Computational Anatomy Toolbox

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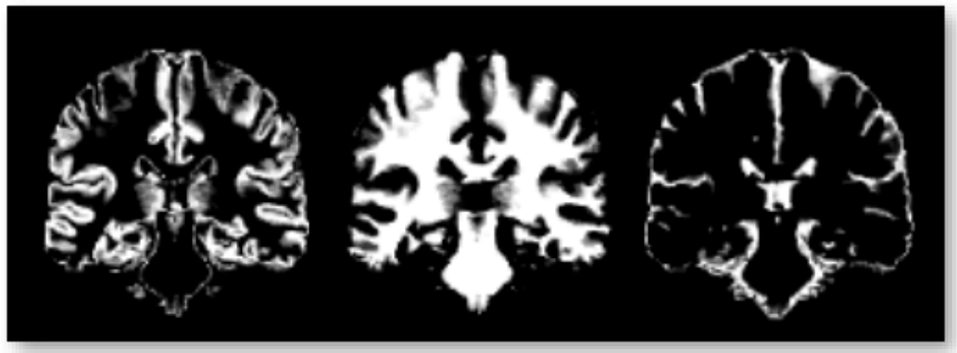
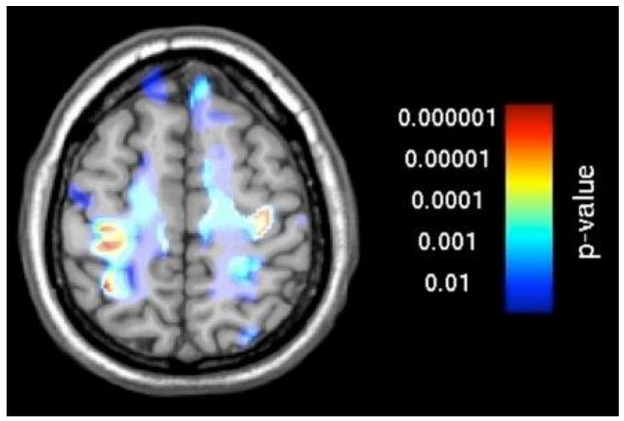
Computational Anatomy

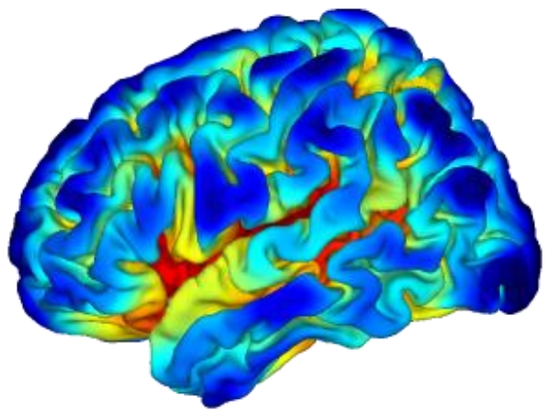
Voxel-based morphometry



Structural plasticity

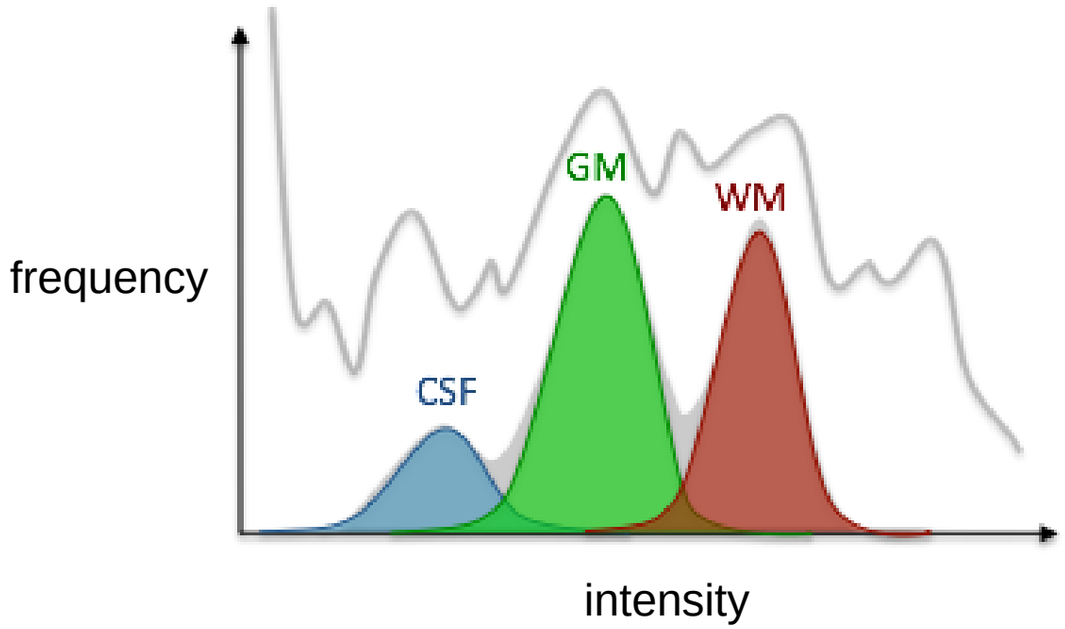


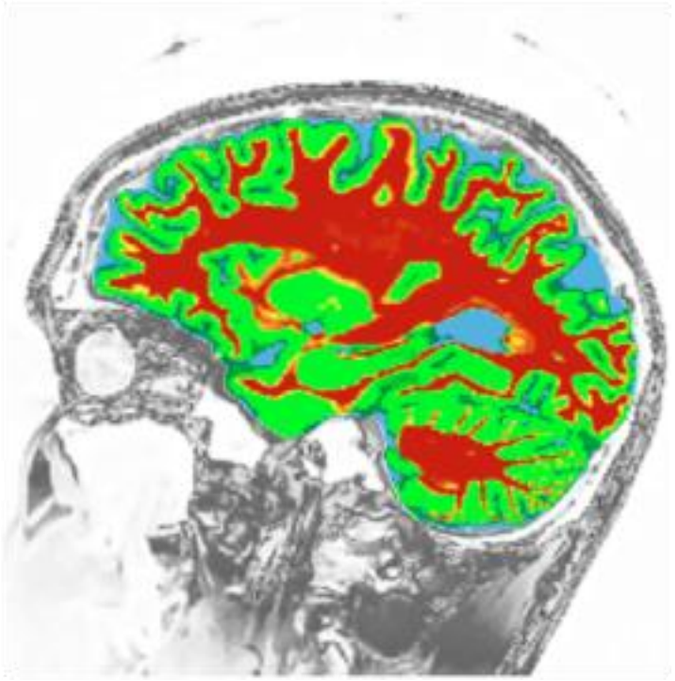
Surface-based morphometry



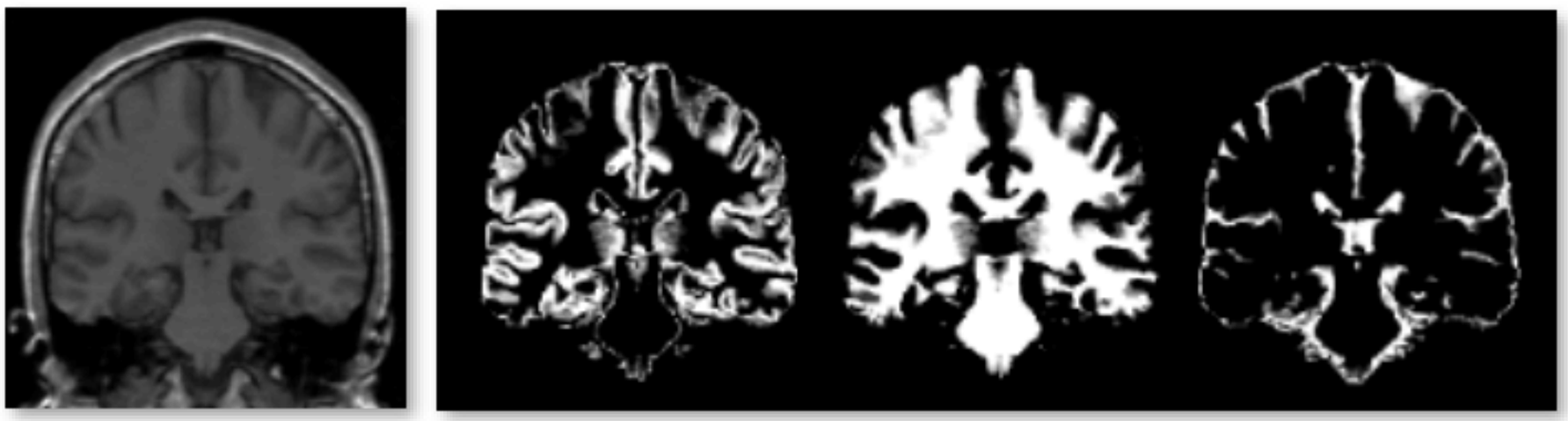
Aging / Dementia

Voxel-based Morphometry (VBM)

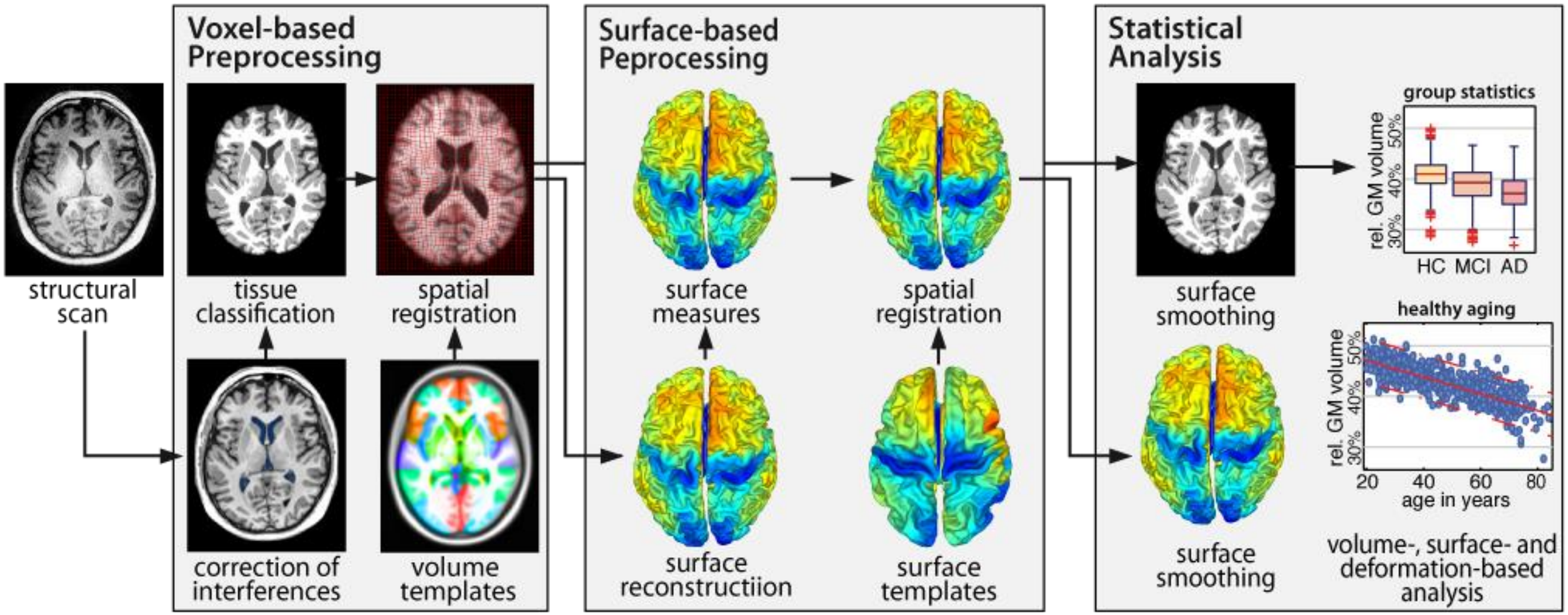




T_1-MRI	gray matter	white matter	CSF



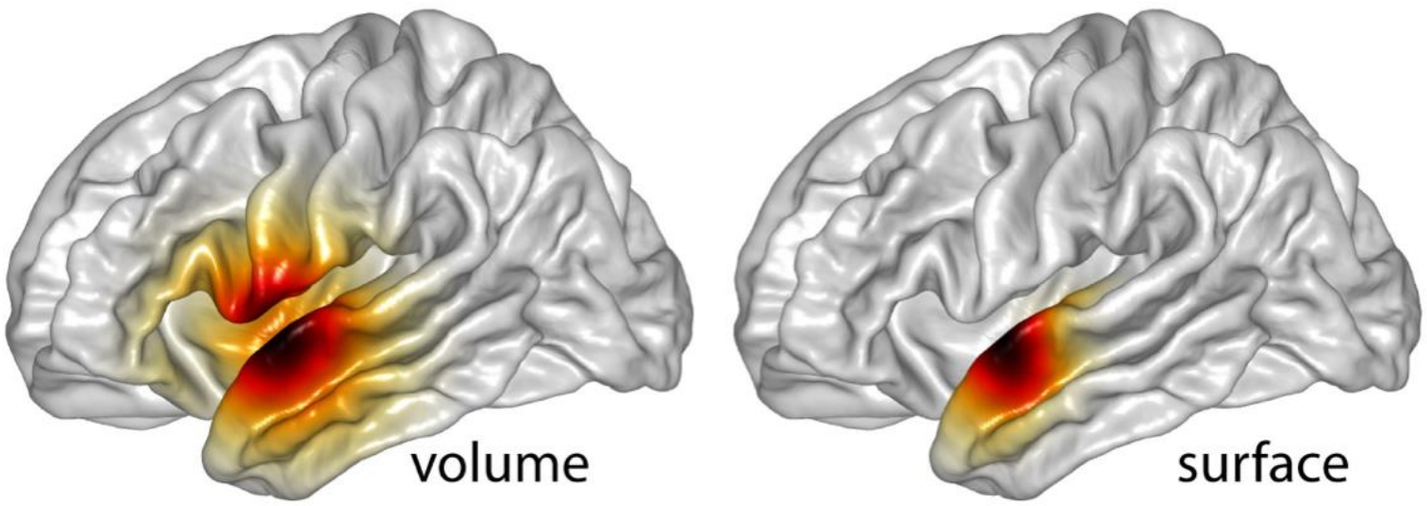
Processing Data



Motivation for Surface-Based Analysis

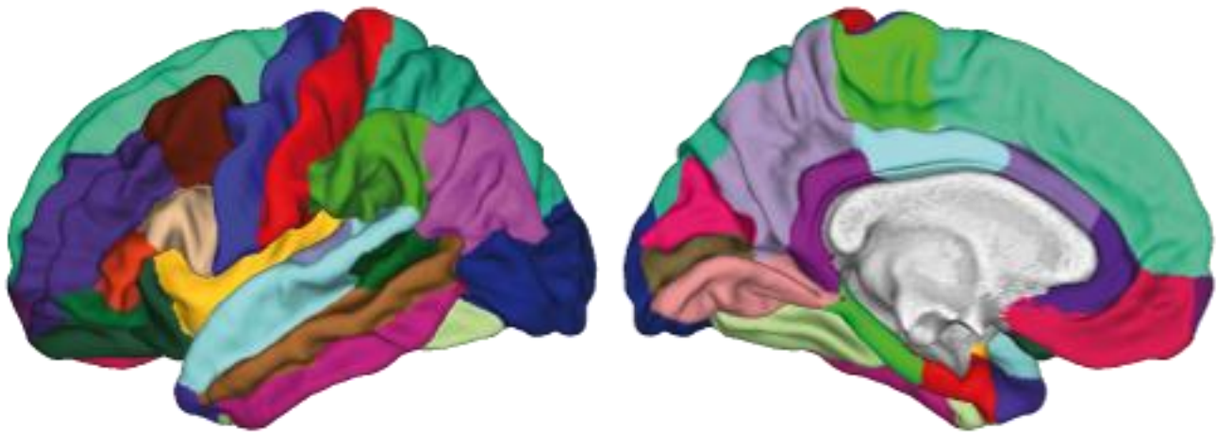
Advantages of surface-based approaches

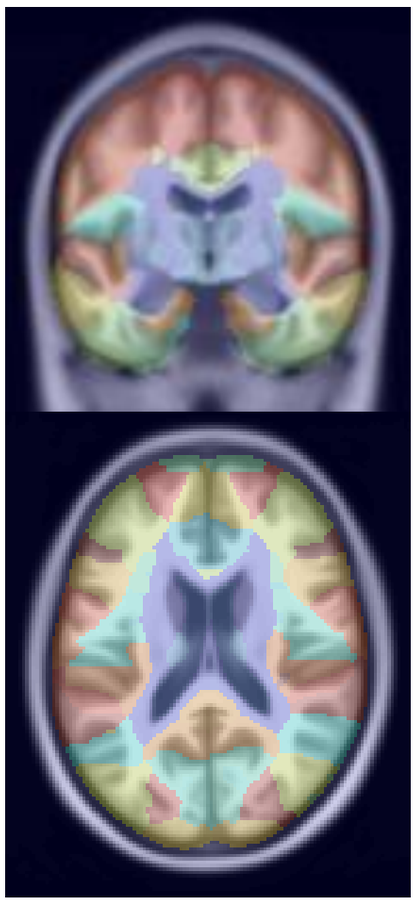
- Analysis of additional parameters (cortical thickness, gyrification, fractal dimension, sulcal depth)
- Visualization
- Advantages for spatial registration (analysis in surface space)
- Euclidiar

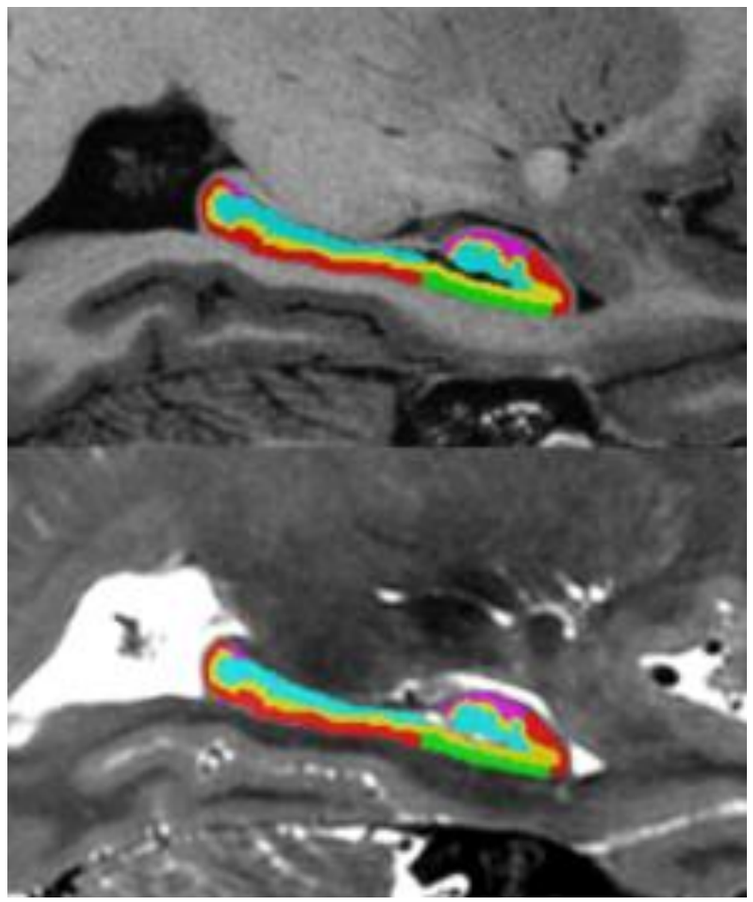


Filterung

Predefined Regions of Interest







Surface atlases:

