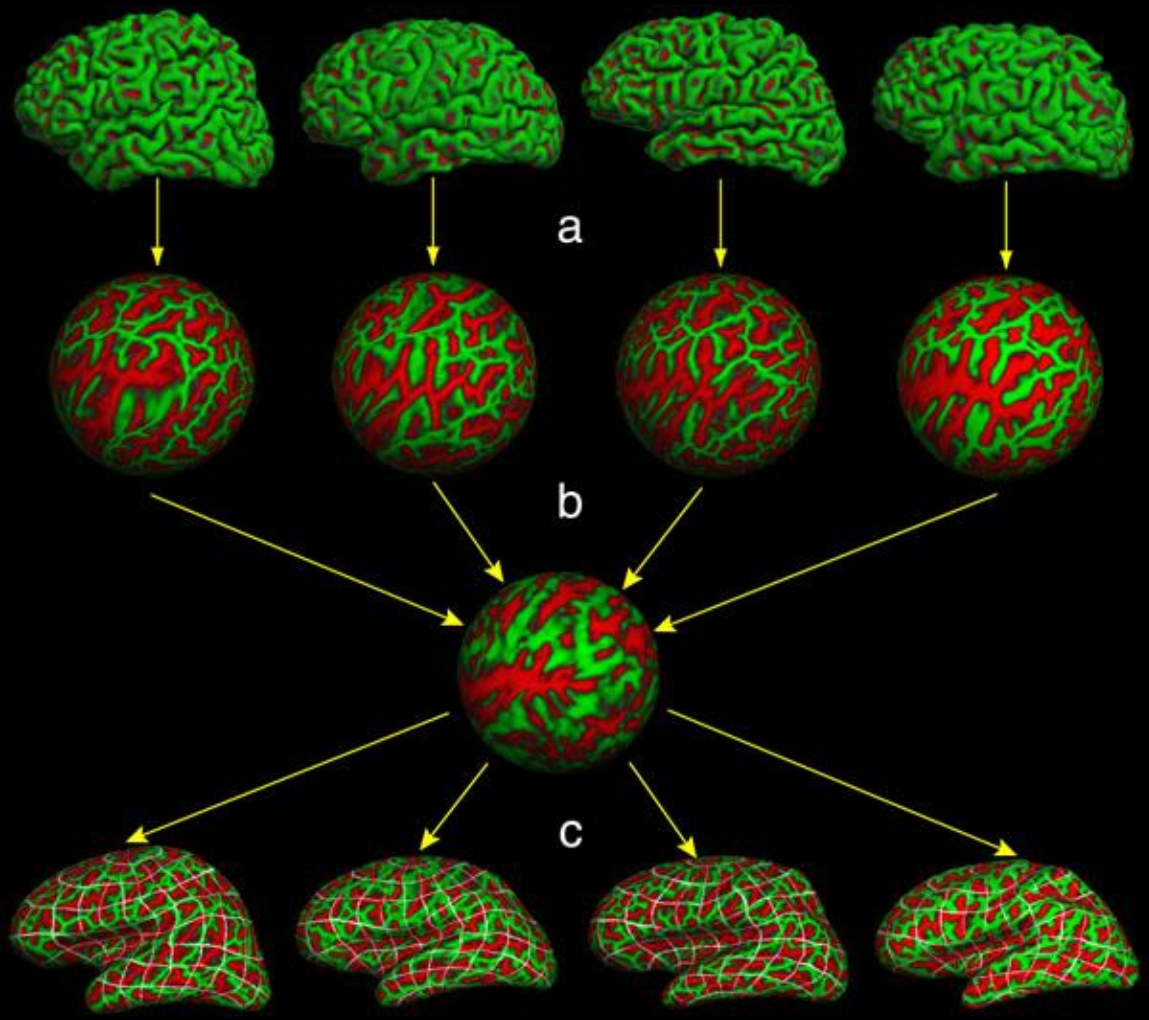
Aim 1 of our NCRR Center Grant, spelling:

"MGH Center for Functional Neuroimaging Technologies; and NCRR Center for Research Resources."

(just kidding)

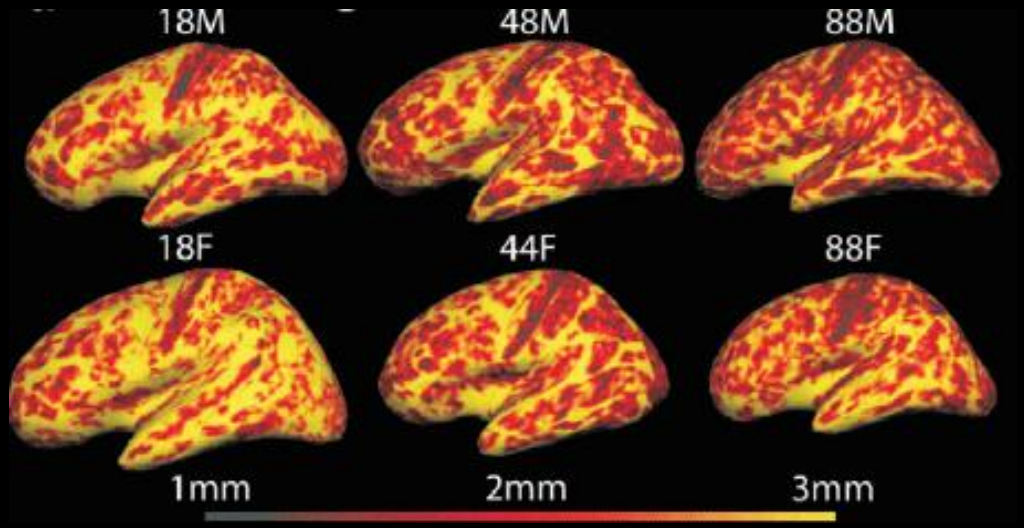
Thanks to Larry Wald for this slide.

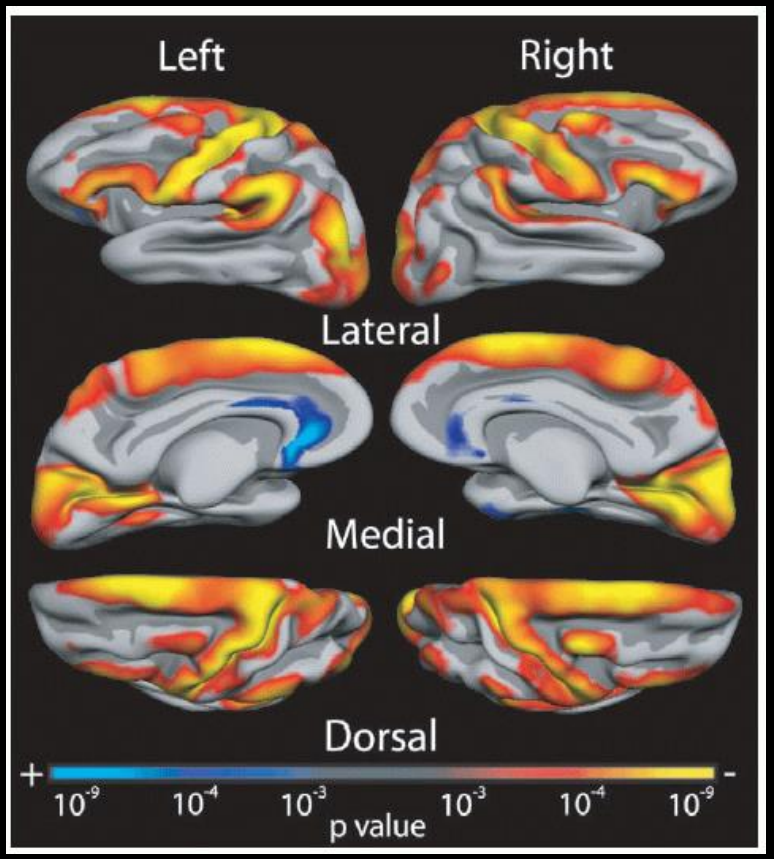
A Surface-Based Registration

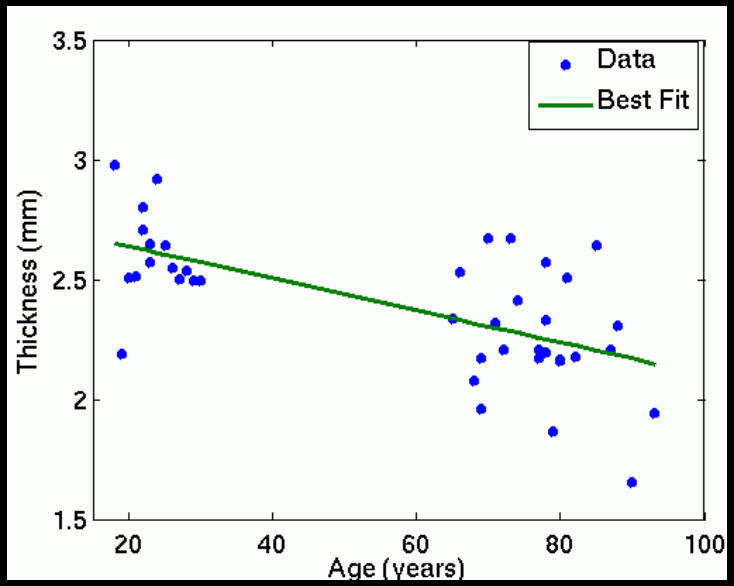


Common space for group analysis (like Talairach) “fsaverage”

Anatomical Study: Aging

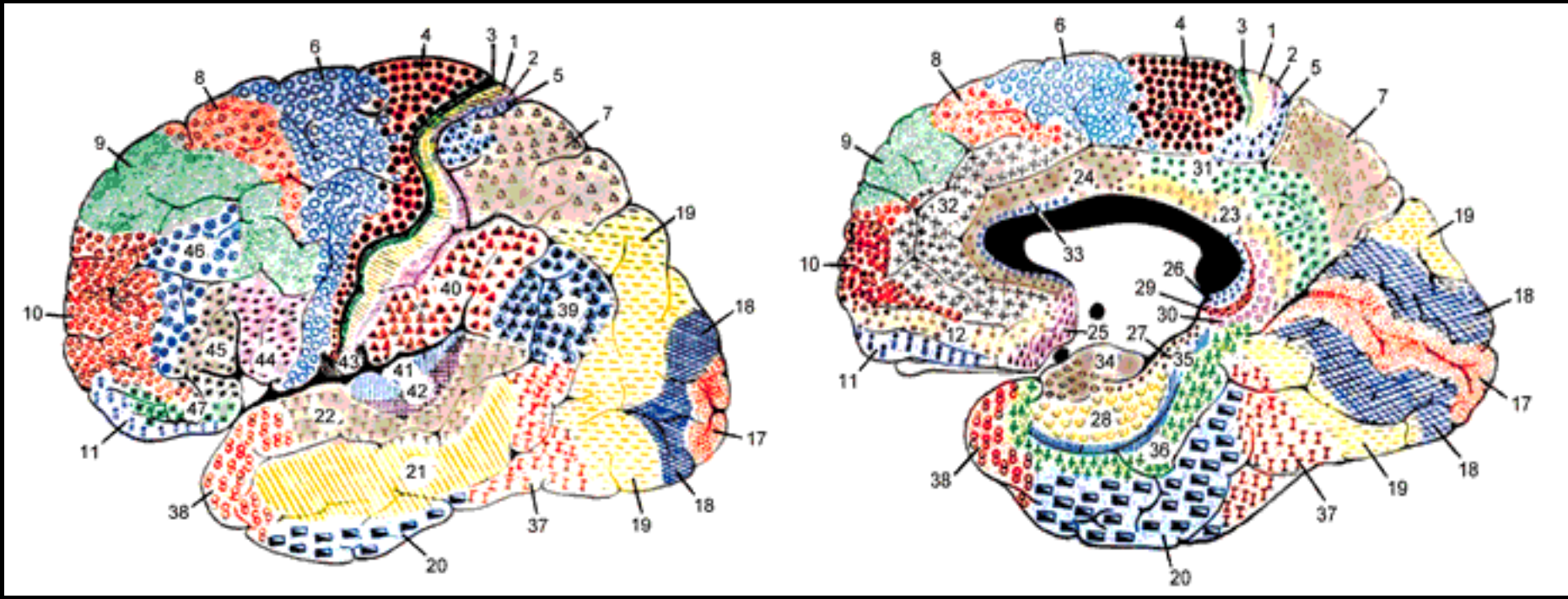






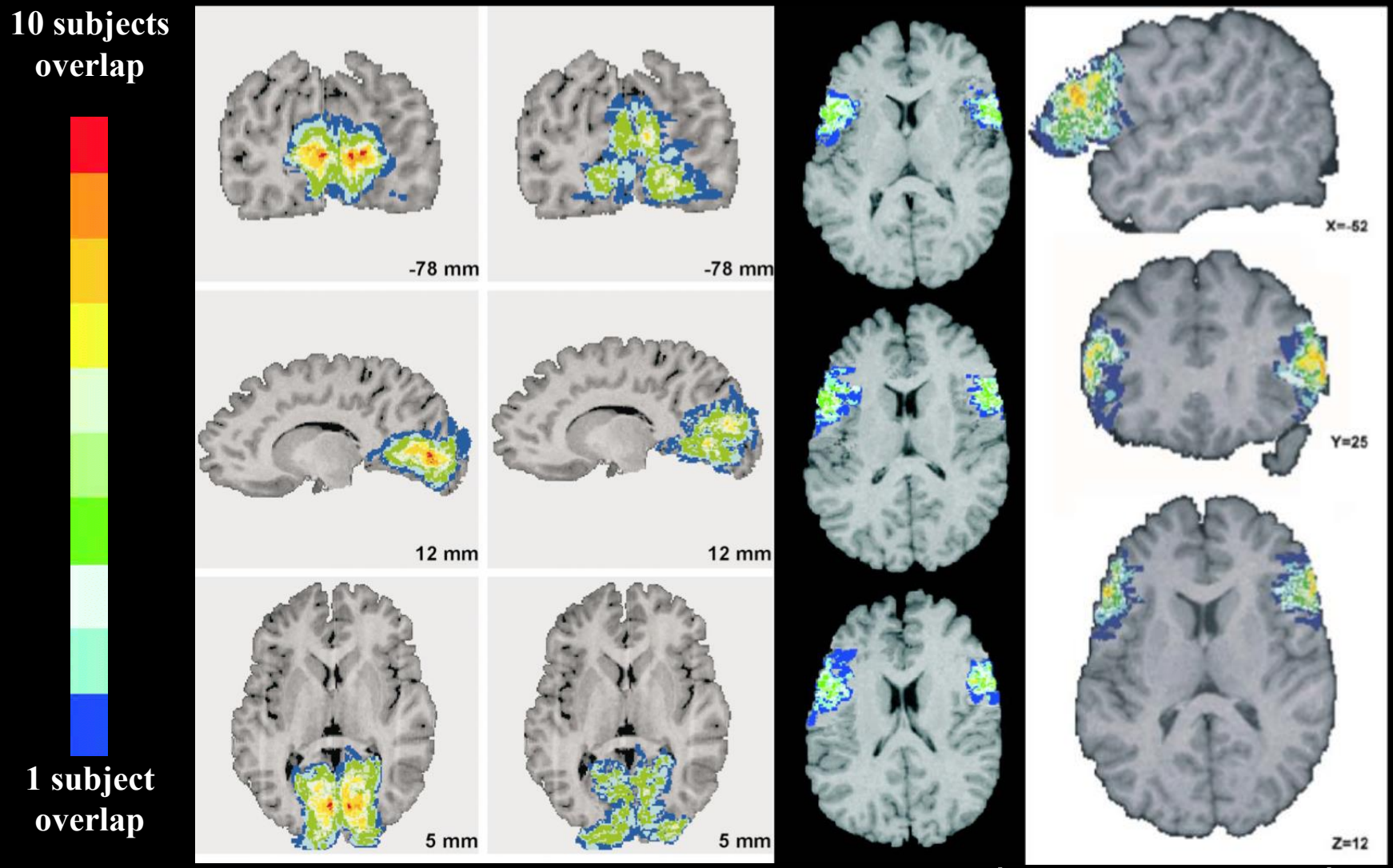
Salat, et al, 2004, Cerebral Cortex

Surface-based Registration Performance



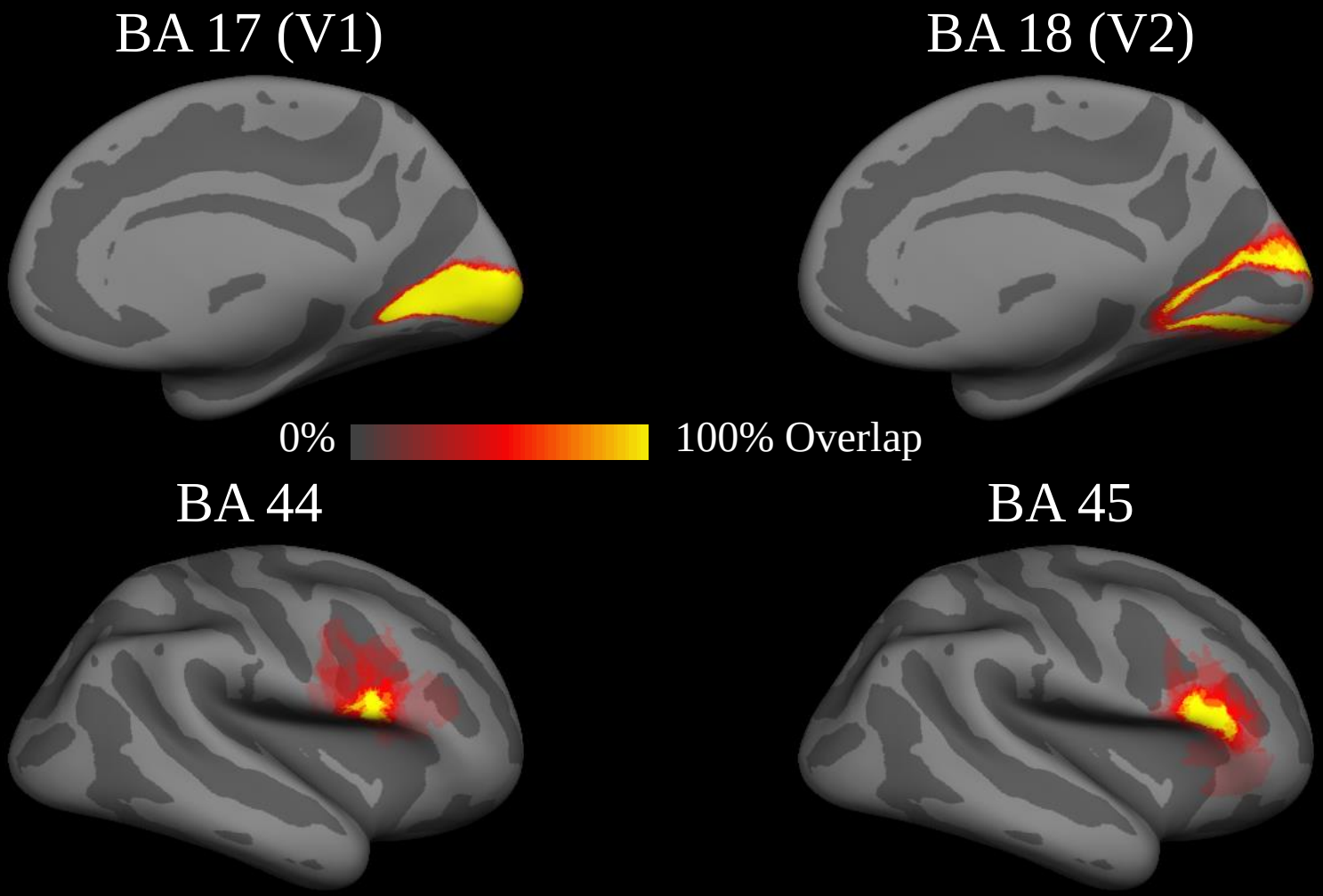
Brodmann, 1909

Predicting Brodmann Areas: Talairach Coordinates



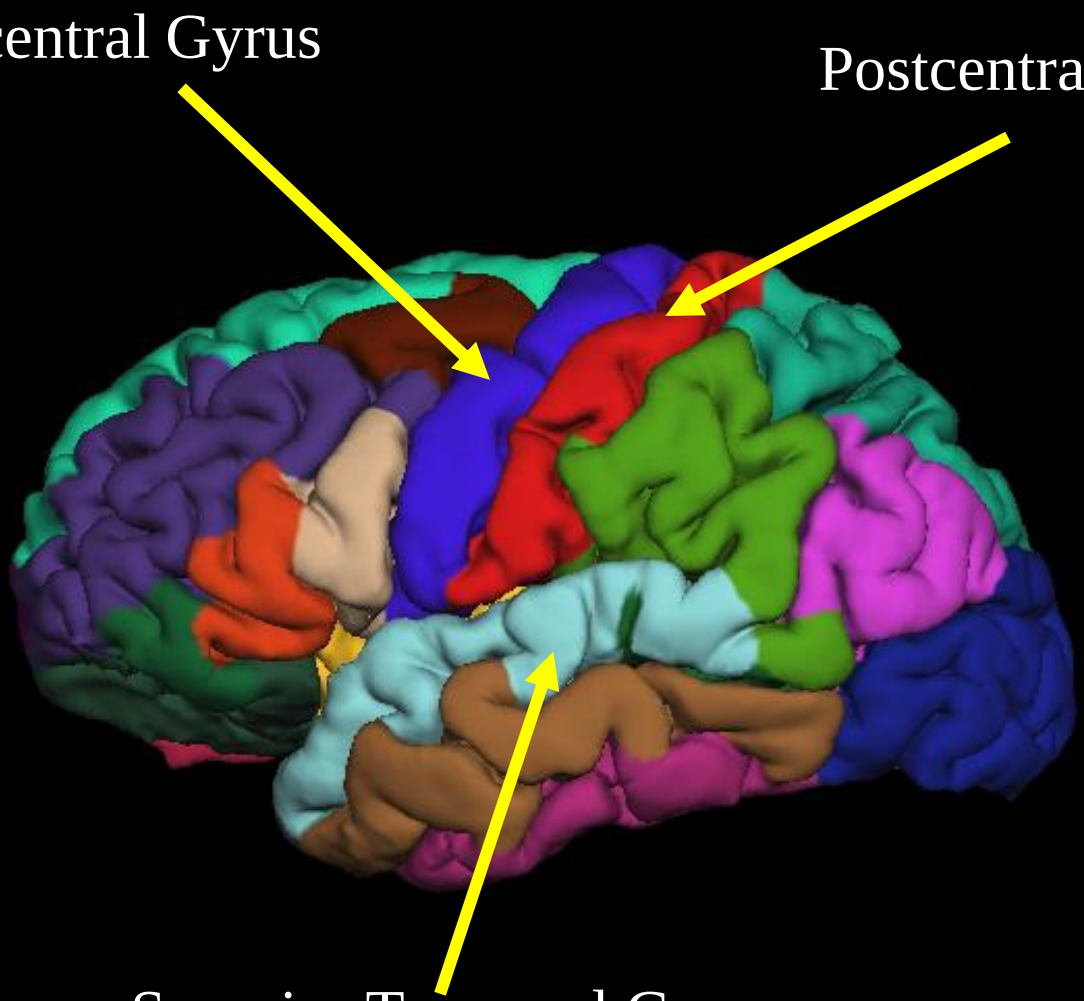
(Amunts et al, 2000, 2004)

Predicting Brodmann Areas from Folding Patterns



Fischl, et al, 2007. Thanks to Katrin Amunts, Karl Zilles and Hartmut Mohlberg for the data, and to Niranjini Rajendran and Evelina Busa for the analysis.