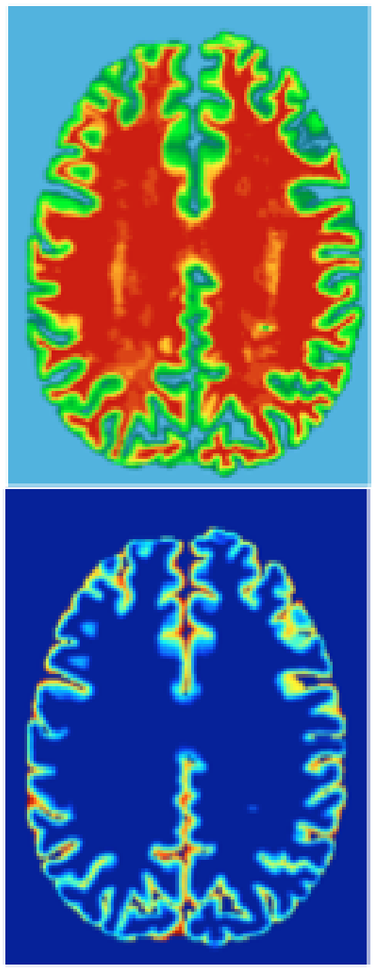
- Desikan-Killiany (2005)
- Destrieux (2009)

3D atlases:

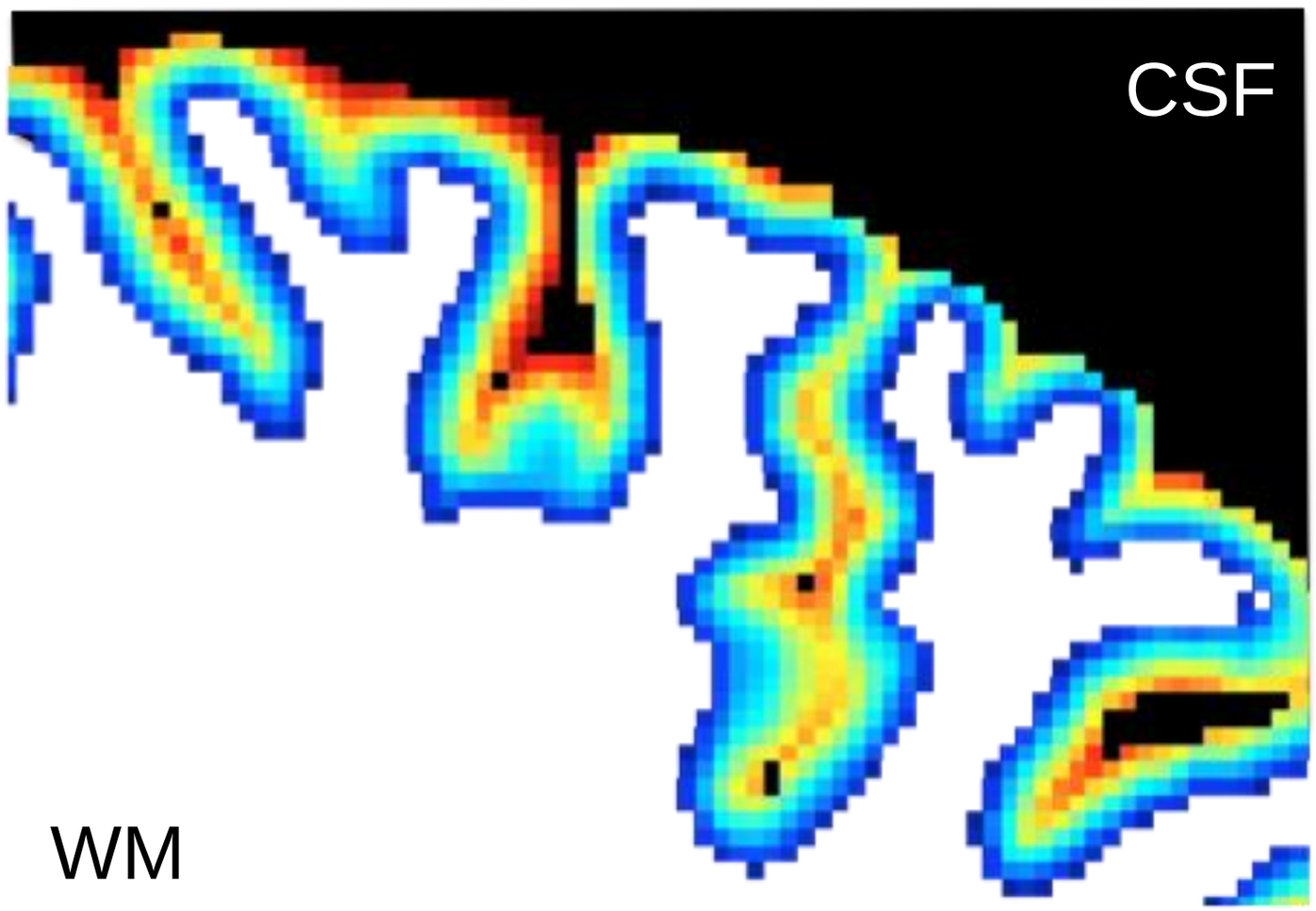
- Neuromorphometrics
- Hammers
- LPBA40
- Mori
- AAL
- Hippocampal subfields / amygdala
- Cerebellar lobes (Larsell)

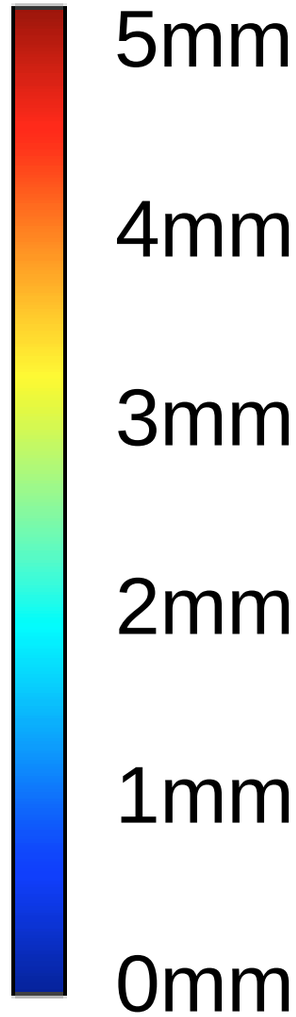
Estimation of Cortical Thickness and Surface

Projection-based Thickness (PBT) - WM distance map



WM

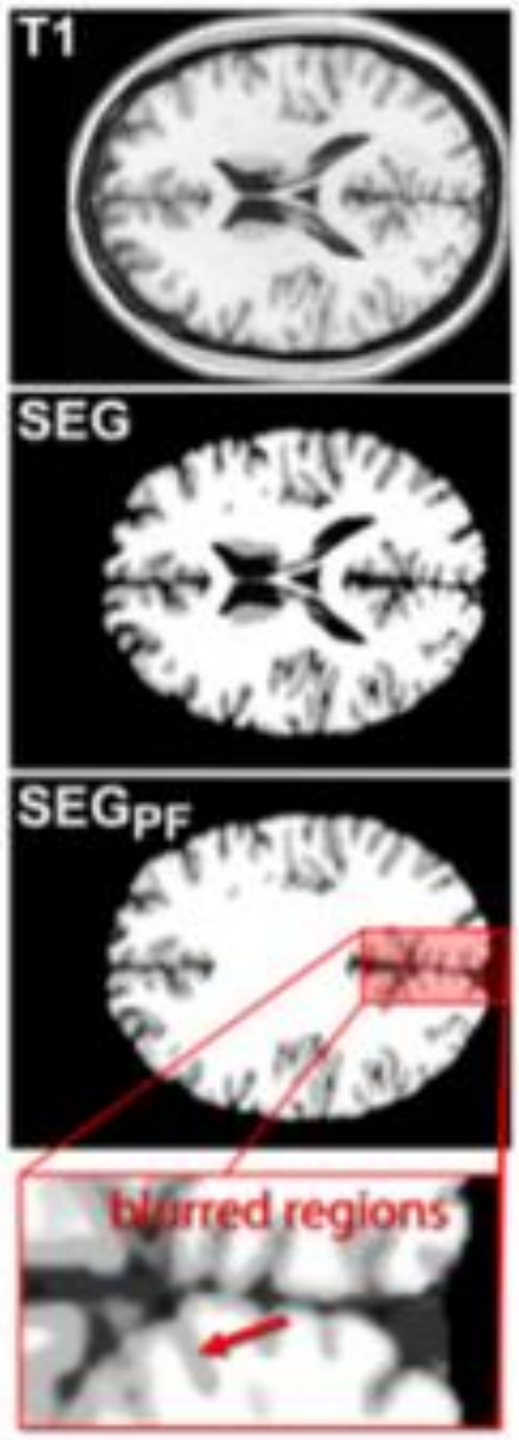


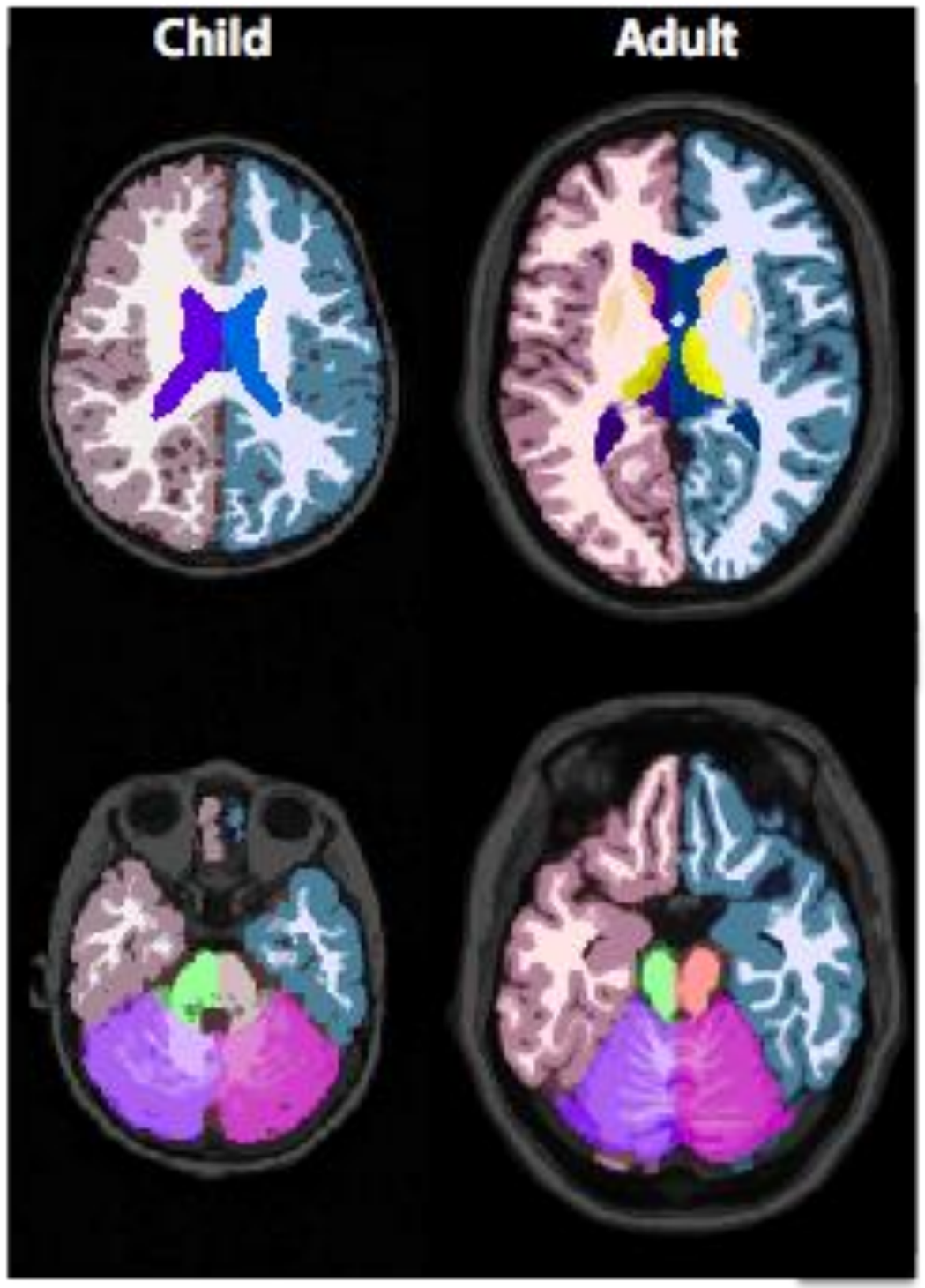


Dahnke et al. NeuroImage 2012

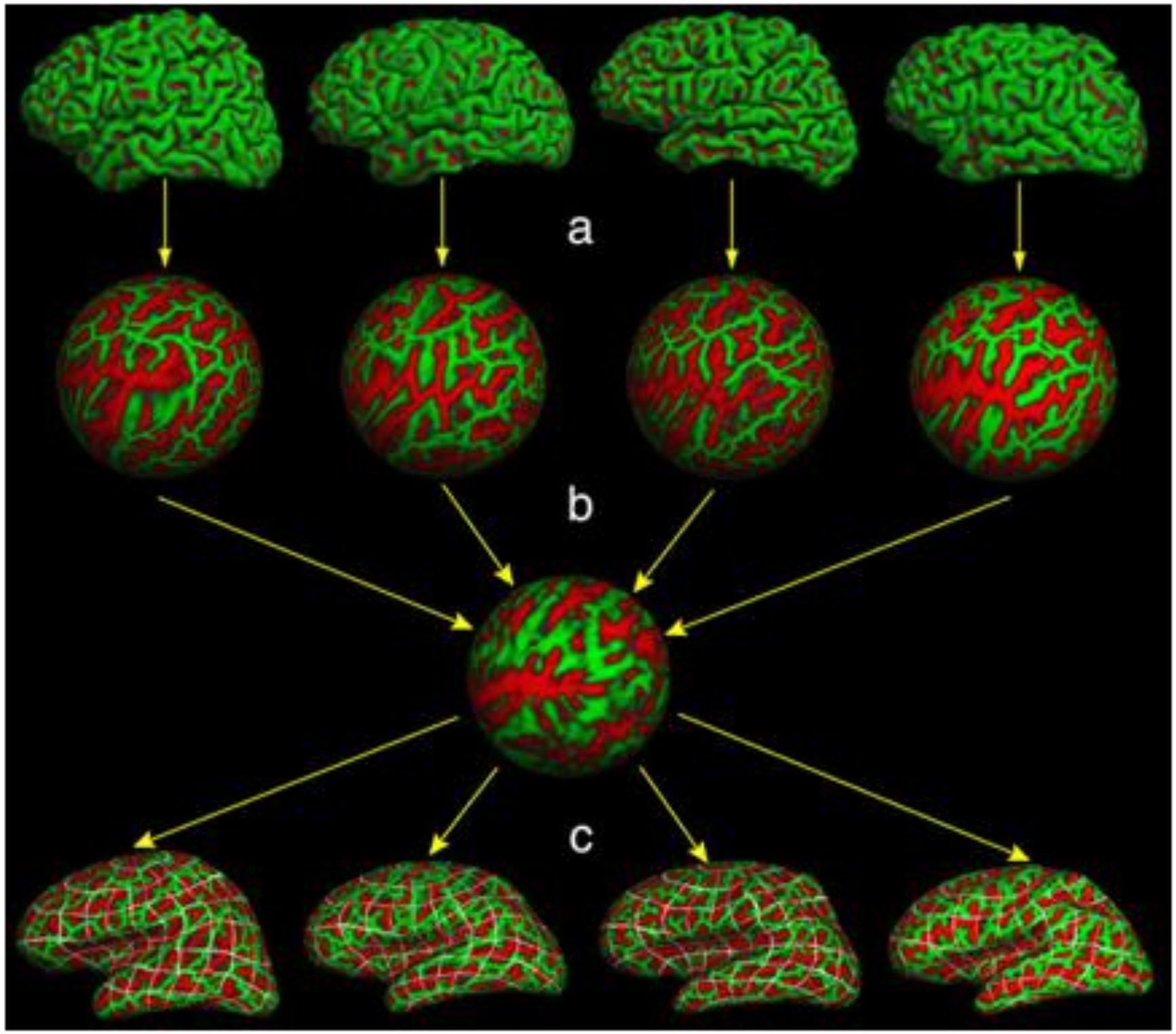
Surface Preprocessing

- Skull-stripping: removal of skull and background
- Segmentation (with bias correction, denoising)
- Filling of subcortical areas
- Partitioning of both hemispheres and removal of cerebellum
- Reconstruction of sulci