Automatic Gyral Segmentation

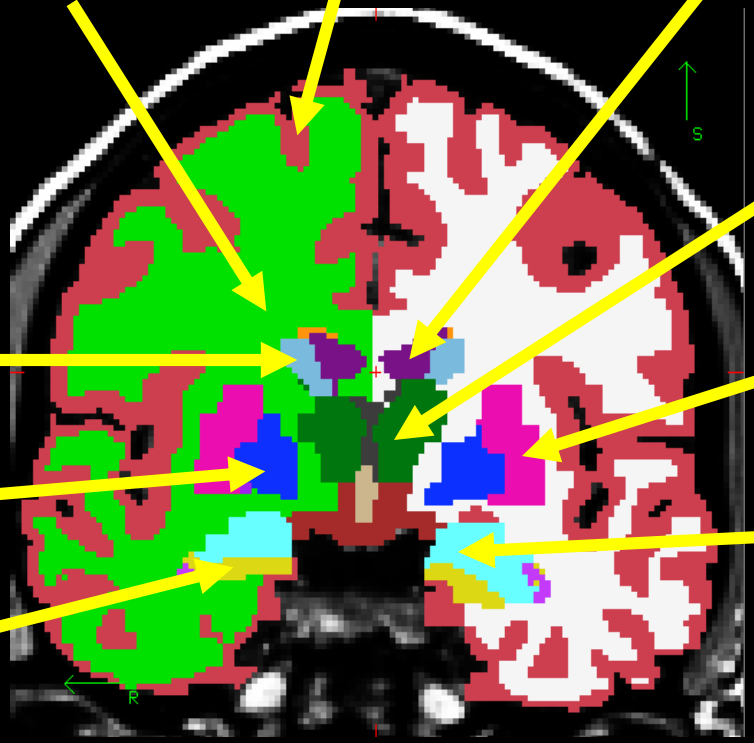


Based on individual's folding pattern

Outline

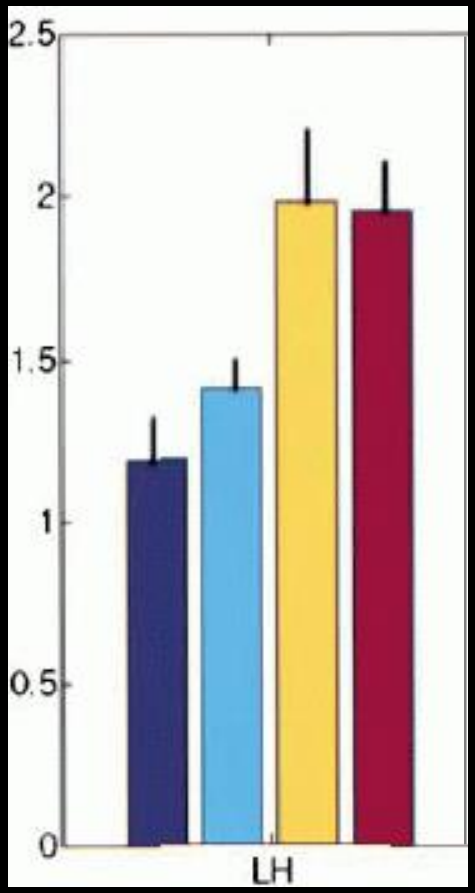
- Anatomical Analysis
  - Surface-based (Cortex)
  - Volume-based
- Multi-modal integration
  - DWI/Tractography
  - fMRI

Volumetric Segmentation (aseg)



Not Shown:
Nucleus Accumbens
Cerebellum

ROI Volume Study



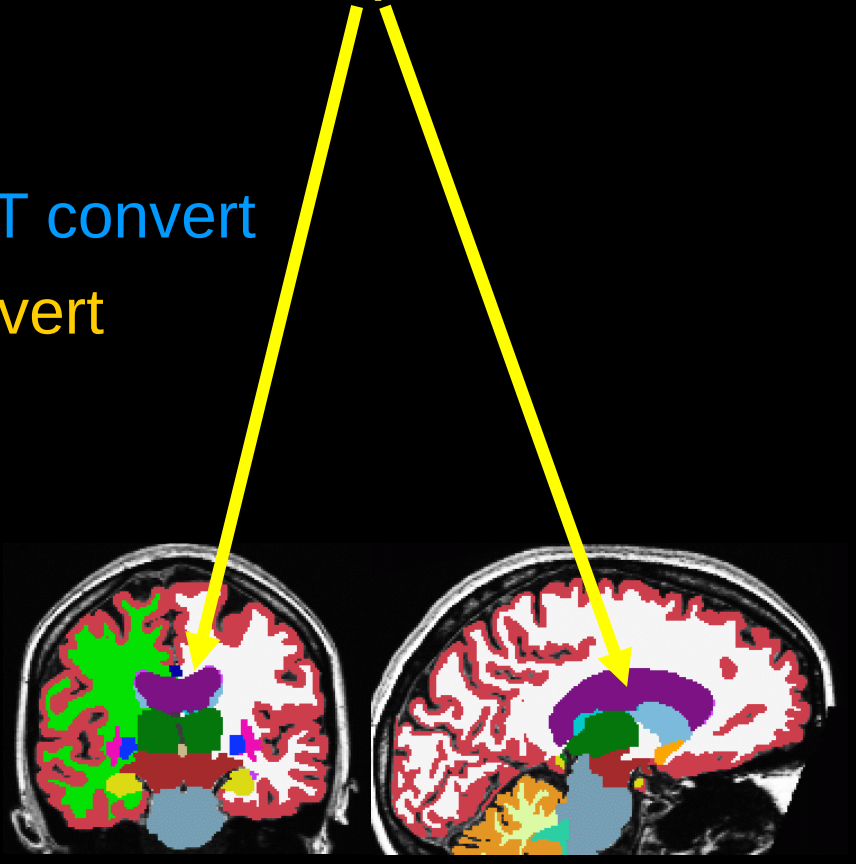
Lateral Ventricular Volume
(Percent of Brain)

Healthy

MCI: Did NOT convert

MCI: Did convert

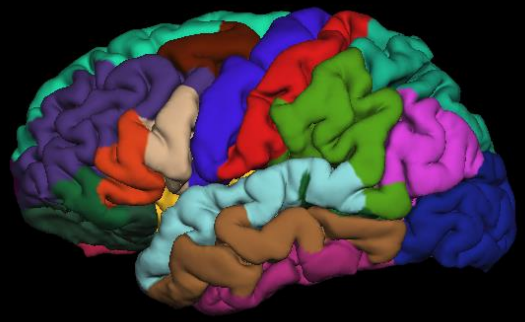
Probable AD



Fischl, et al, 2002, Neuron

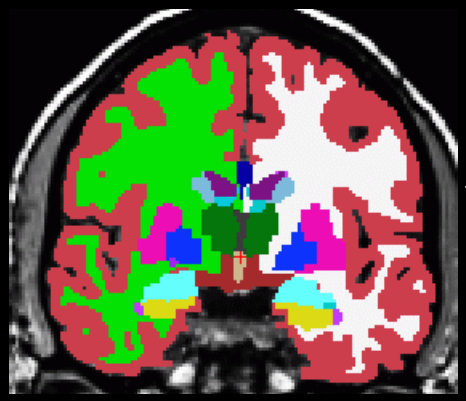
Combined Segmentation

aparc



aparc+aseg

aseg



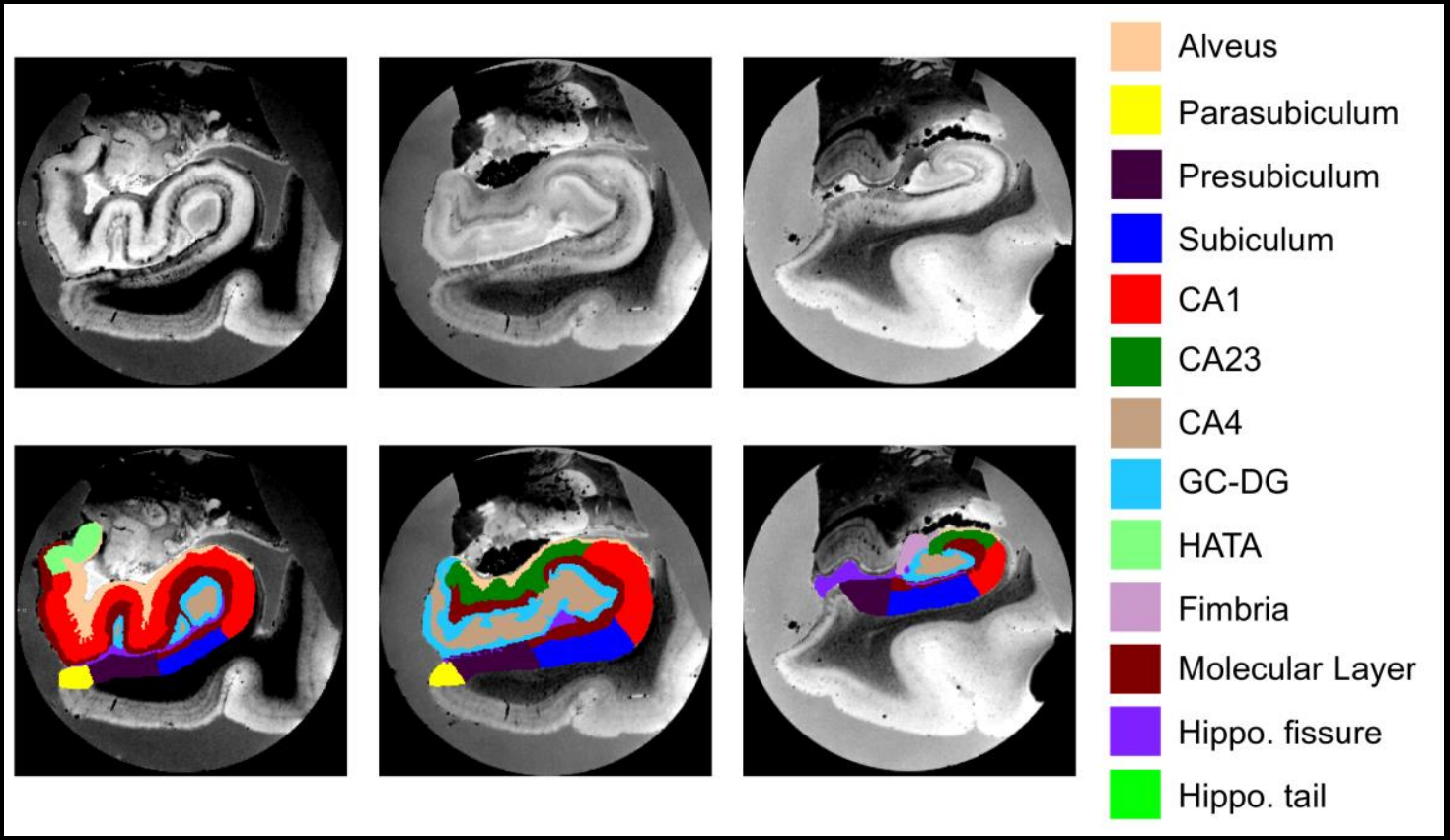
wmparc

Nearest Cortical Label to point in White Matter

Ex vivo MRI of hippocampal subfields

Resolution as high as 0.1 mm isotropic

- Allows precise manual tracing of hippocampal subfields.
- The delineation only relies on geometry for subdividing the CA.



Joint work with J. Eugenio Iglesias, Koen van Leemput and Jean Augustinack

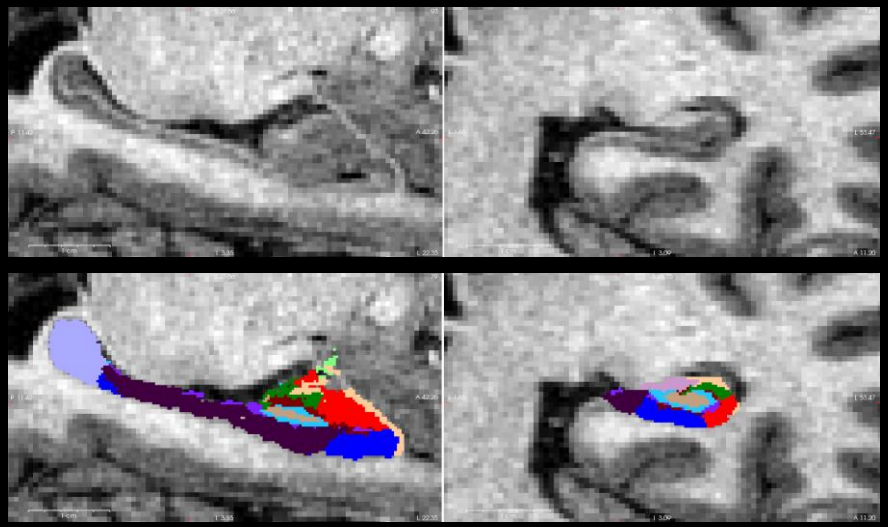
Automated Segmentation

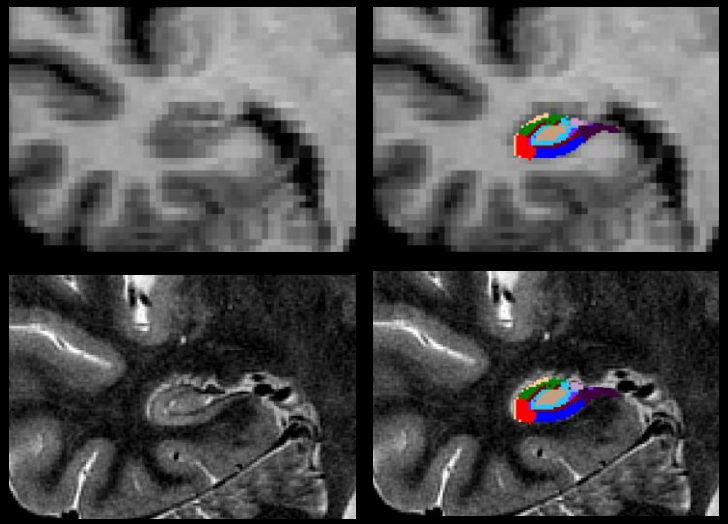
We use the atlas as a prior, and connect it to the image through a Gaussian likelihood term for each label.

- This makes the segmentation sequence-independent.

0.6 mm isotropic T1 (Winterburn et al.)

1 mm T1 + 0.4x0.4x2 mm T2 (ADNI)