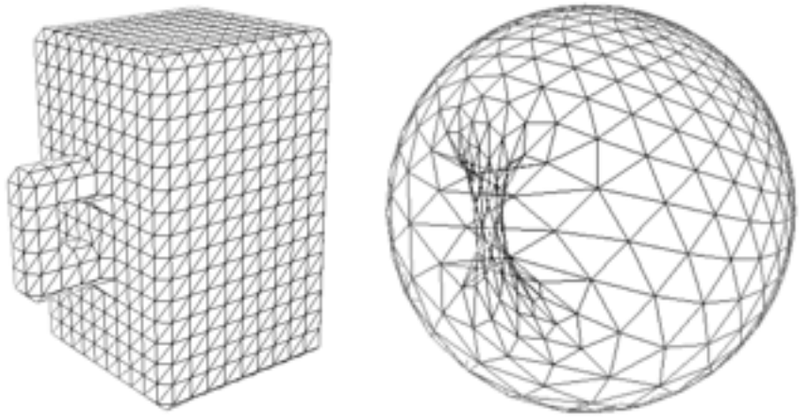


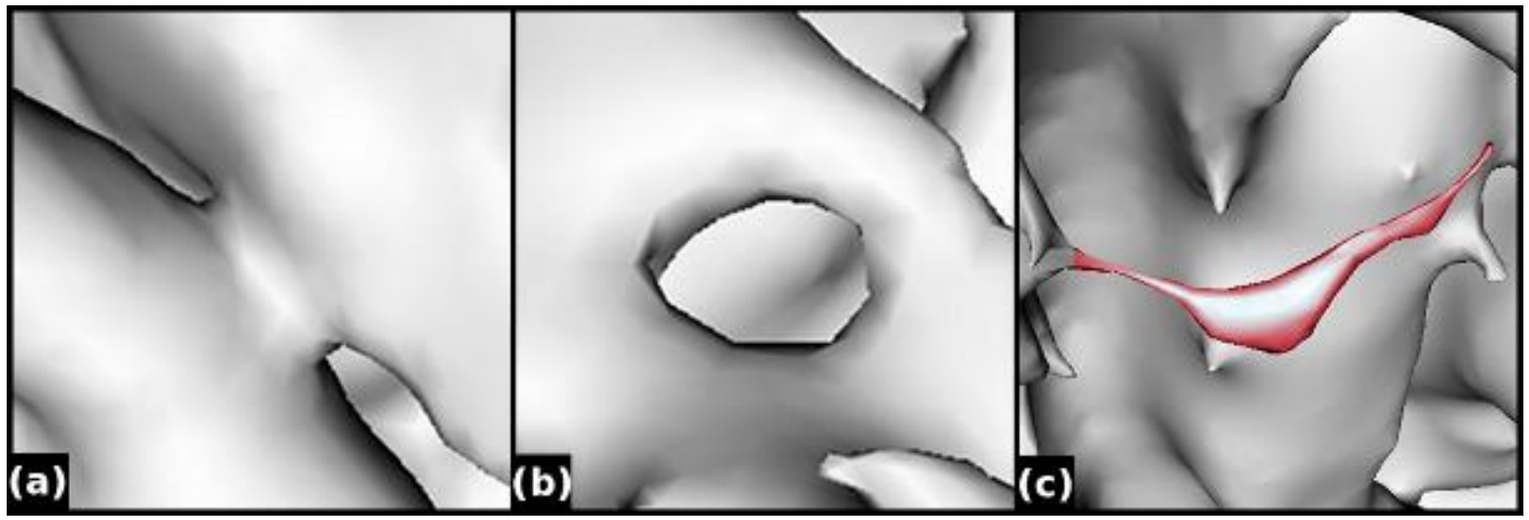
Surface-based Coordinate System



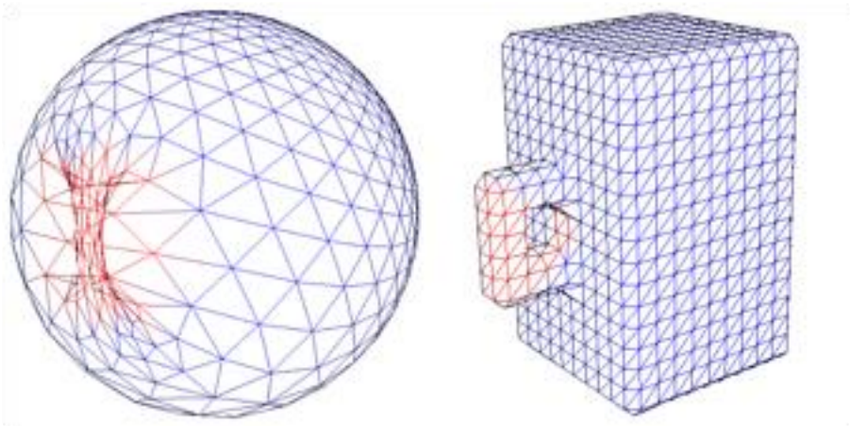
Detection of Topology Defects

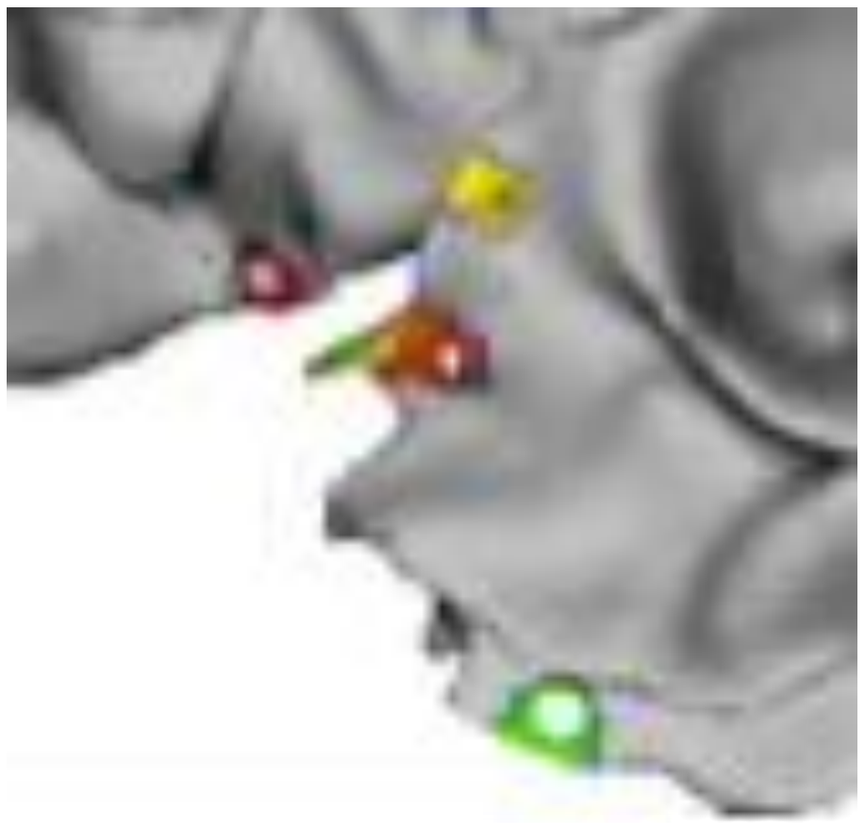
Spherical projection





Detection of overlaps

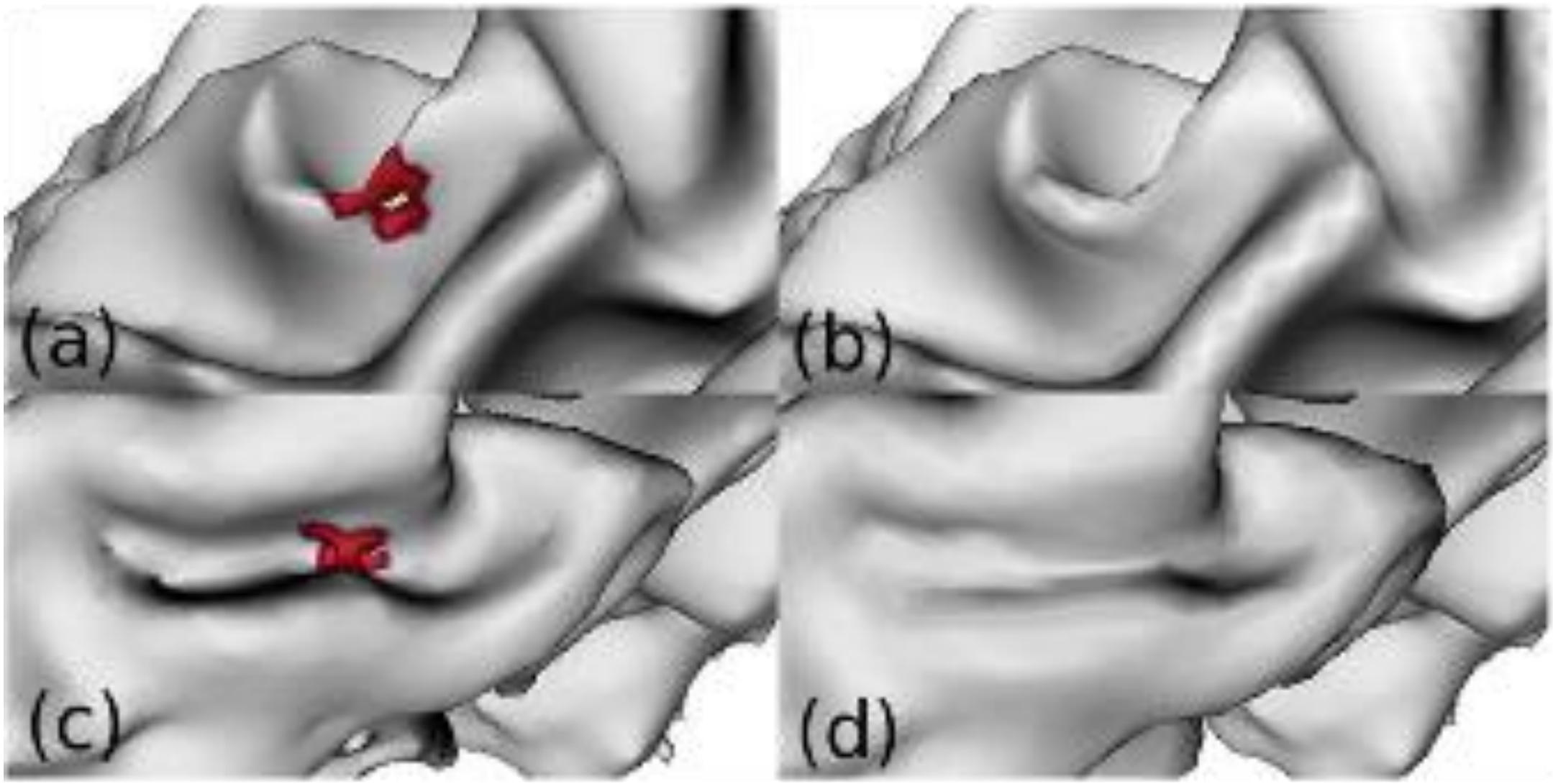




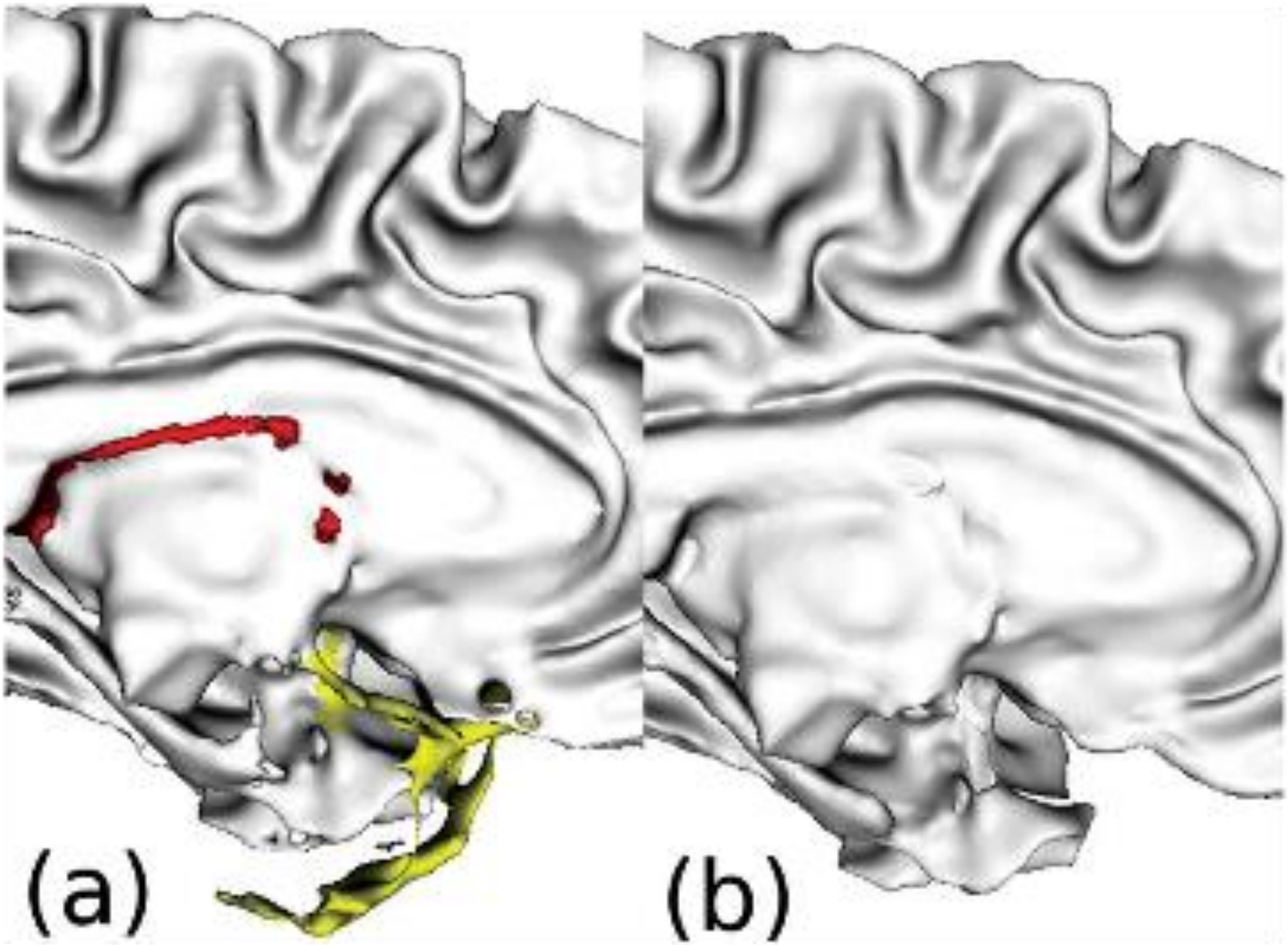
Topology Correction: Results

„cut“

„fill“

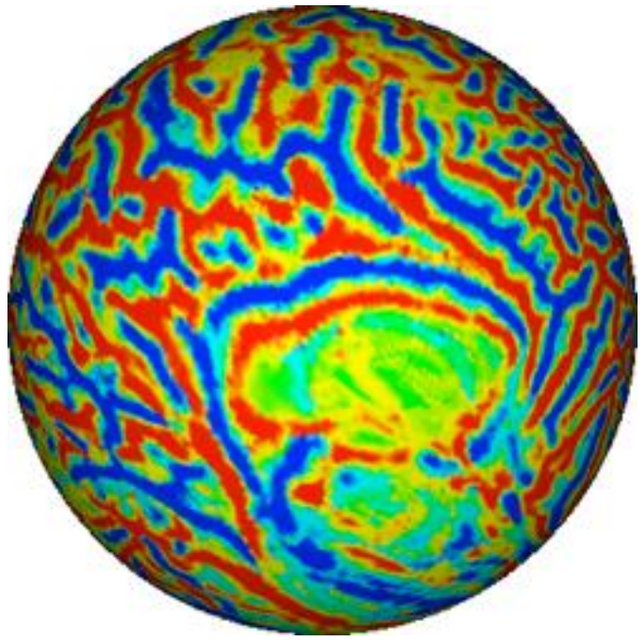


Topology Correction: Results

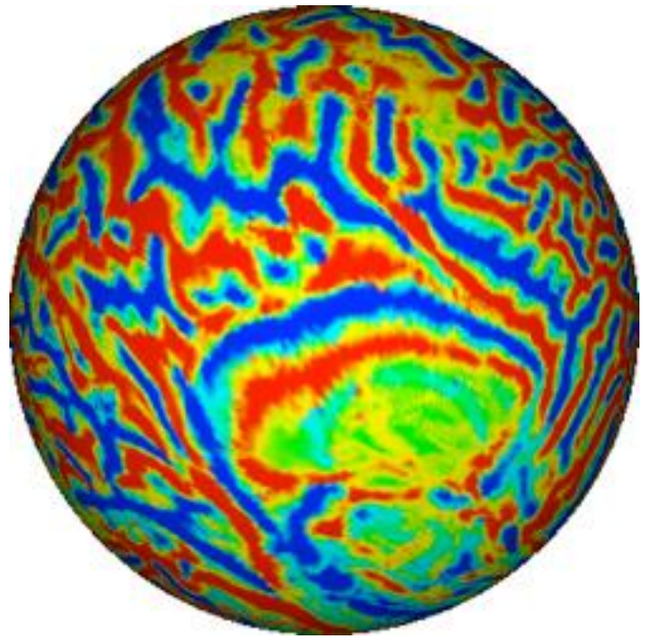


Surface-based Registration

Source

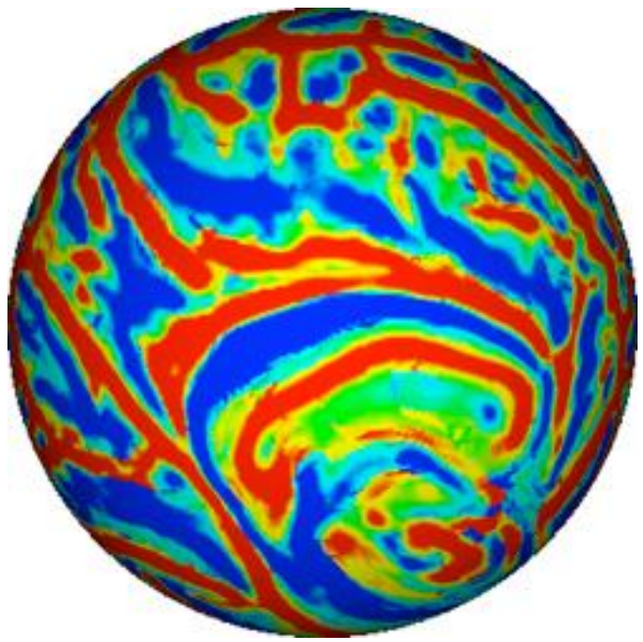


registered source



Non-linear

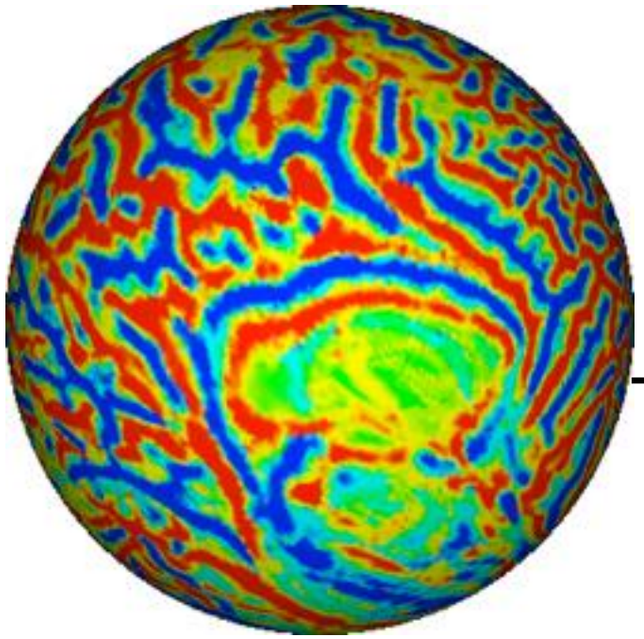
registration



Template

Coordinate Transformation

Spherical coordinate system



Coordinate

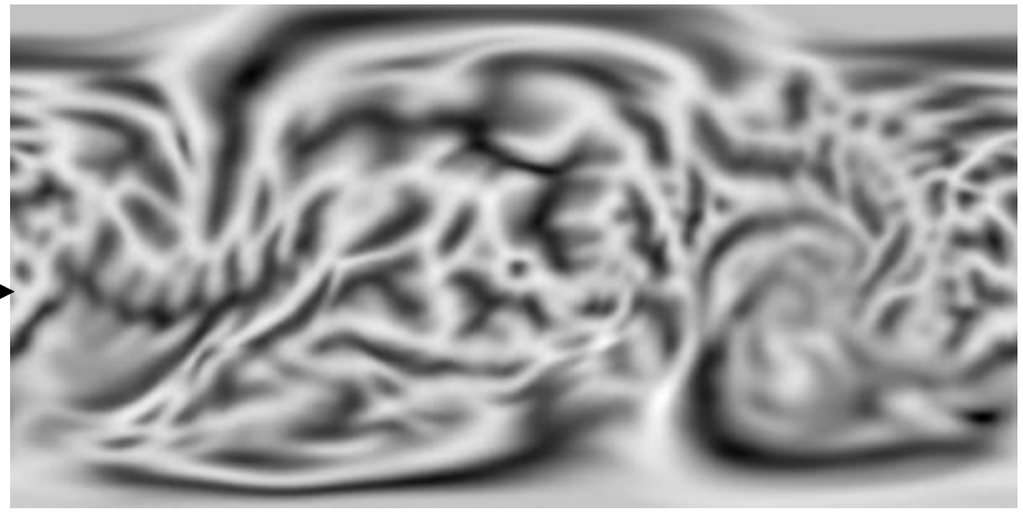
Transformation

Cartesian 2D coordinate system

2D-Registration