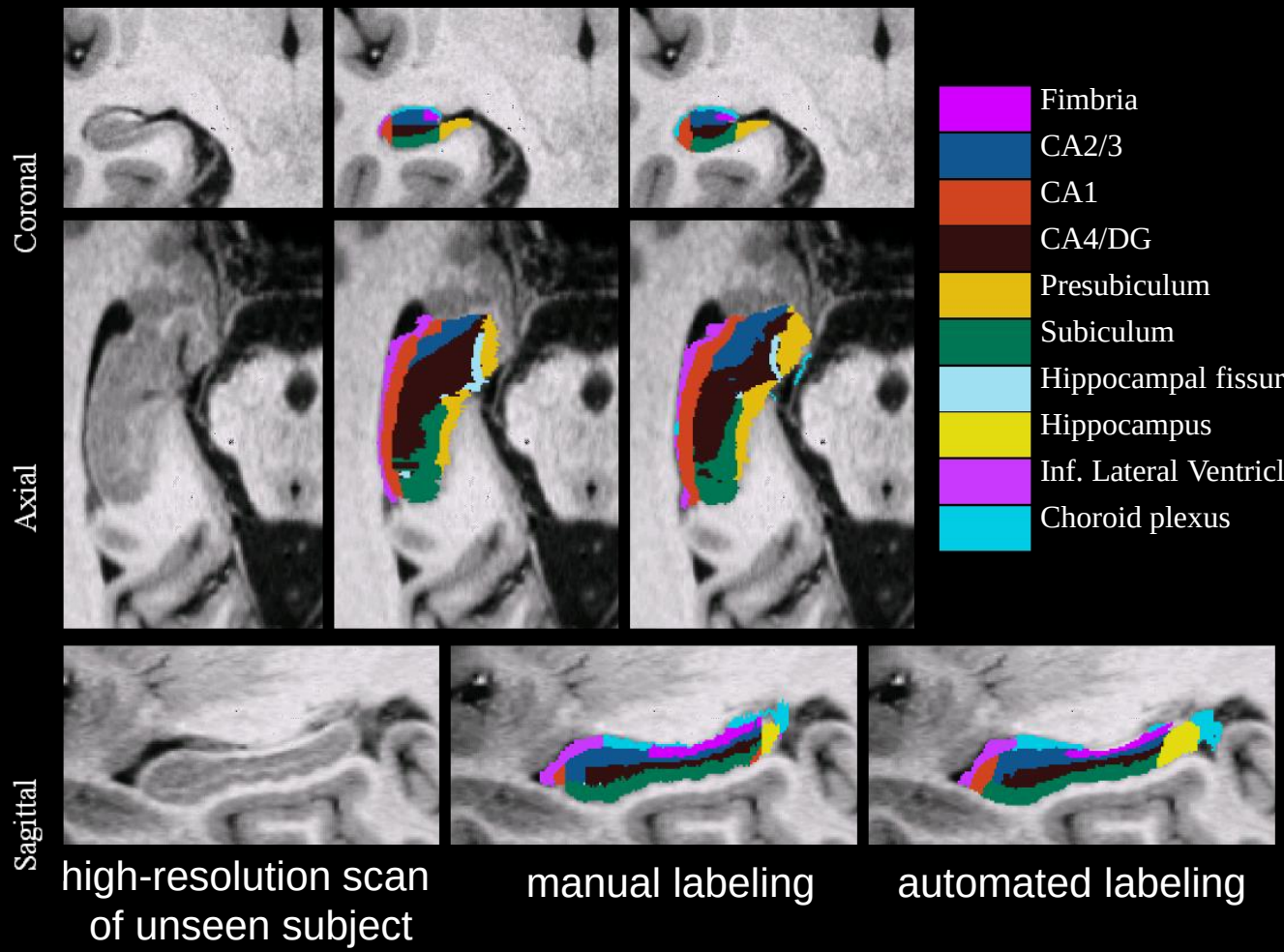


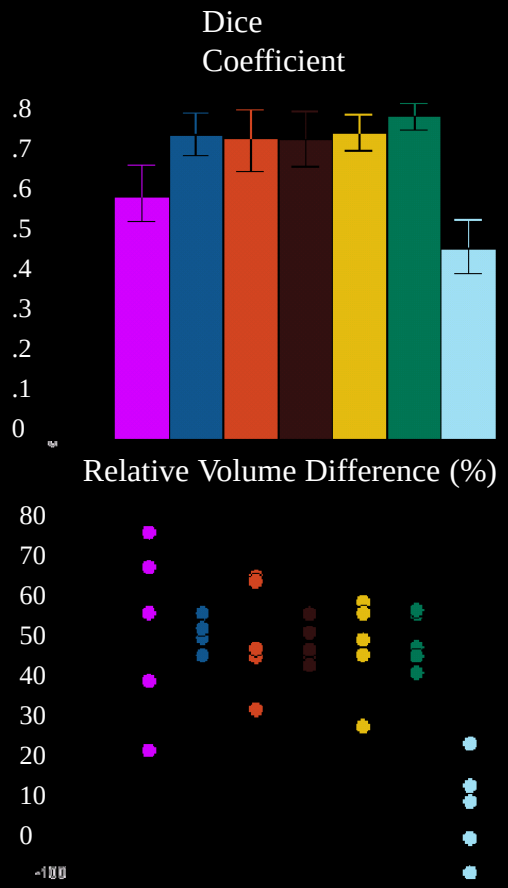


Joint work with J. Eugenio Iglesias, Koen van Leemput and Jean Augustinack

Automated Subfield Segmentation

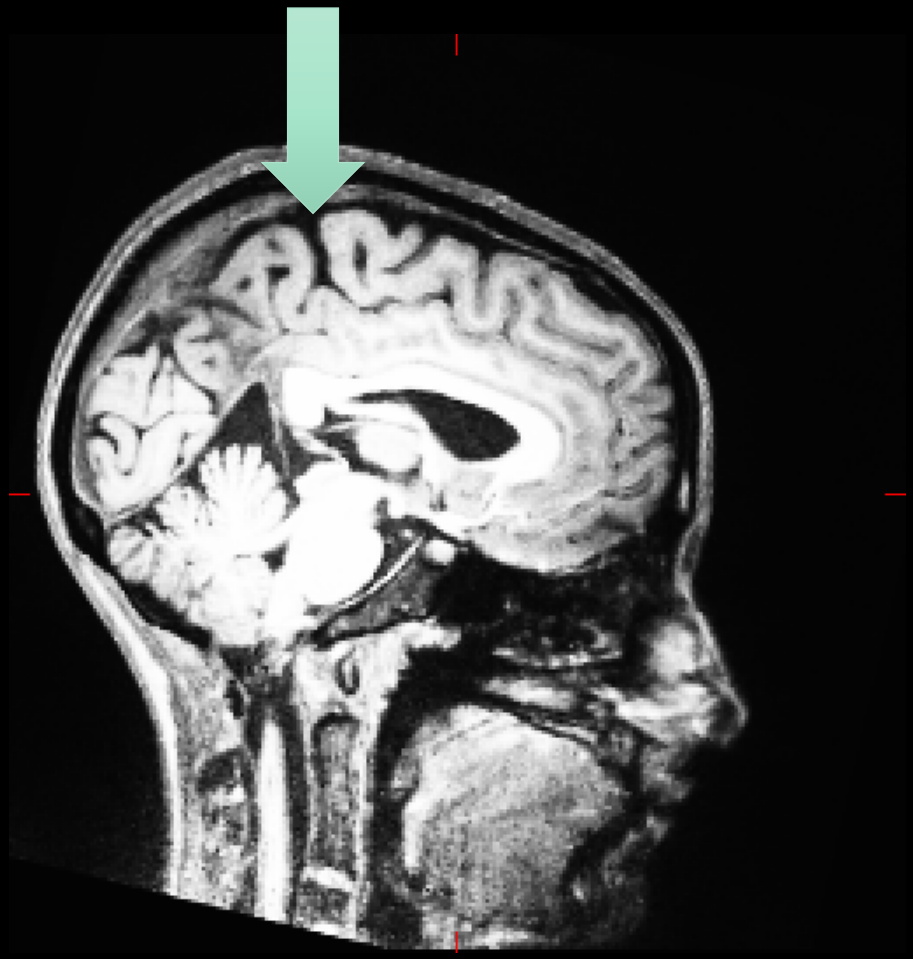
- Leave-one-out cross-validation with 5 subjects