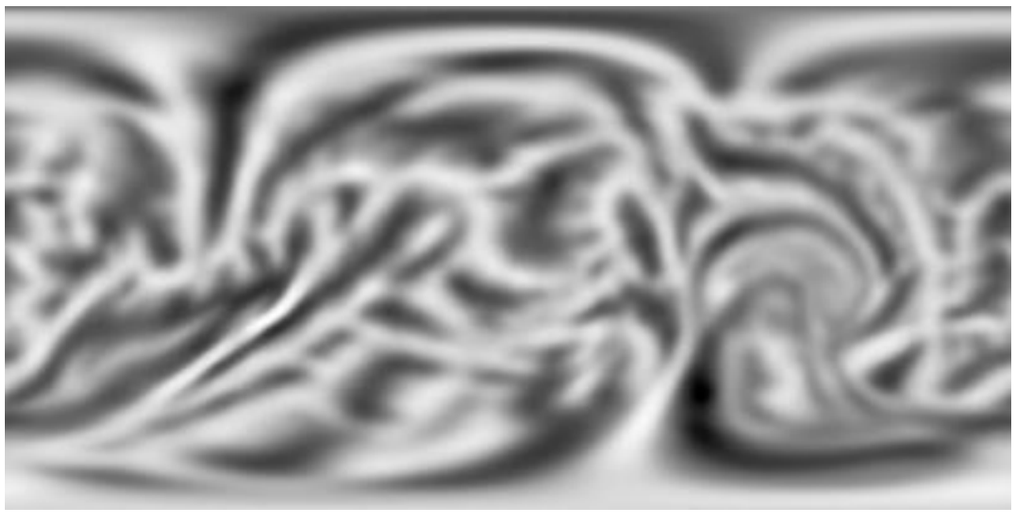
Source

registered source



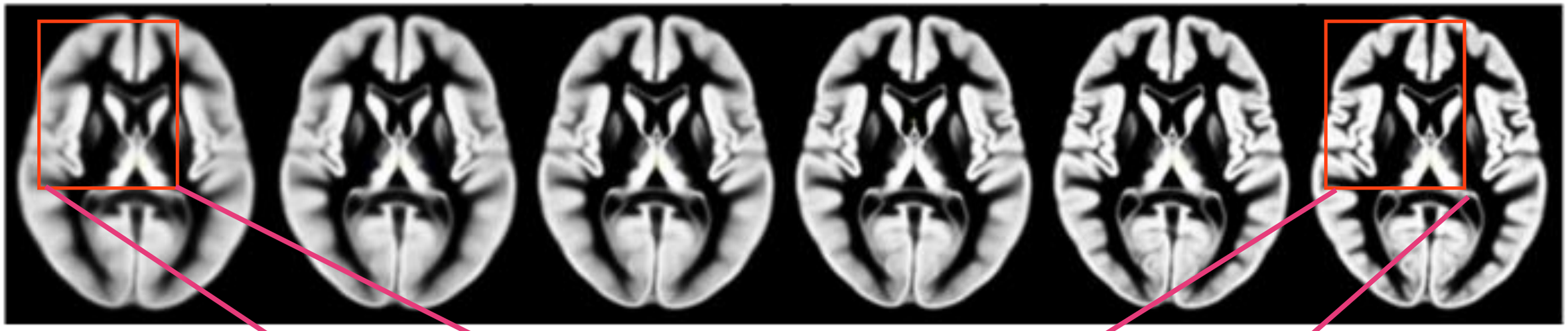
Non-linear

Registration



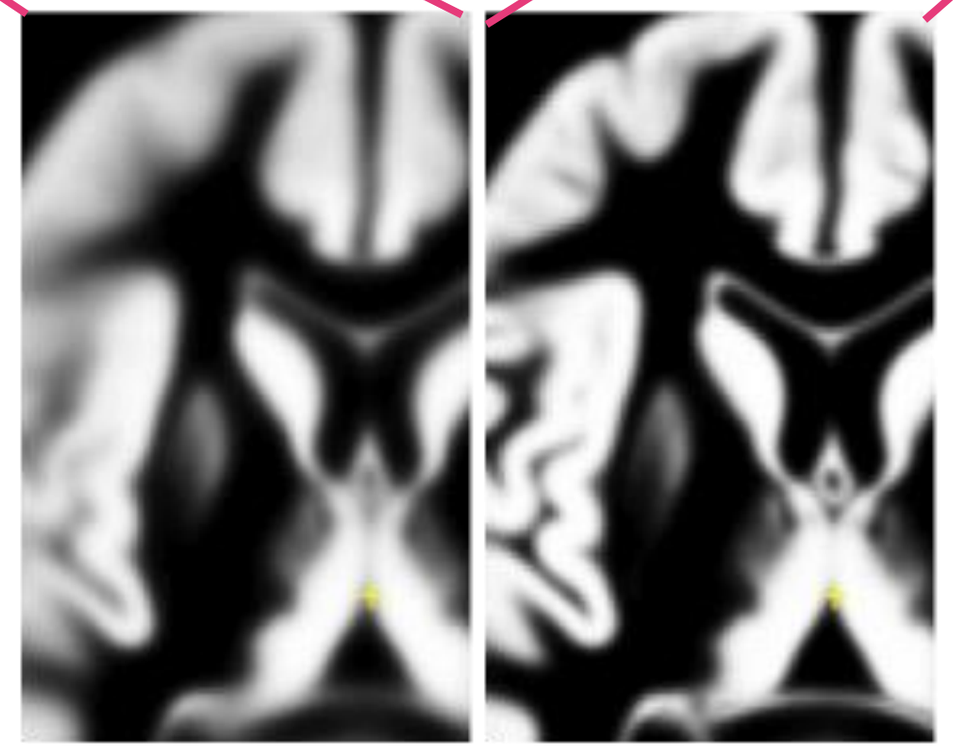
Template

DARTEL



Iteration 1 - 6

Diffeomorphic
Anatomical
Registration
Through
Exponential
Lie Algebra



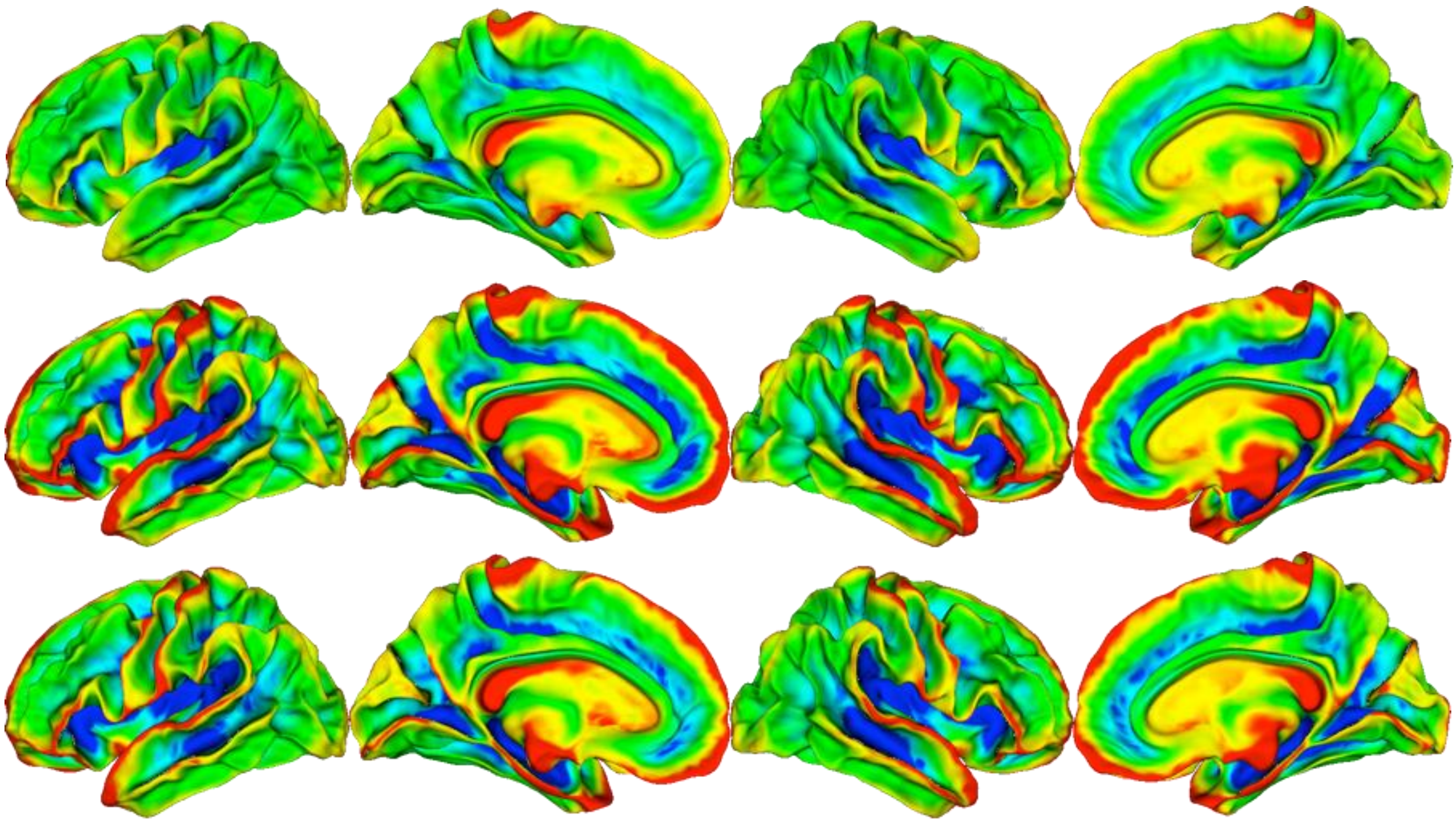
Ashburner & Friston
NeuroImage 2007

Registration: Validation

Affine

Free-surfer

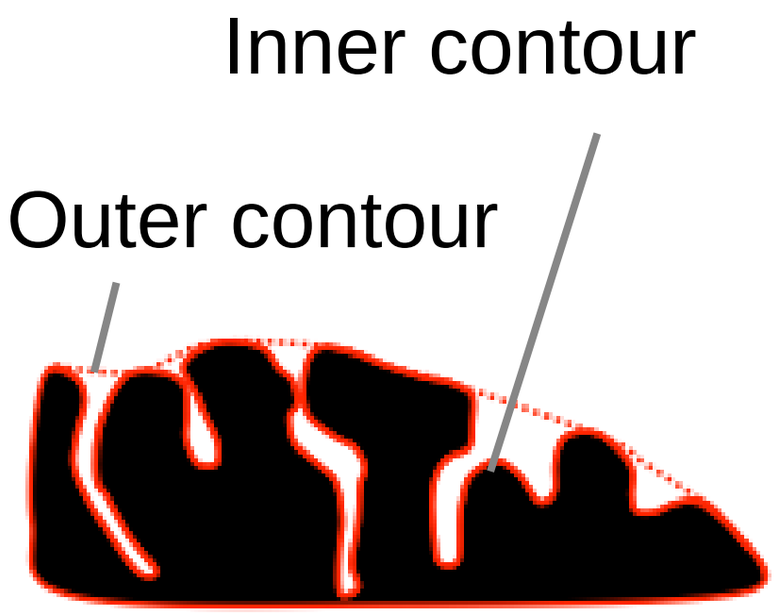
CAT



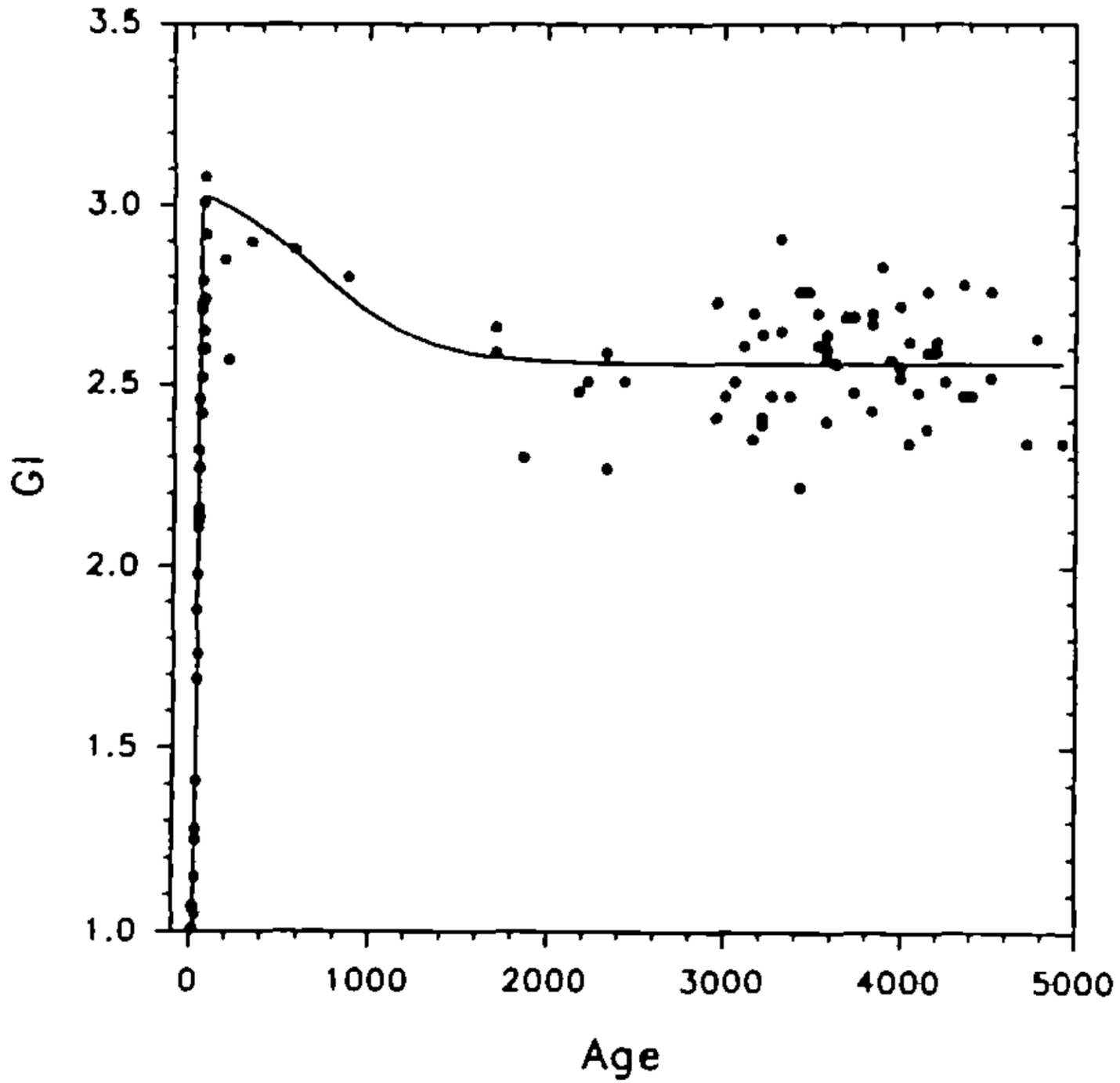
T-Value

-25 0 25

Gyrification Index



Zilles et al. , Anat Embryol 1988

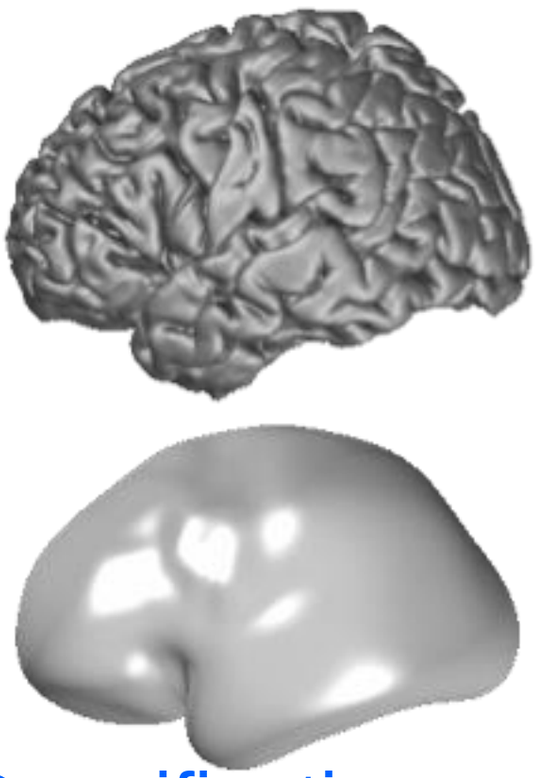


Armstrong et al., Cerebral Cortex 1995

Traditional gyrification index

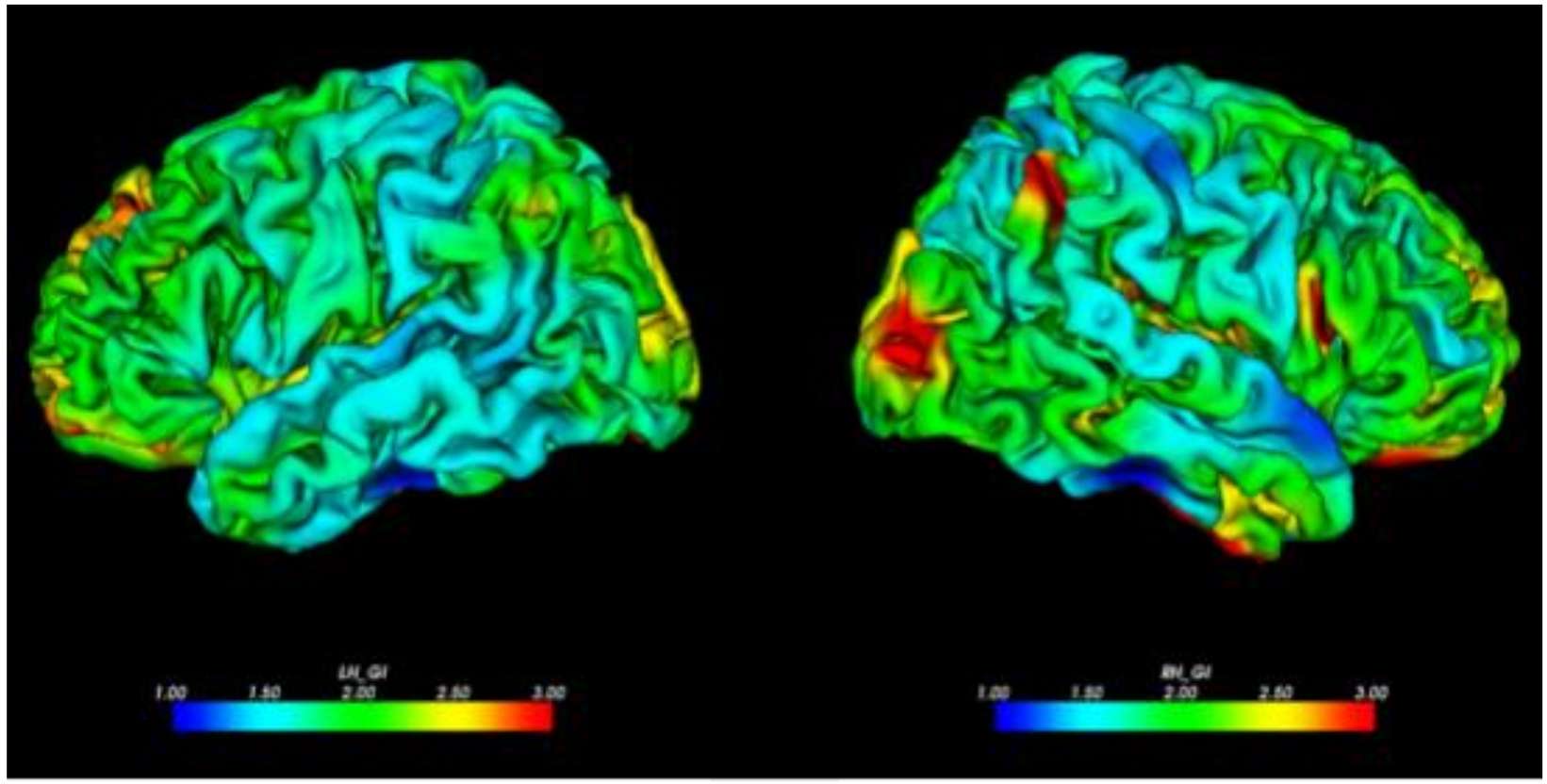
- Relation between inner and outer contour of cortex in coronal slices
- relatively stable after 5-7 years -> sensitive marker for neurodevelopmental effects

3D-Gyrifizierungsindex



3D gyrification index

- Relation between inner and outer surface



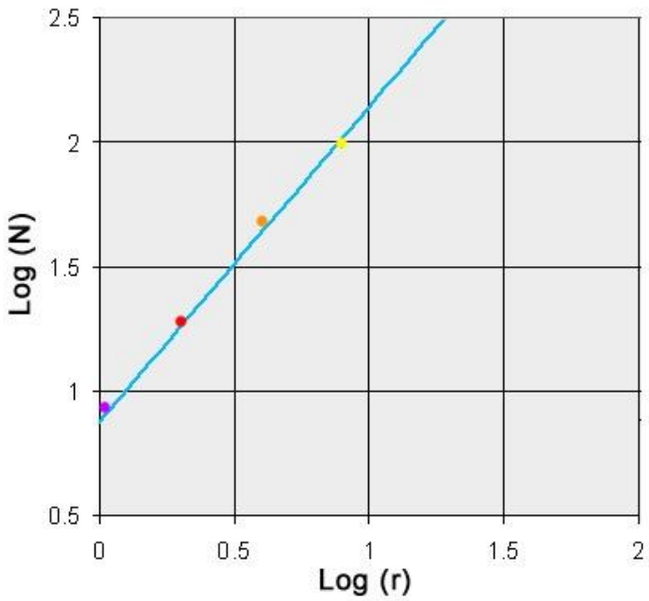
Sex effects Lüders et al., Neuroimage 2006
Williams Syndrom Gaser et al., Neuroimage 2006
Correlation with IQ Lüders et al., Cerebral Cortex 2007

Fractal Dimension

Unit = 200 km,
Length = 2400 km (approx.)

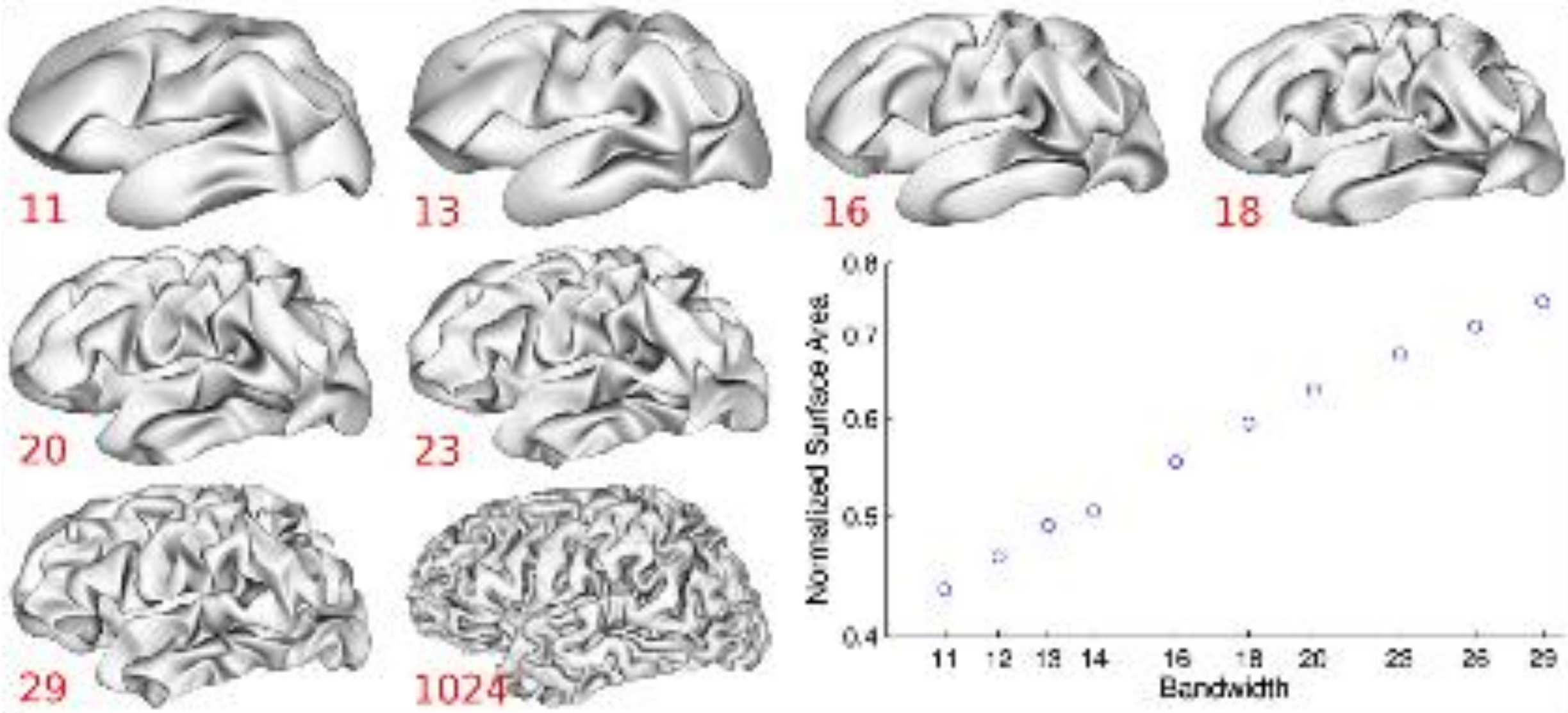
Unit = 100 km,
Length = 2800 km (approx.)

Unit = 50 km,
Length = 3400 km (approx



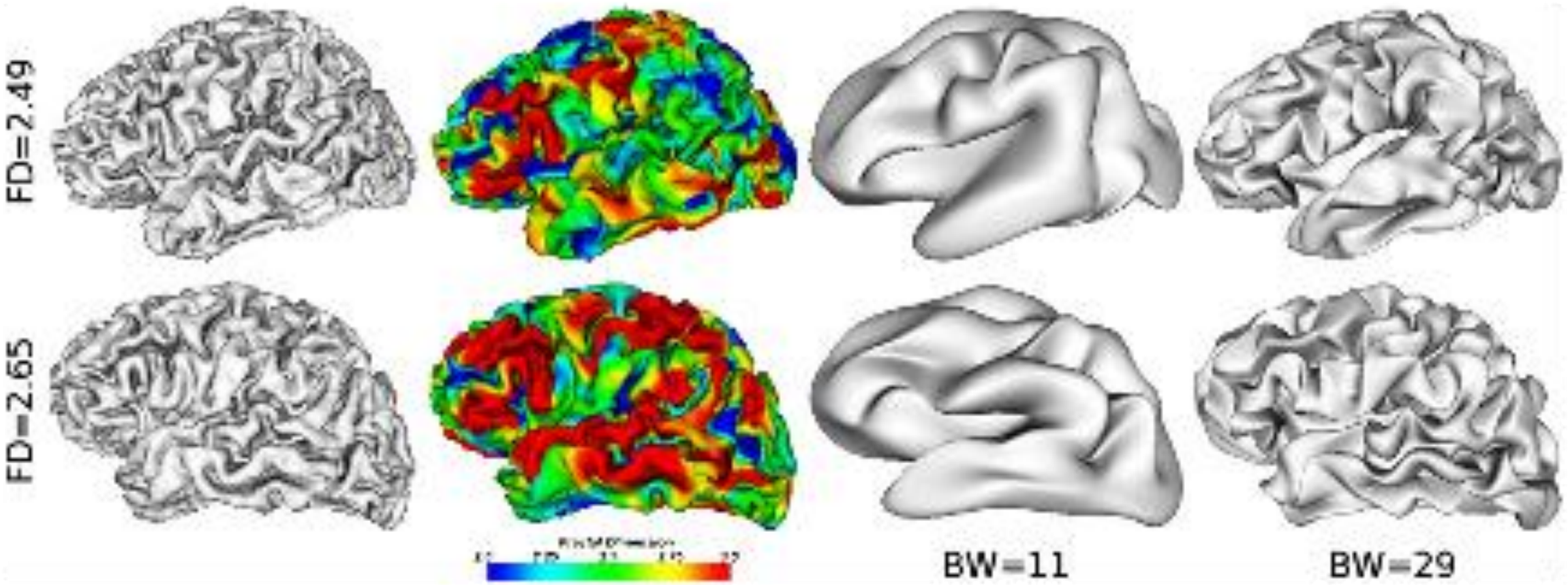
Coast line of England (Source: Wikipedia)

Fractal Dimension



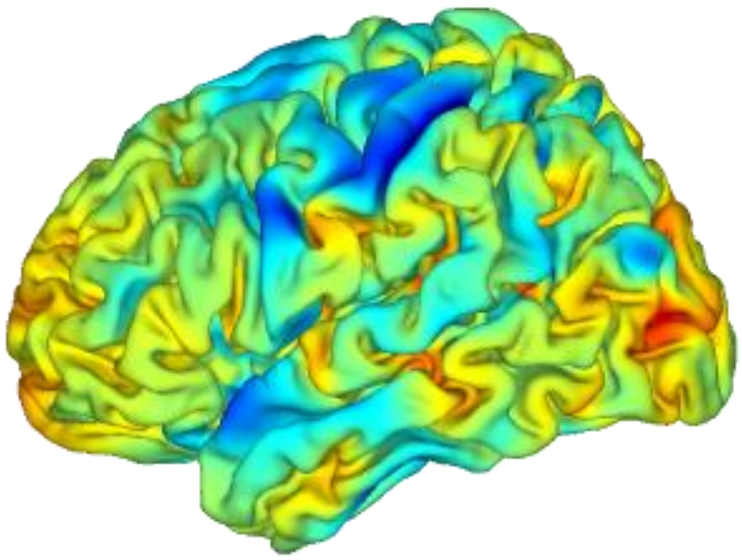
Yotter et al., NeuroImage 2011

Fractal Dimension

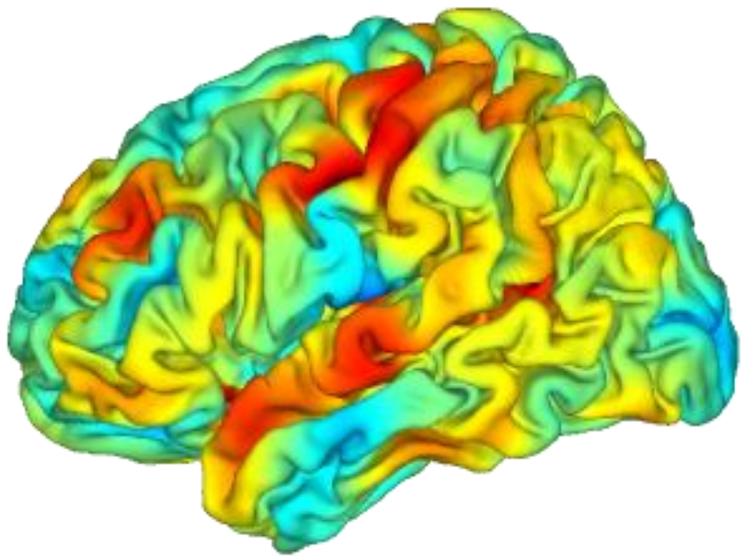


Yotter et al., NeuroImage 2011

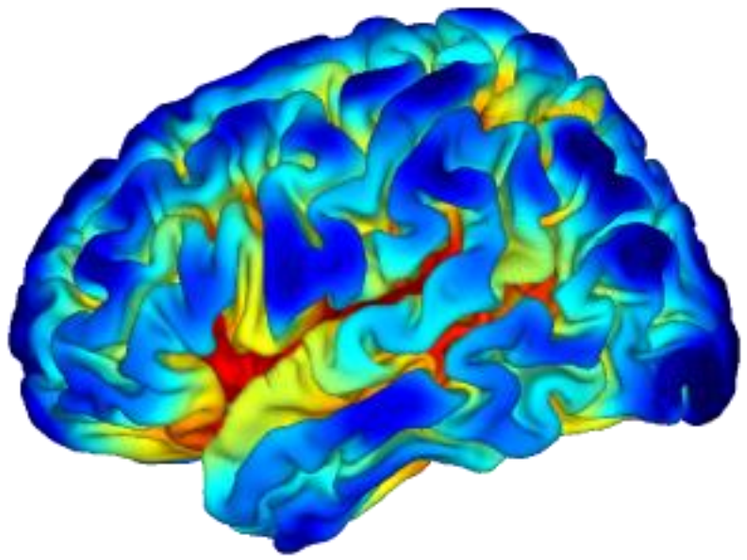
Folding Measures



gyrification
(smoothed 15mm)
(absolute mean curvature)

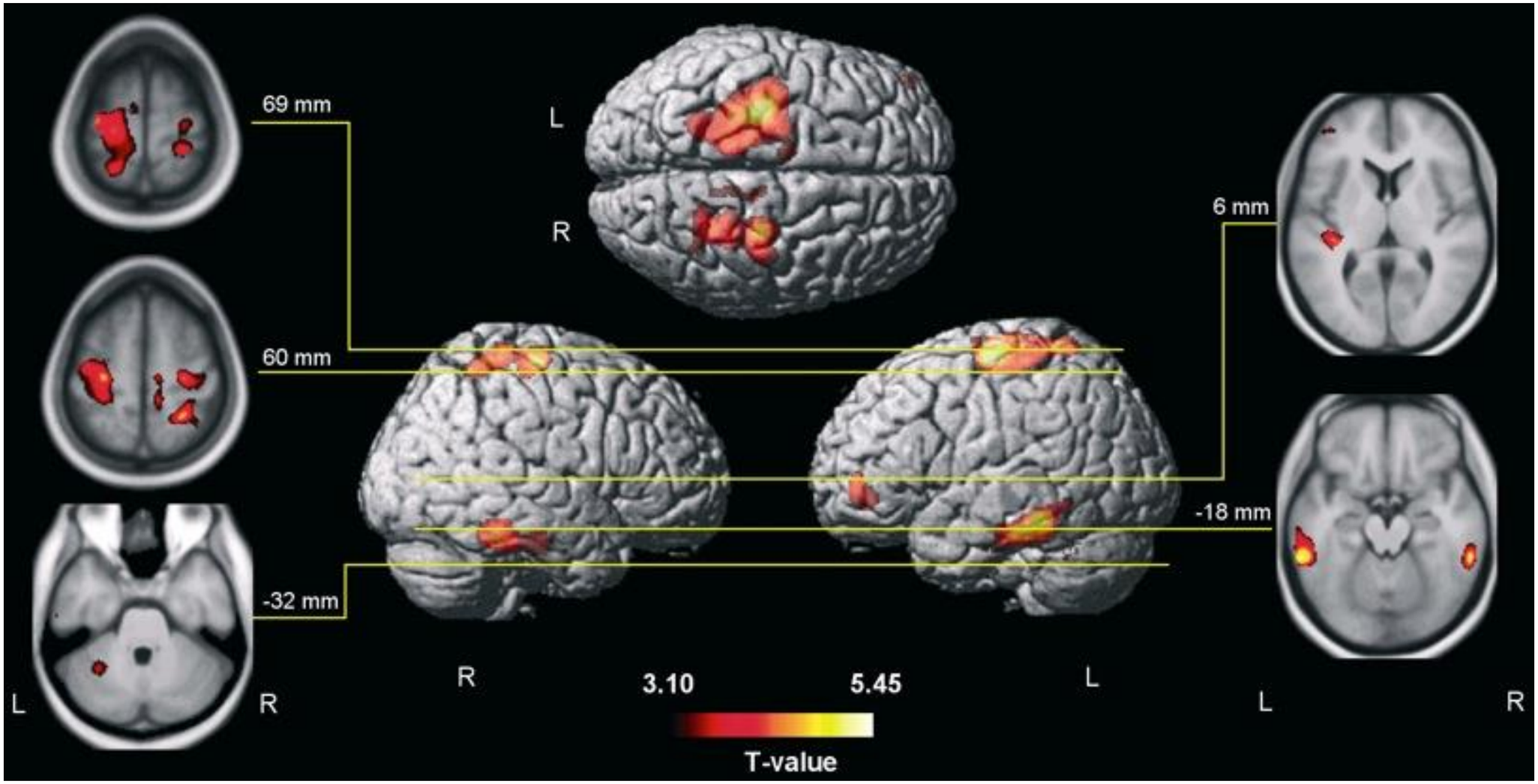


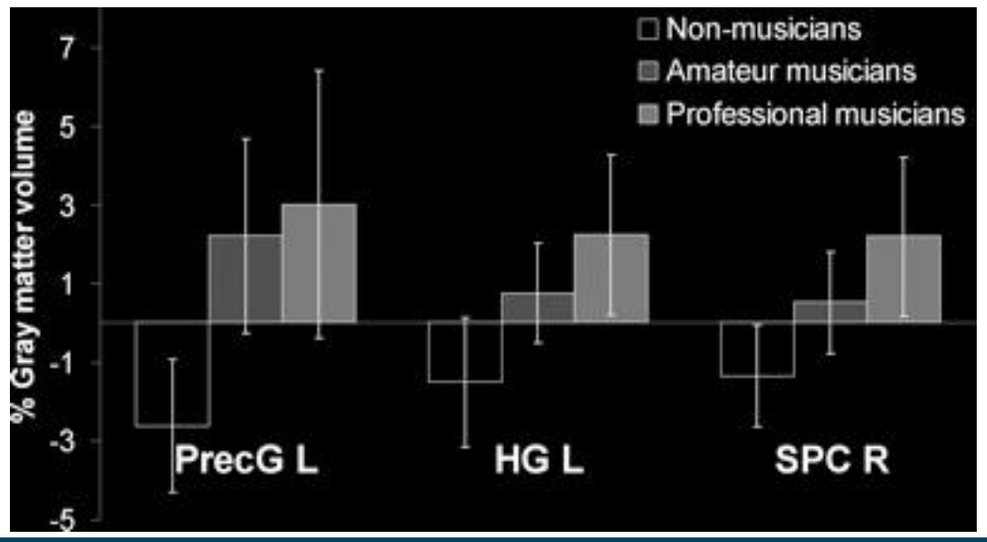
fractal dimension



sulcal depth
(smoothed 15mm)