Collaboration with Koen van Leemput, J. Eugenio Iglesias and Jean Augustinack

Robust Registration

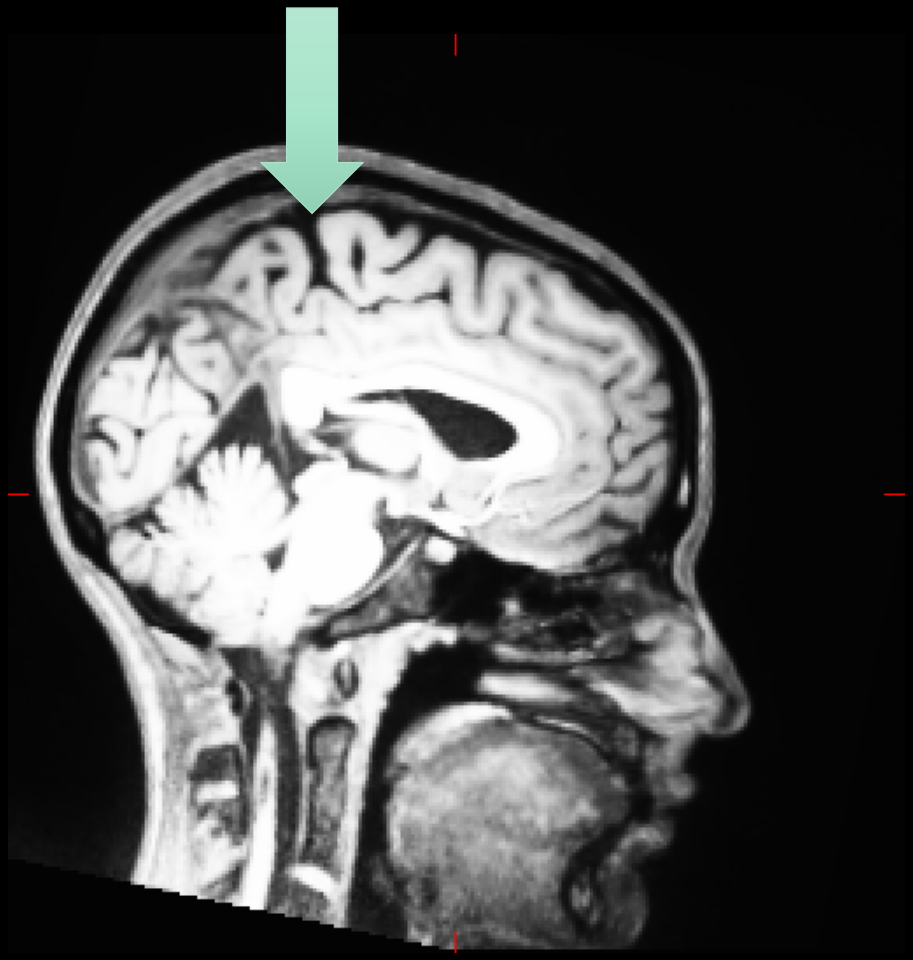


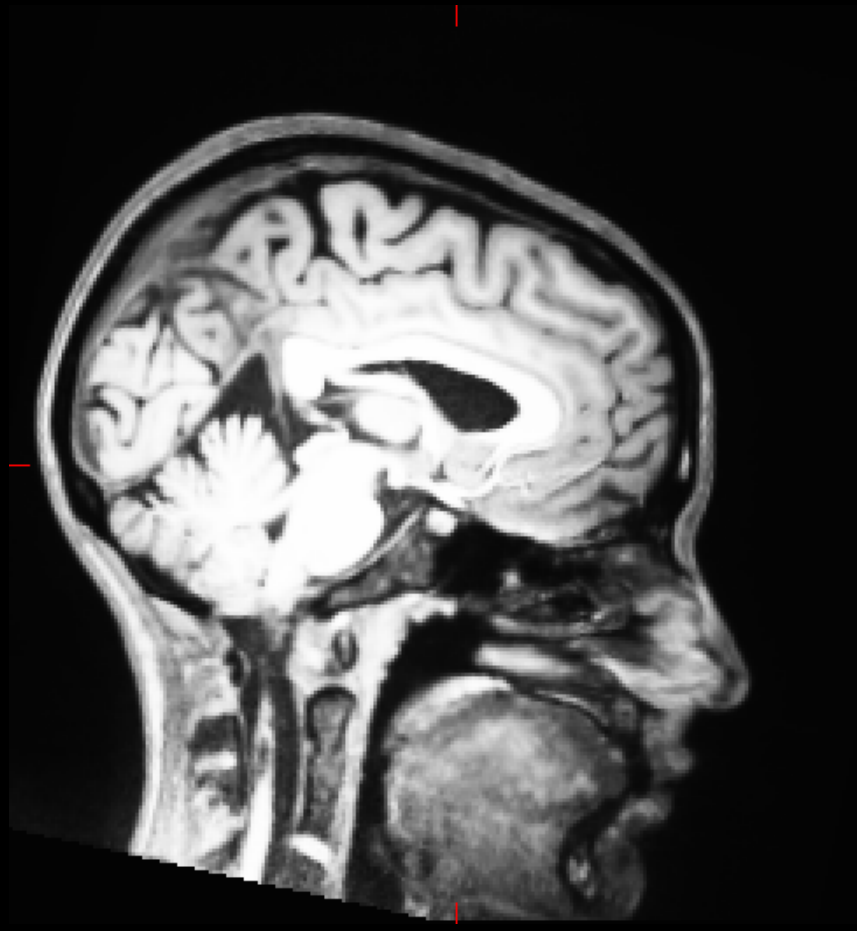
Target

Target

Reuter et al, 2010 NeuroImage

Robust Registration



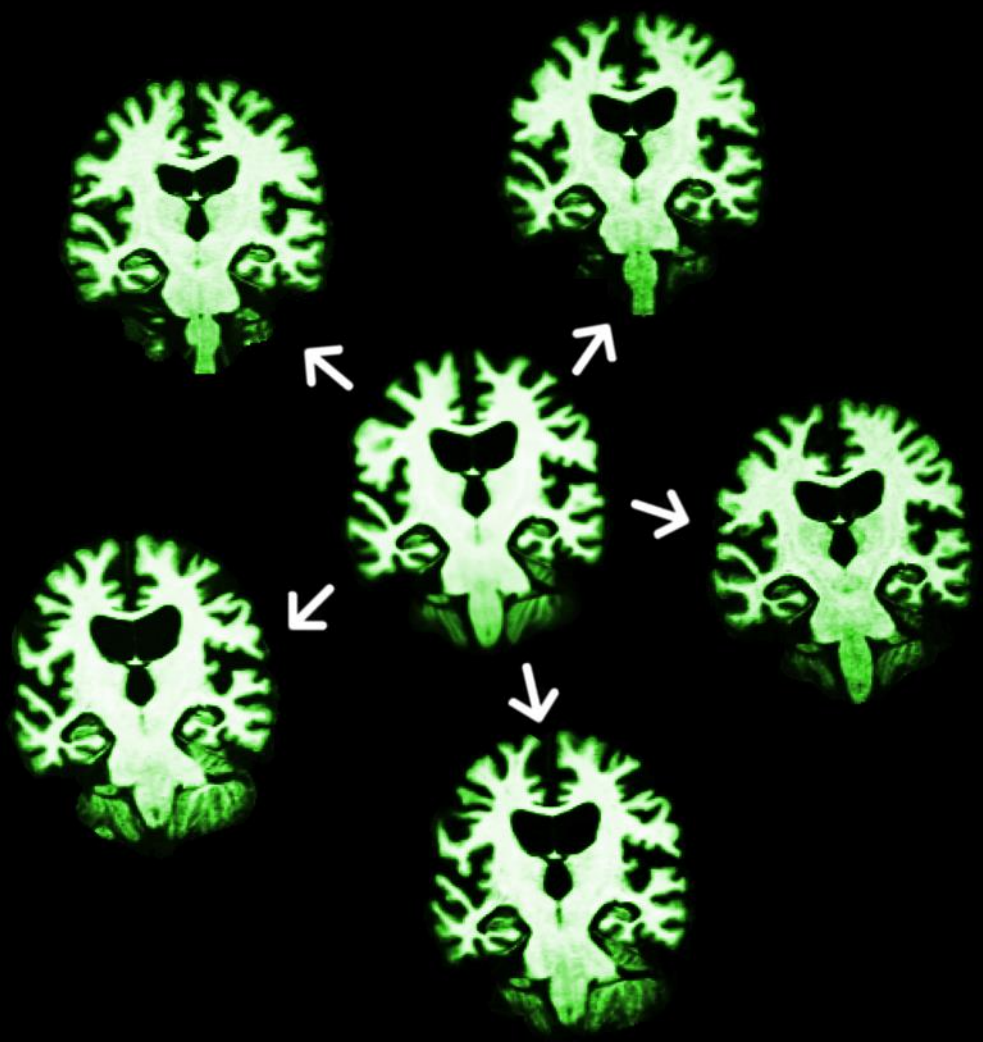


Registered Src correlation ratio

Registered Src Robust

Reuter et al, 2010 NeuroImage

Longitudinal Processing



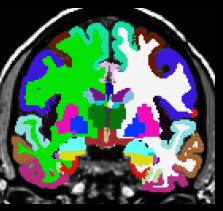
1. Create unbiased subject template (iterative registration to median)
2. Process template
3. Initialize time points
4. Let it evolve there

- Avoid Bias: All time points are treated the same
- Increases sensitivity and reliability!

Reuter et al. OHBM 2010, NeuroImage 2011 & 2012

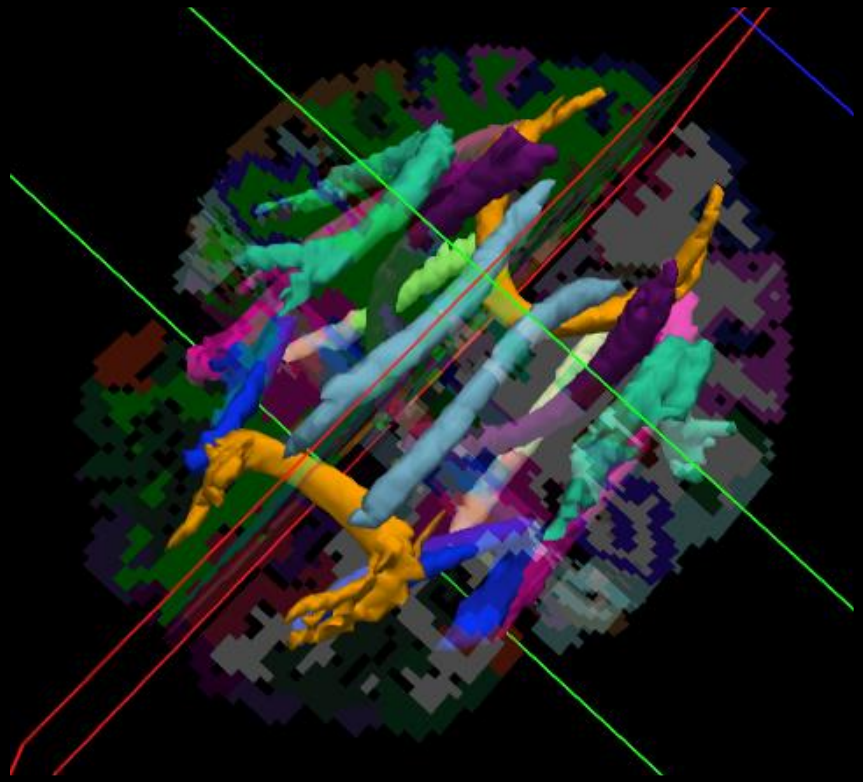
Outline

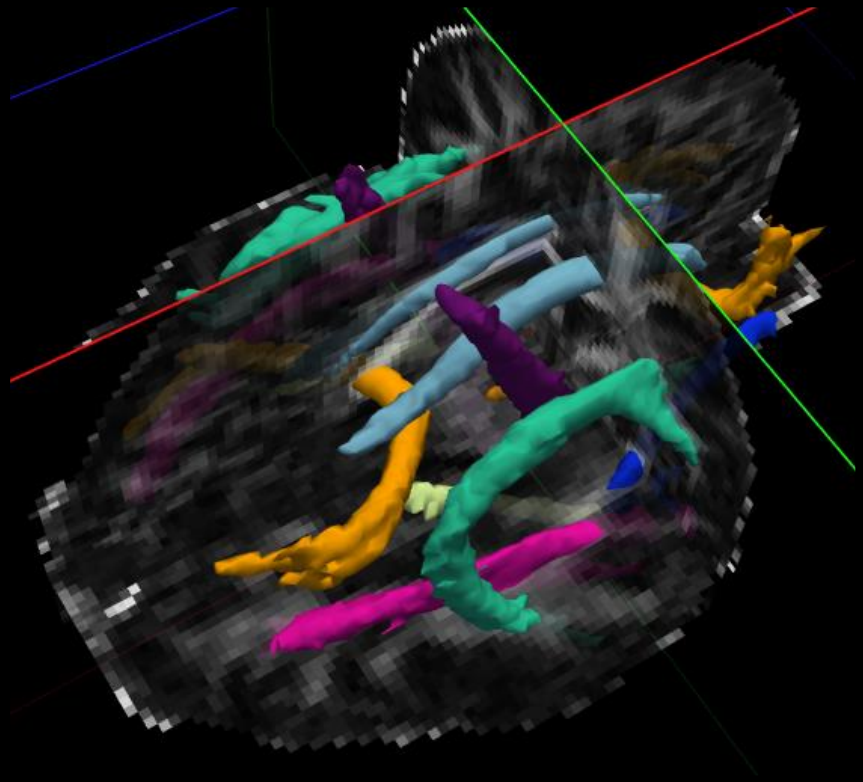
- Anatomical Analysis
  - Surface-based (Cortex)
  - Volume-based
- Multi-modal integration
  - DWI/Tractography
  - fMRI



Tractography with TRACULA

(TRActs Constrained by the Underlying Anatomy)





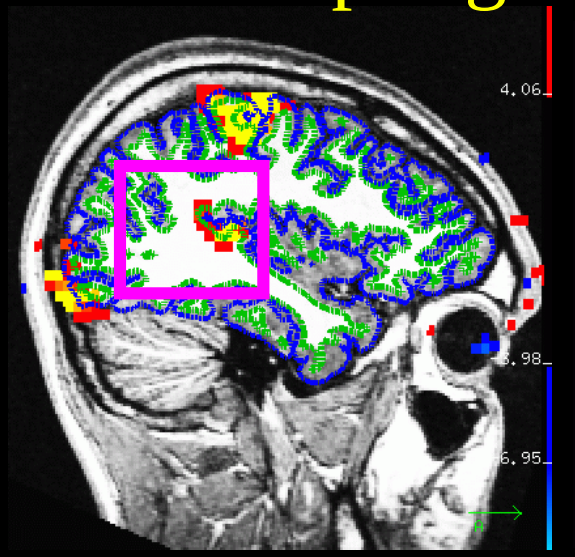
- Completely automated modeling of 18 major fascicles
- Uses prior probabilistic information on the anatomical structures that each fascicle goes through or next to

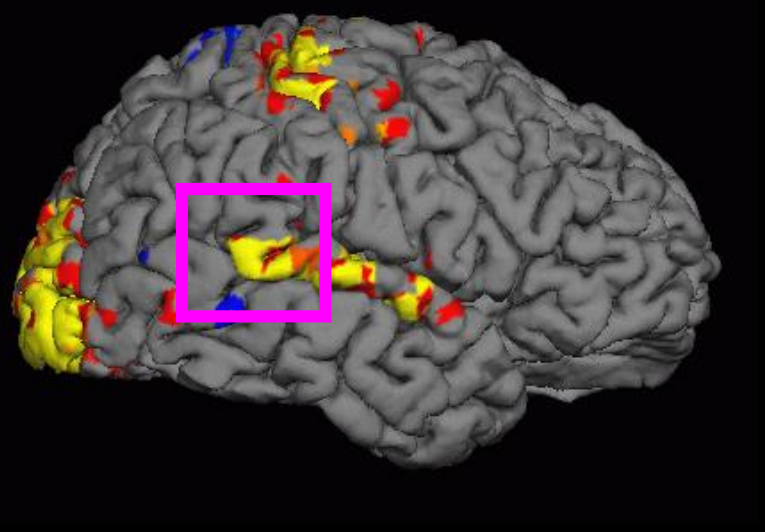
Collaboration with Anastasia Yendiki, Lilla Zöllei, Saad Jbabdi, Tim Behrens and Jean Augustinack

Outline

- Anatomical Analysis
  - Surface-based (Cortex)
  - Volume-based
- Multi-modal integration
  - DWI/Tractography
  - fMRI – task

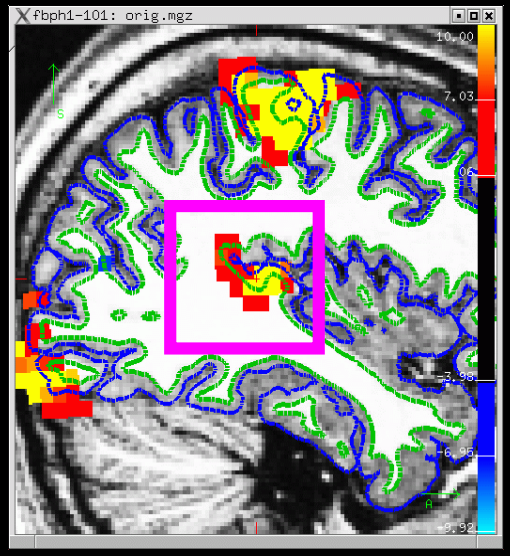
Sampling on the Surface

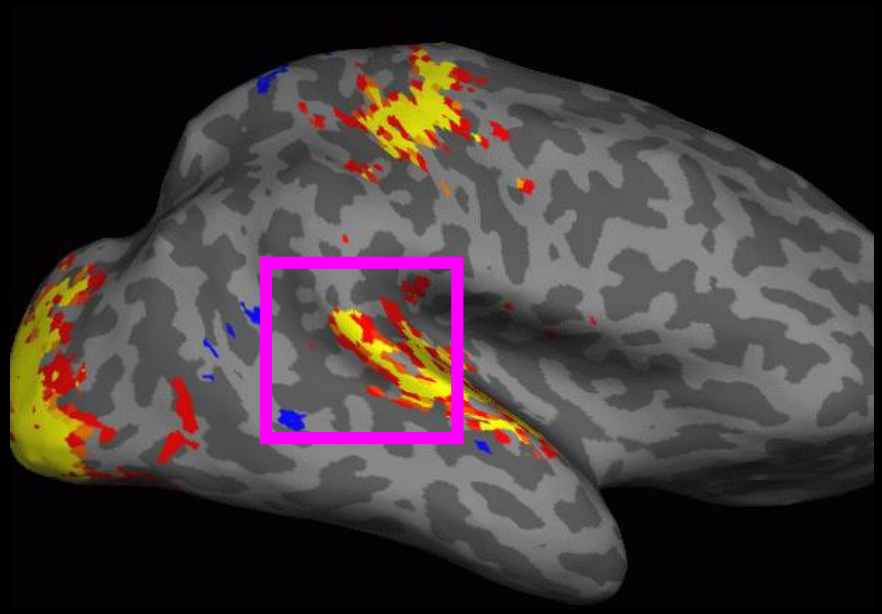




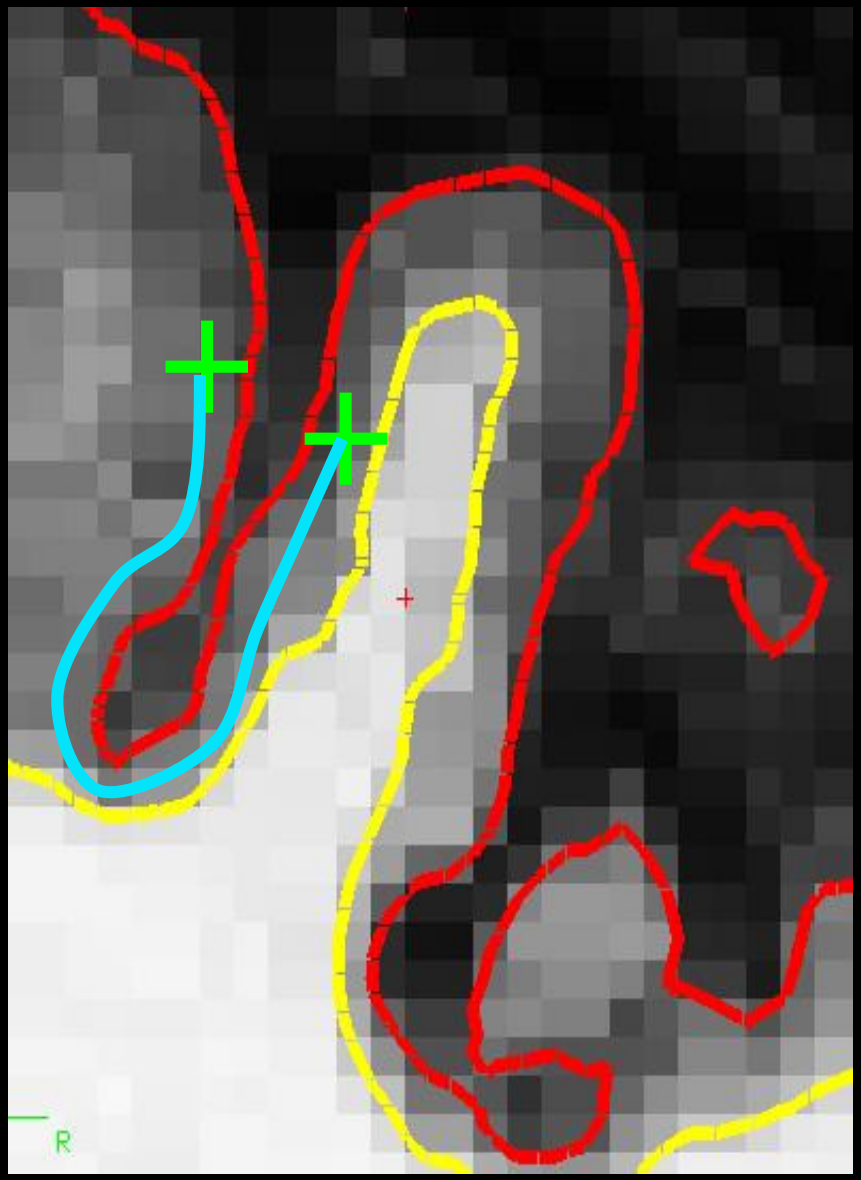
15 sec ‘ON’, 15 sec ‘OFF’