Musicians vs. Non-musicians

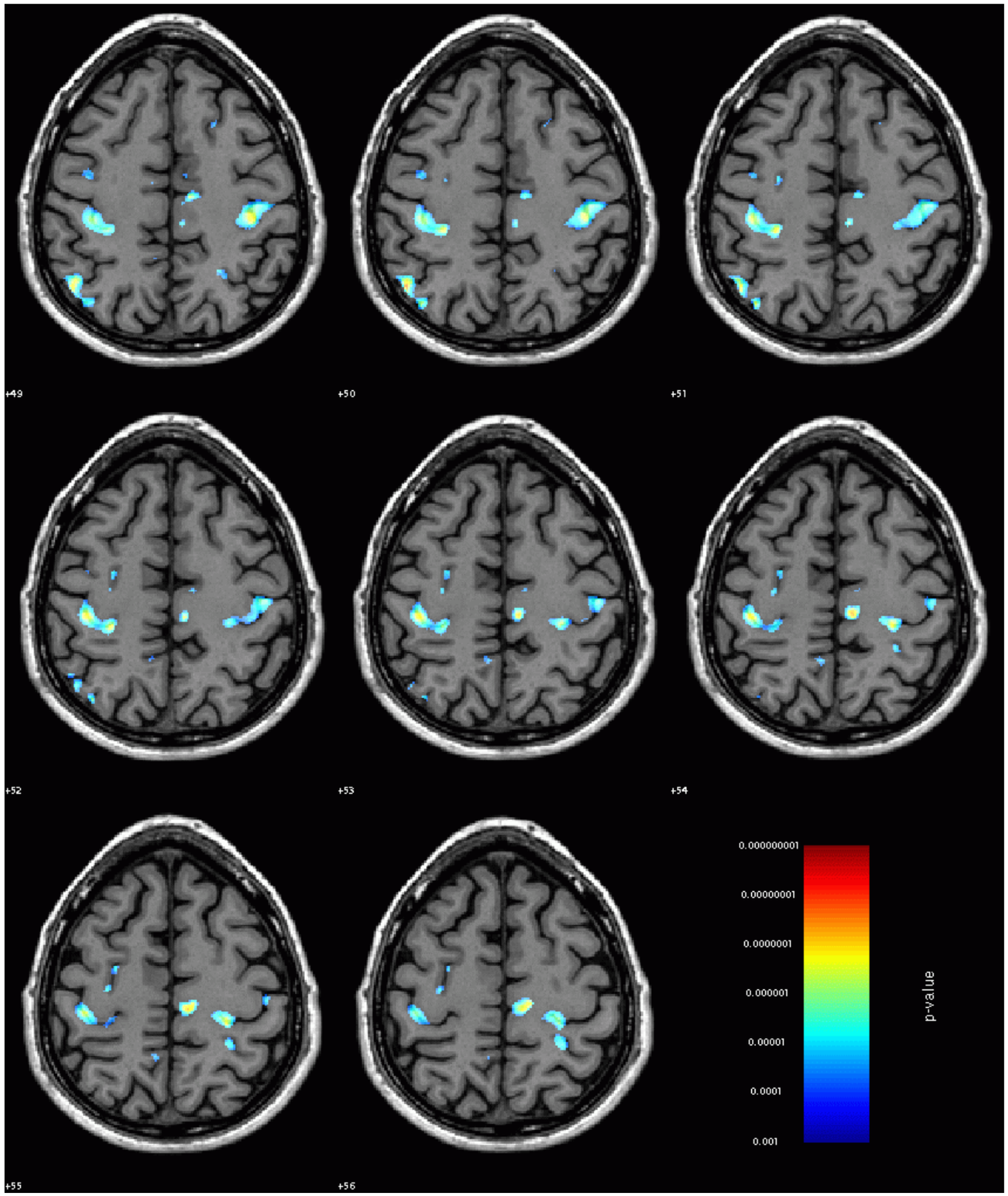




20 professional musicians
20 amateur musicians
40 non-musicians

Gaser & Schlaug, J Neurosci 2003

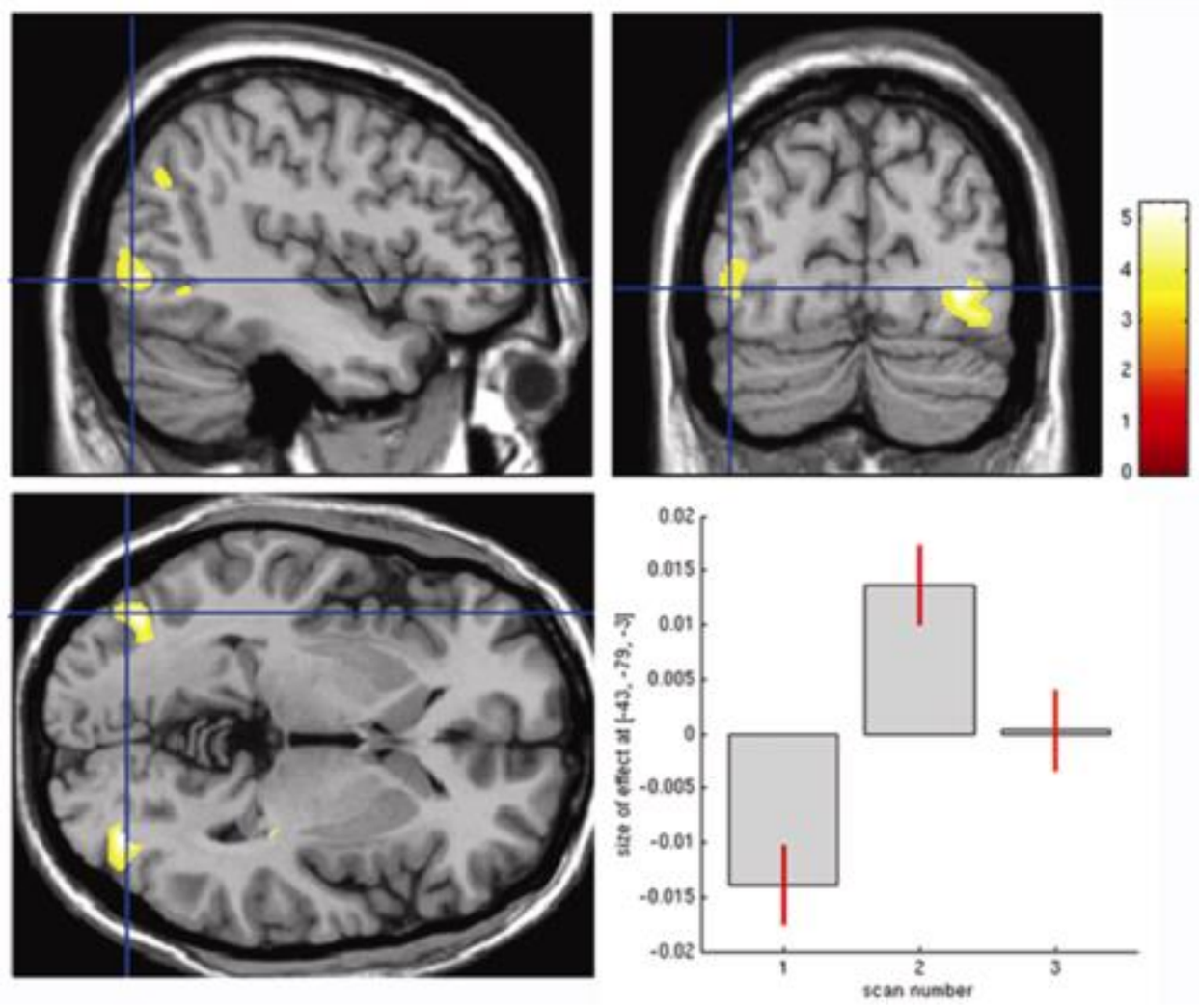
Musical Training - Single subject



Juggling and the Brain?

„Juggling will let your brain grow.“

Learning and Structural Plasticity



12 volunteers

- 3 months training of a 3-ball-cascade
- followed by 3 months with our training

12 controls

- no juggling

Draganski et al., Nature 2004

Brain age prediction

41 years

65 years

46 years

. . .

41 years

Multivariate pattern recognition

BrainAGE score = Predicted age - true age

Example Data: ADNI

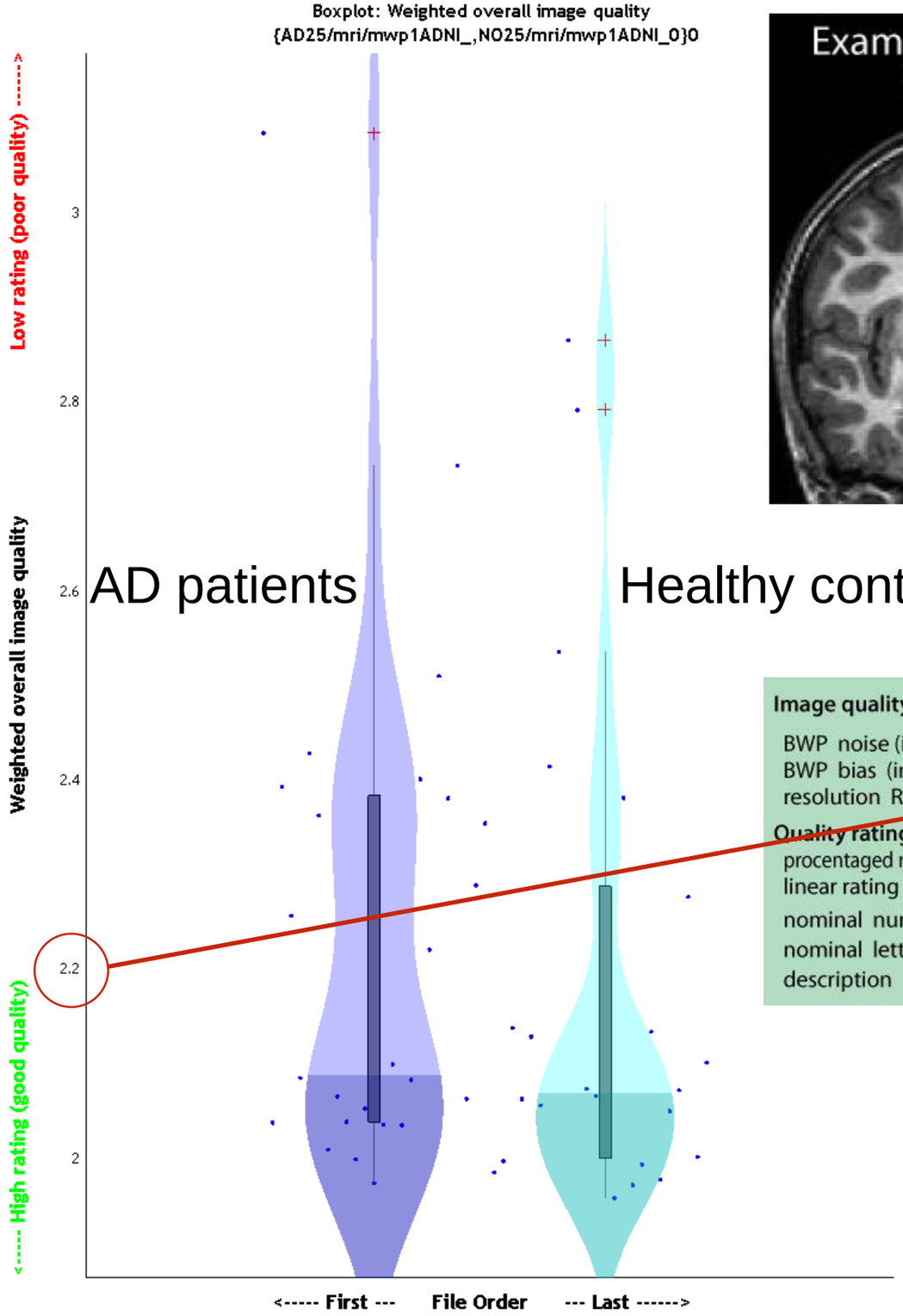
- 25 patients with Alzheimer's Disease (AD)

  10 males, 15 females, mean age 75.97±7.1 years; mean MMSE 23.48±2.35

- 25 healthy control subjects

  10 males, 15 females, mean age 77.96±6.41 years; mean MMSE 28.75±1.48

Quality Assurance



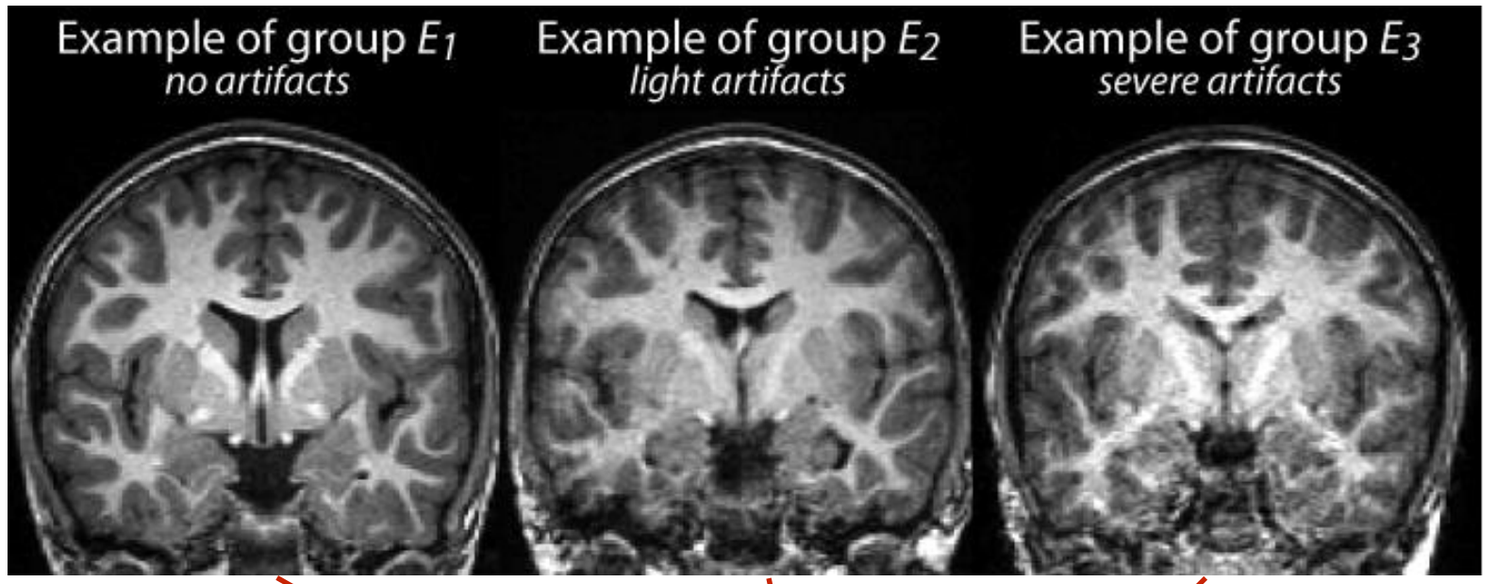
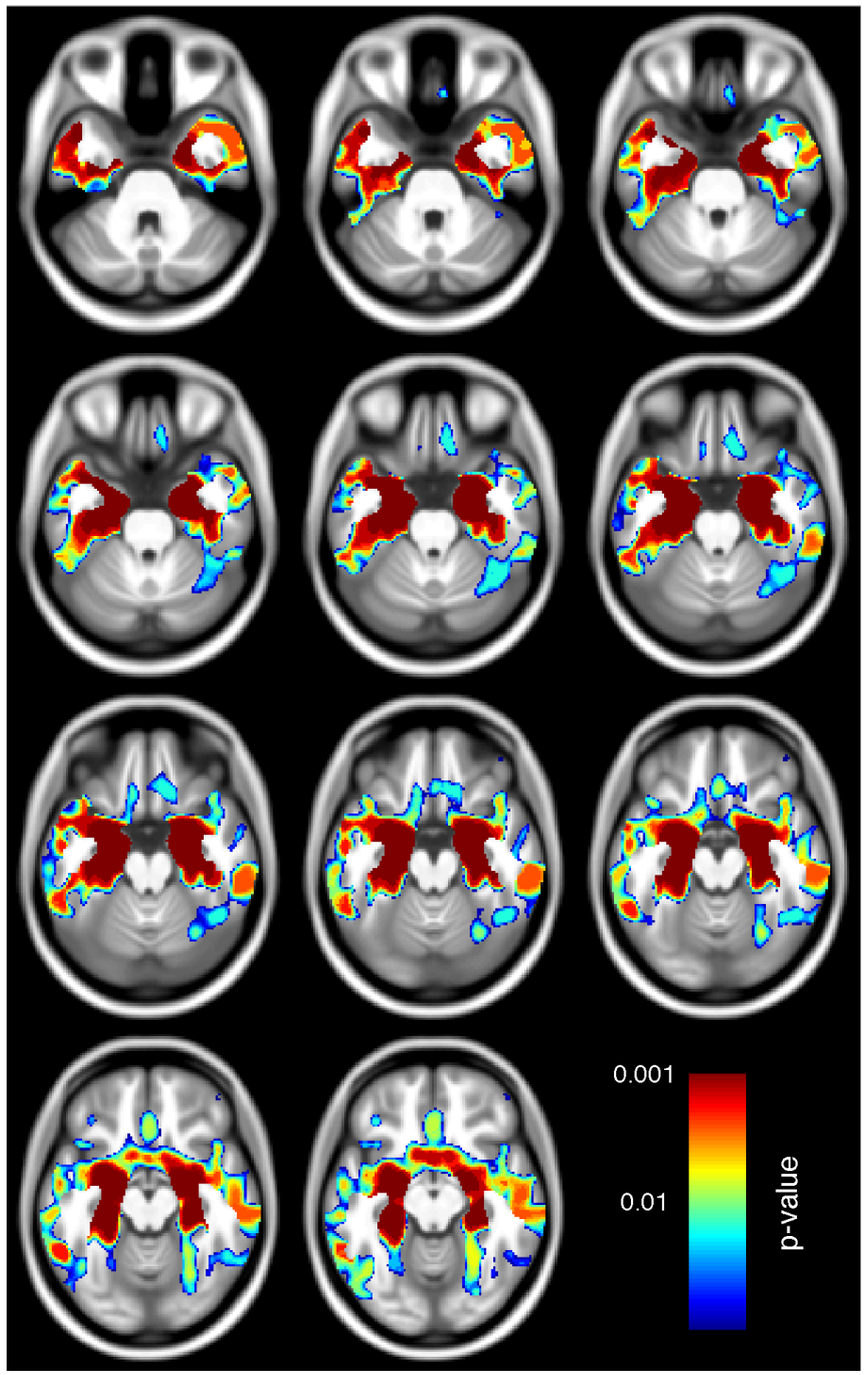
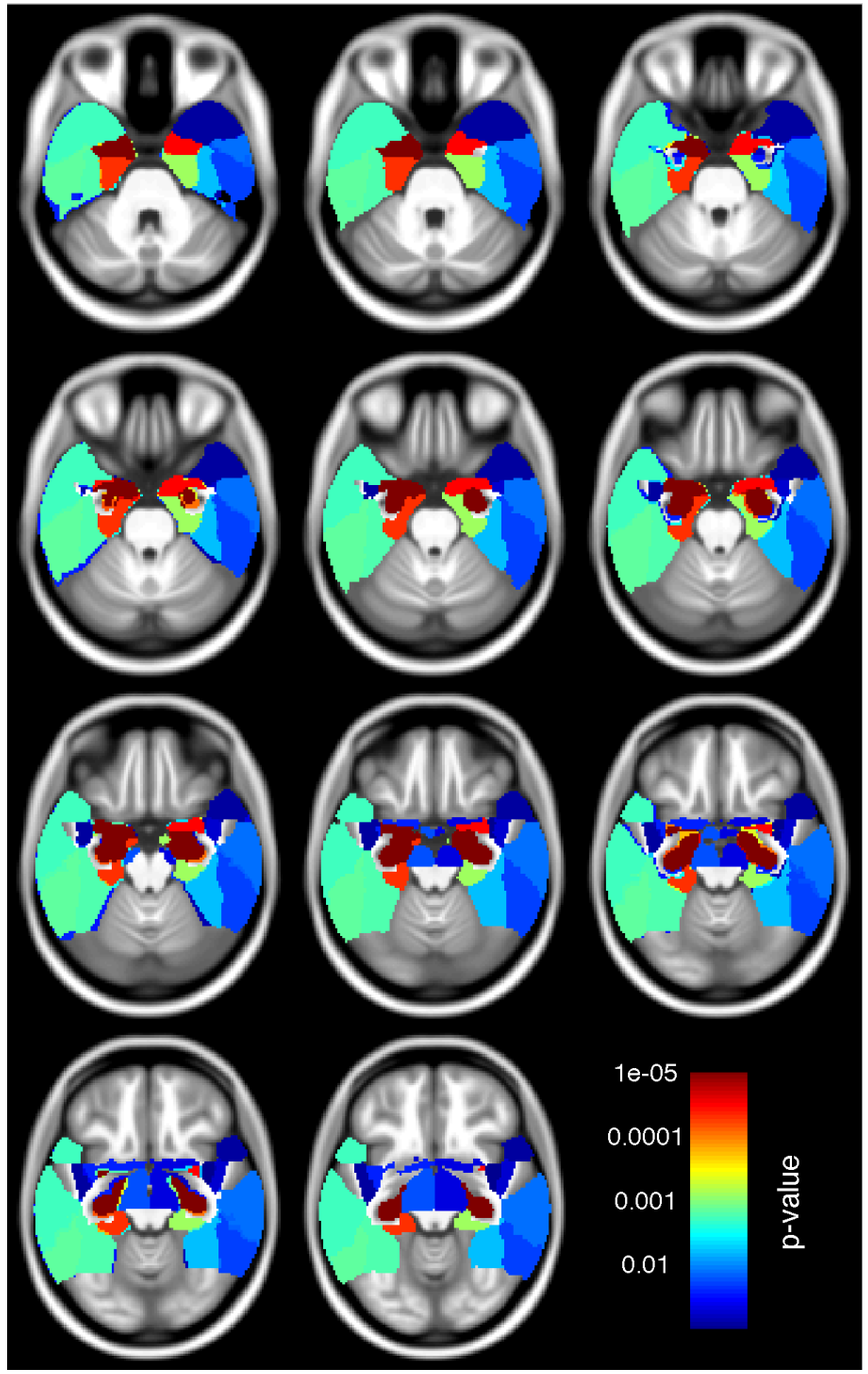


Image quality definition	excellent			good		satisfactory		sufficient		critical		unacceptable / failed	
BWP noise (in percent)	0	1	2	3	4	5	6	7	8	9	10	15	20
BWP bias (in percent)	0	20	40	60	80	100	120	140	160	180	200	300	400
resolution RES (mm)		0.5		1.0		1.5		2.0		2.5		4.0	5.5
Quality ratings													
procentaged rating points (rps)	100	95	90	85	80	75	70	65	60	55	50	25	0
linear rating scale	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	8	10.5
nominal numbers	1+	**1**	1-	2+	**2**	2-	3+	**3**	3-	4+	**4**	4-	5+	**5**	5-	**6**
nominal letters	A+	**A**	A-	B+	**B**	B-	C+	**C**	C-	D+	**D**	D-	E+	**E**	E-	**F**
description	excellent			good		satisfactory		sufficient		critical		unacceptable / failed	

ADNI - Gray Matter

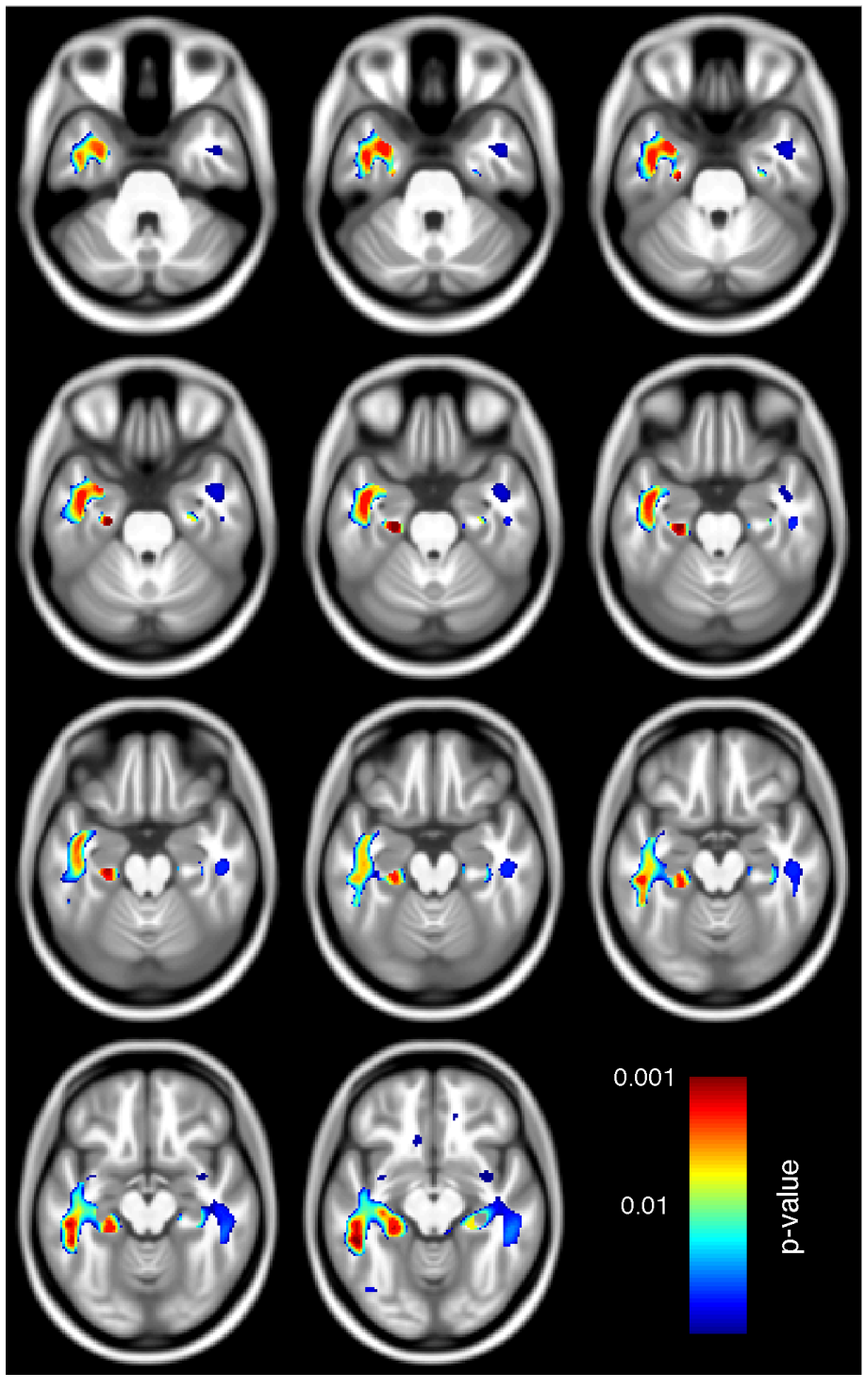


Voxel-based Morphometry GM
p<0.05 (FEW corrected)

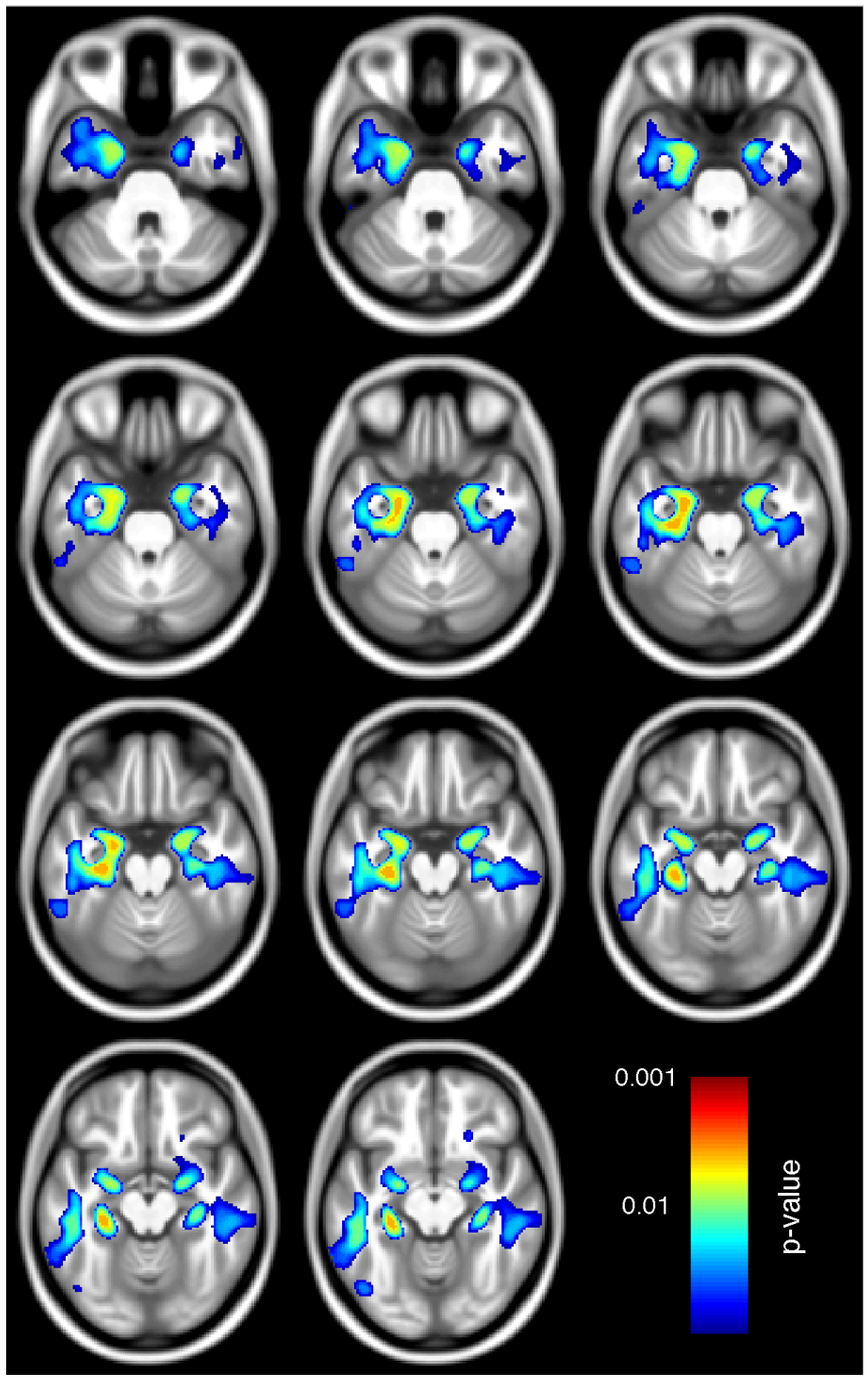


ROI-based Morphometry GM
q<0.01 (FDR corrected)

ADNI - White Matter / DBM

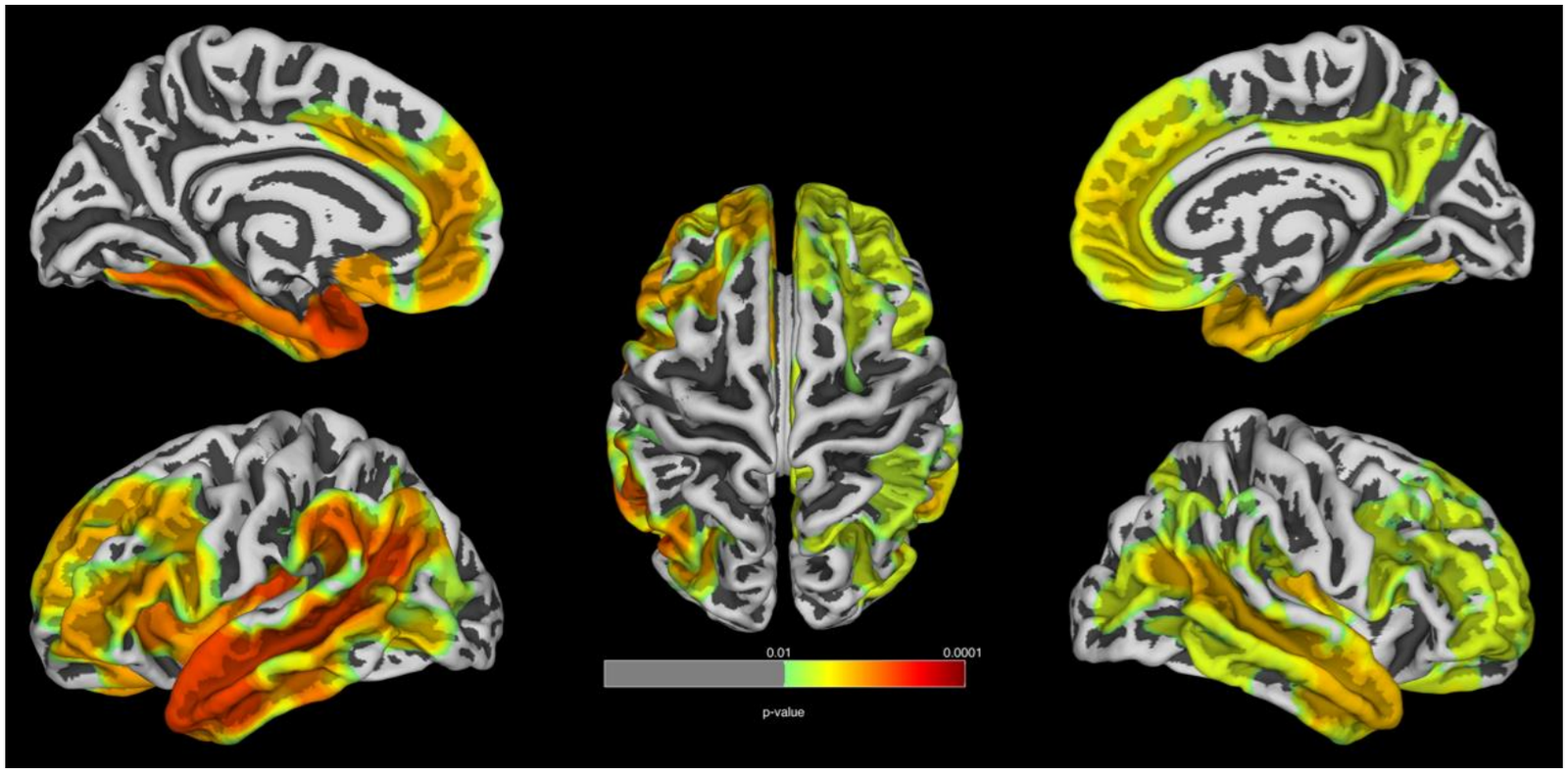


Voxel-based Morphometry WM
p<0.05 (FEW corrected)