- Flickering Checkerboard
- Auditory Tone
- Finger Tapping

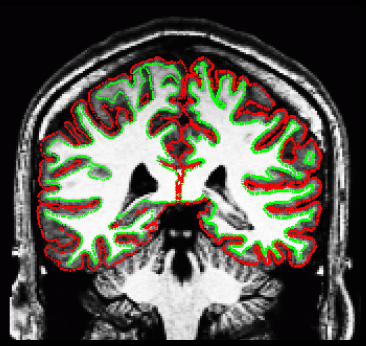




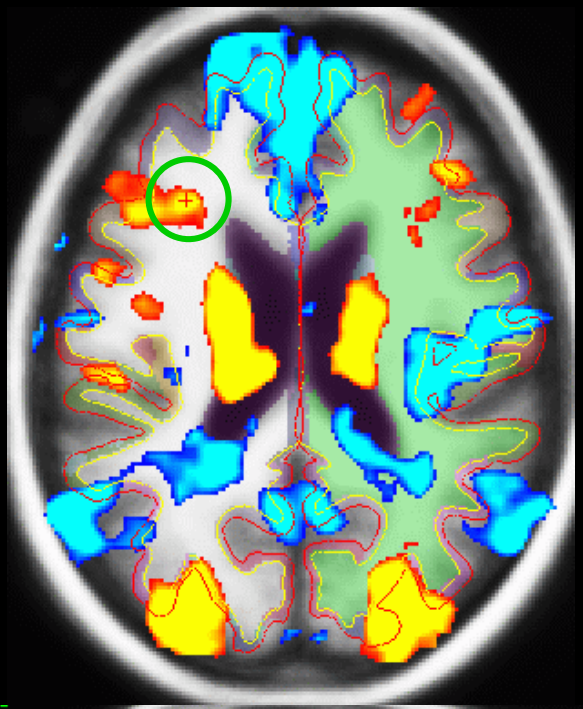
Spatial Smoothing

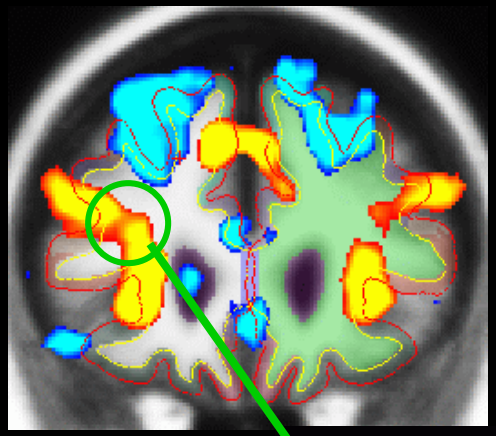


- 5 mm apart in 3D
- 25 mm apart on surface!
- Kernel much larger
- Averaging with other tissue types (WM, CSF)
- Averaging with other functional areas



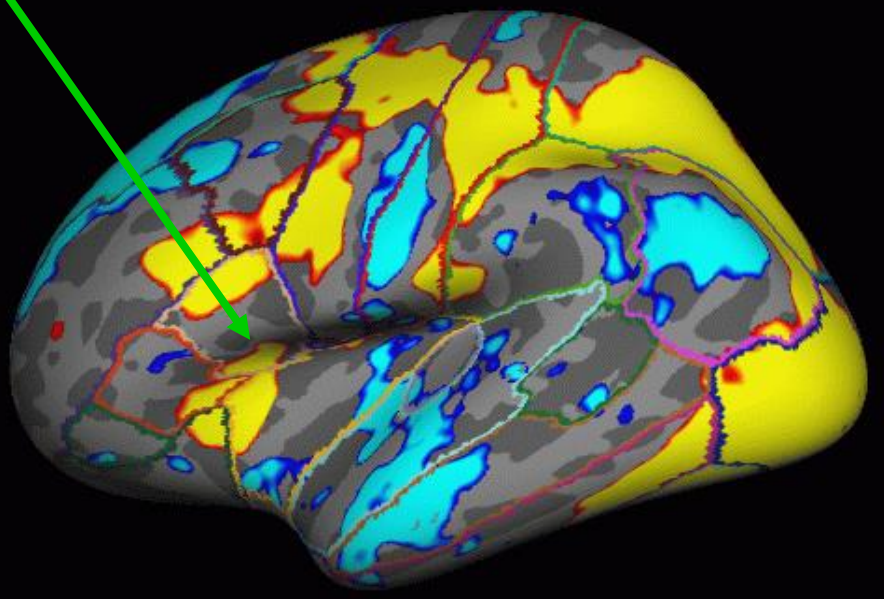
Group fMRI Analysis: Volume vs Surface

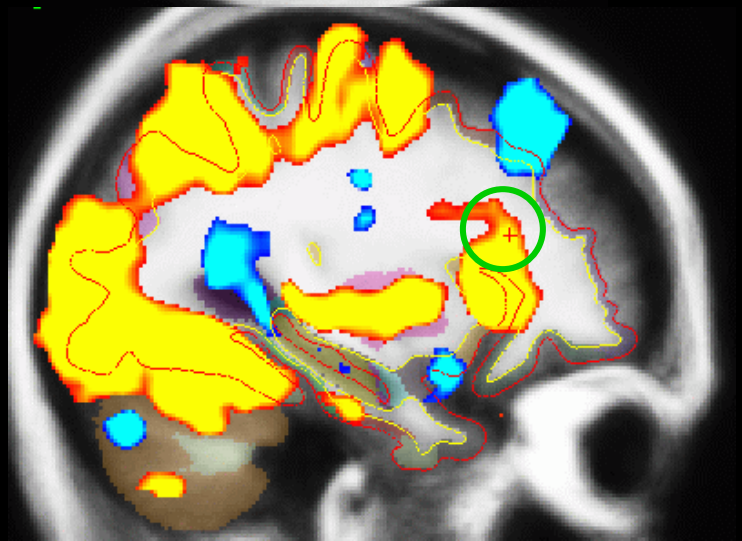




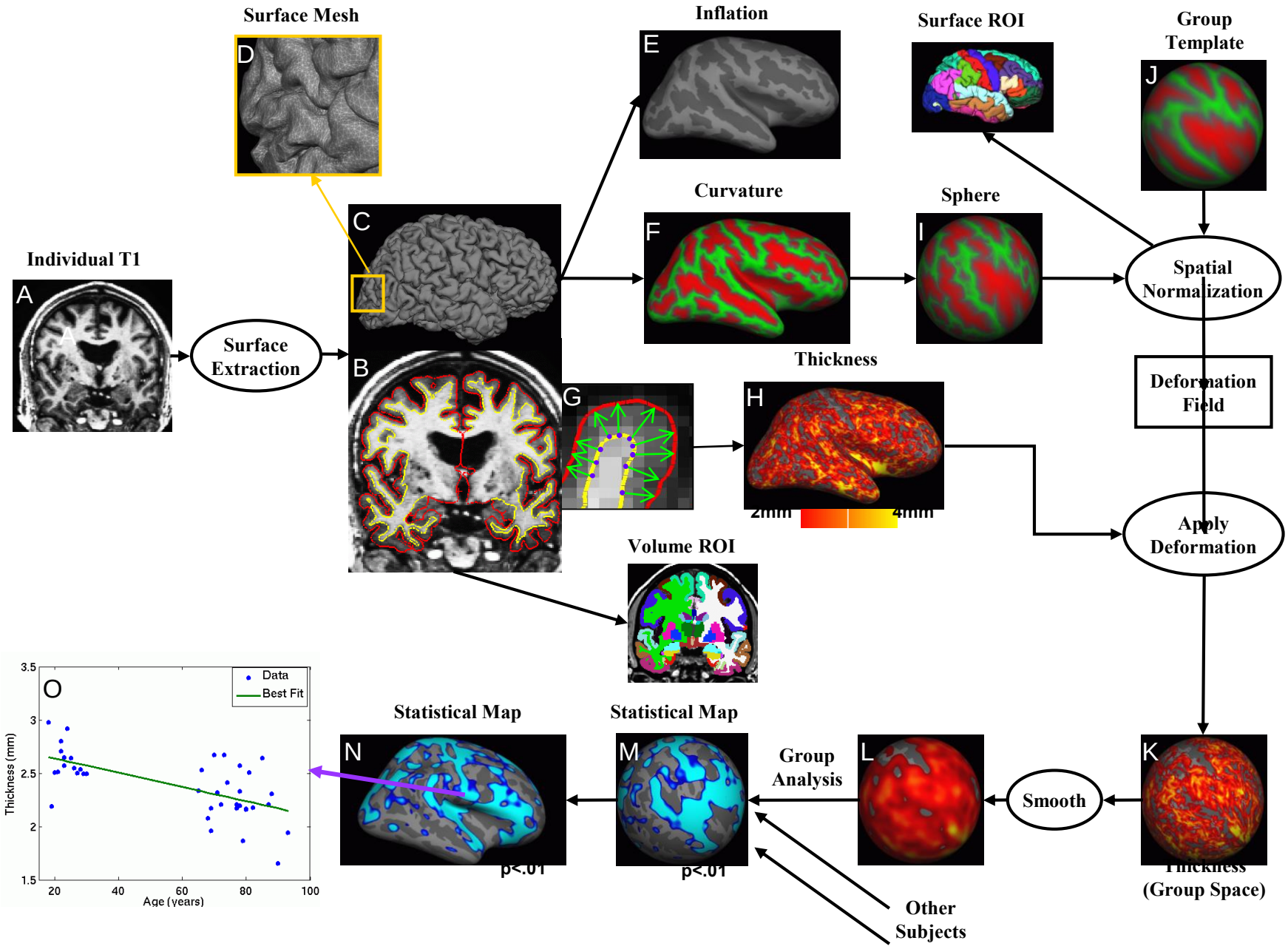
Affine registration to MNI305

5mm volume smoothing vs.
10mm surface smoothing





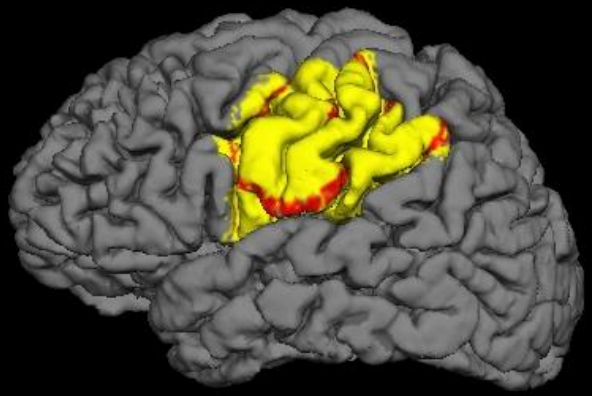
FreeSurfer Analysis Pipeline Overview



What is FreeSurfer?

- Cortical extraction and labeling
- Subcortical Segmentation
- Surface-based Inter-subject Registration
- Fully automated
- Multi-modal integration

Use FreeSurfer



Be Happy