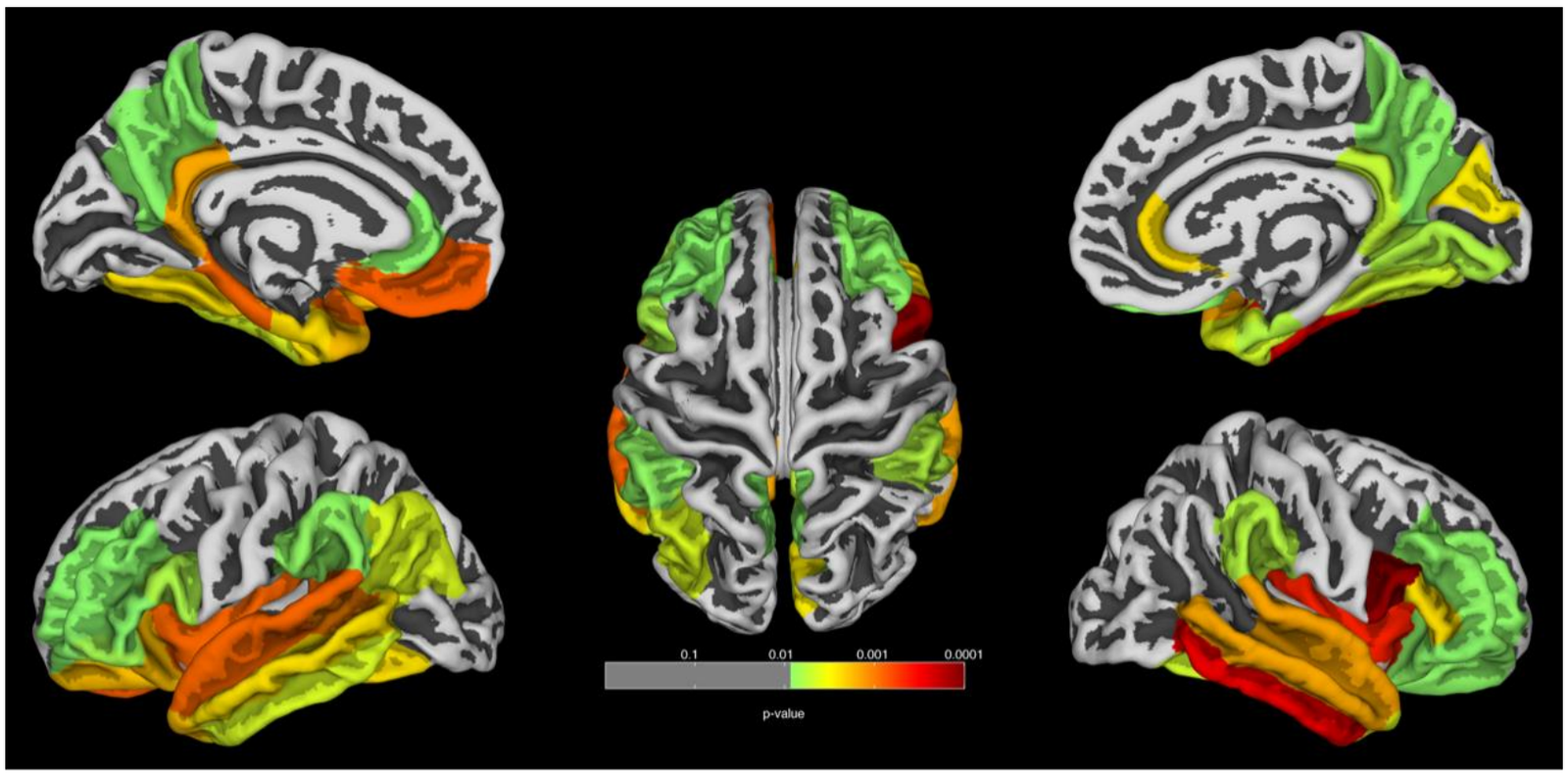


Deformation-based Morphometry
p<0.05 (FEW corrected)

ADNI - Cortical Thickness

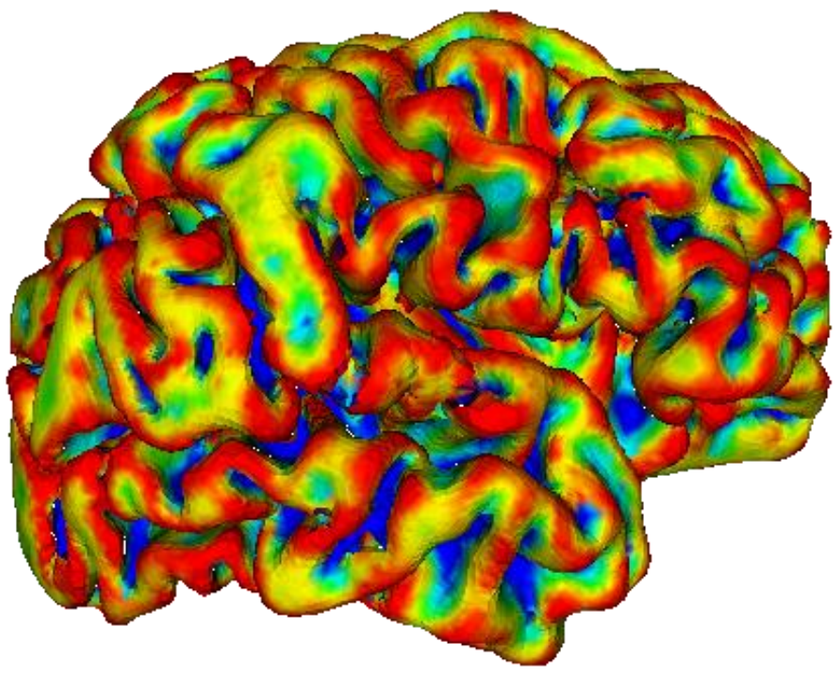


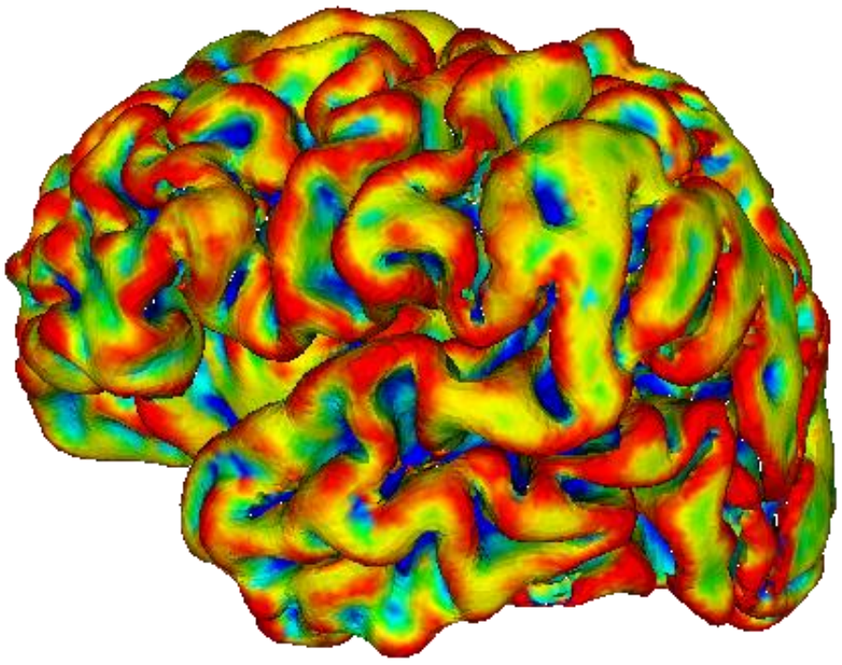
Surface-based Morphometry
p<0.01 (FEW corrected)



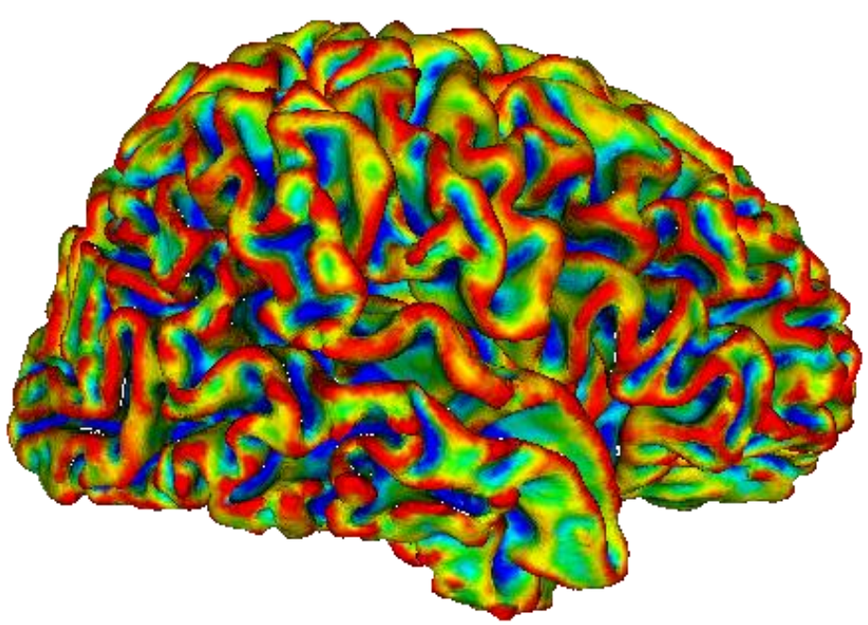
ROI-based Morphometry
q<0.01 (FDR corrected)

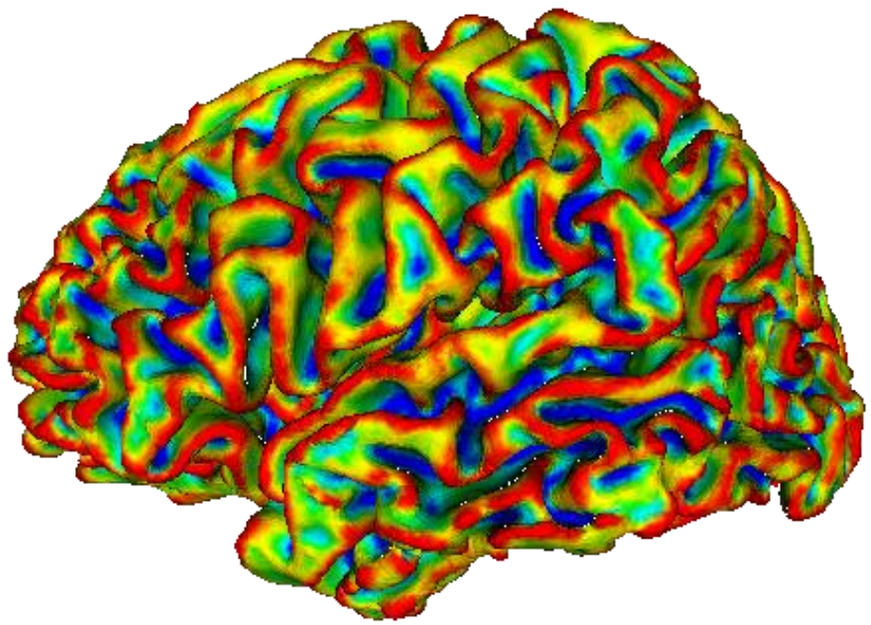
Neonate Data



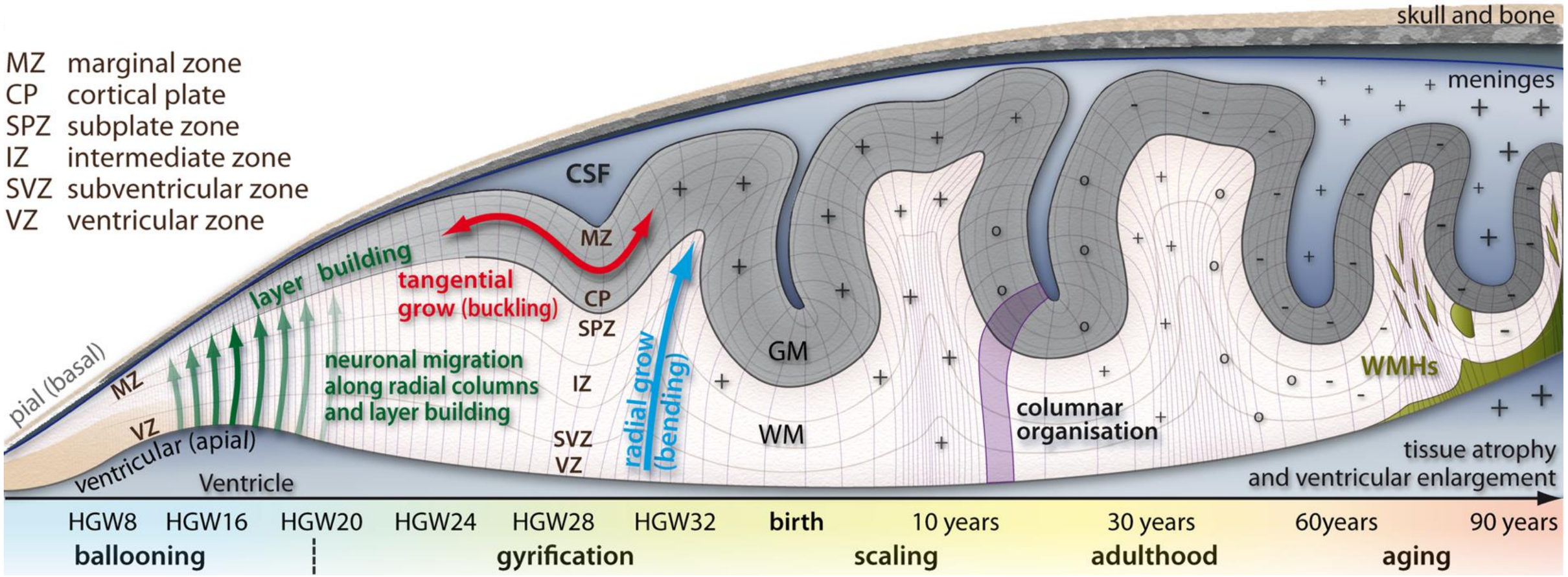


Average T_1 with 0.3mm Resolution

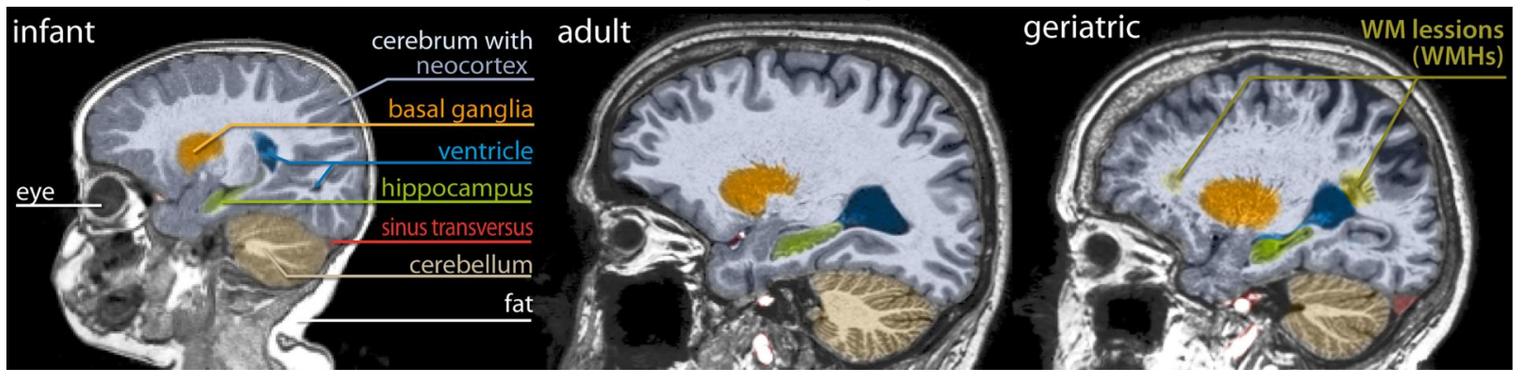




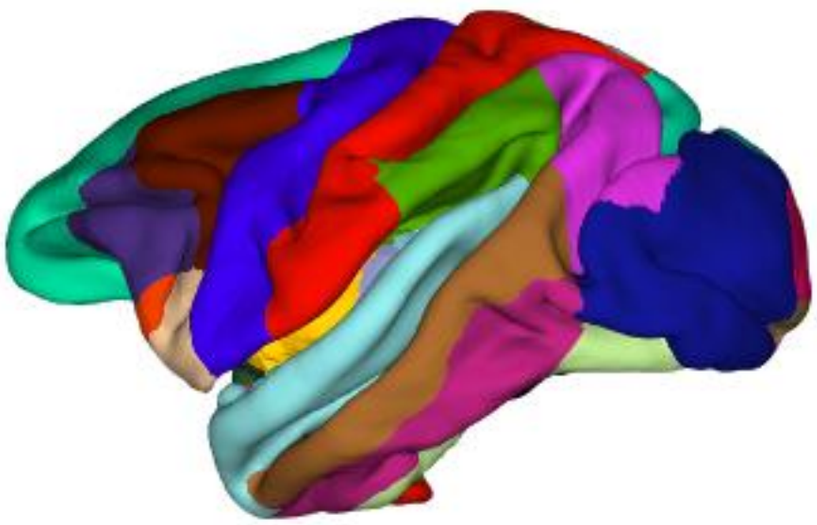
Individual Development and Aging



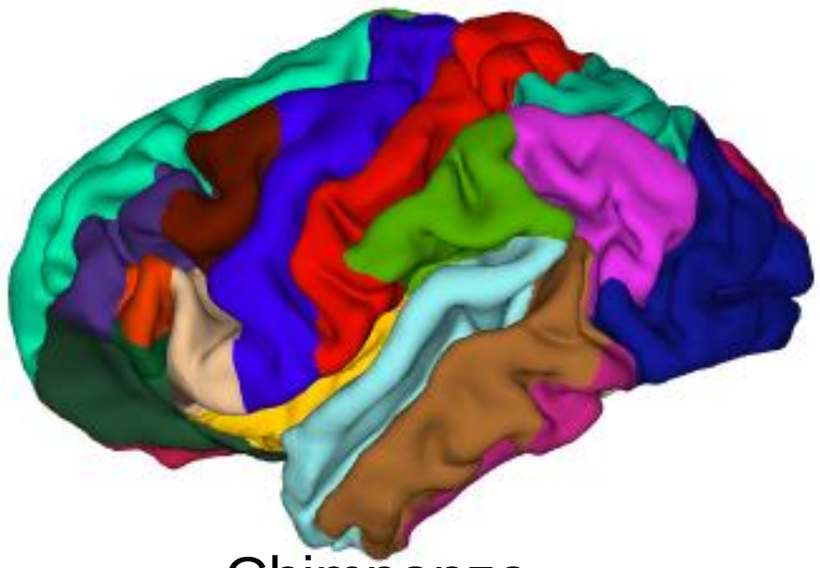
Dahnke & Gaser 2017



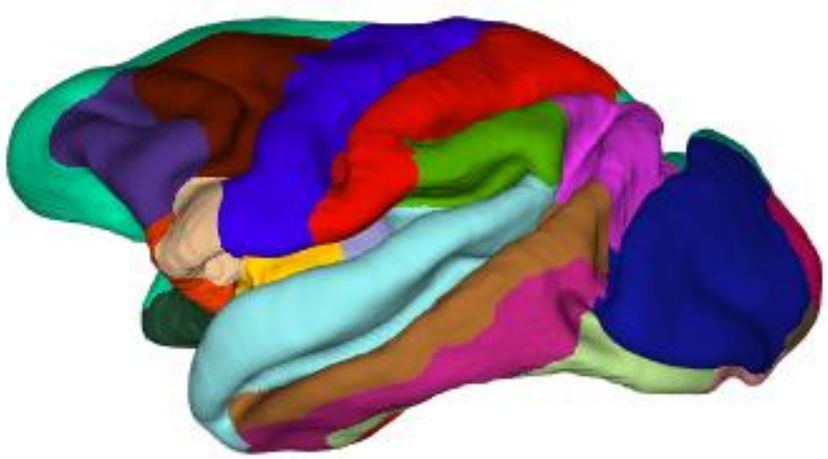
Non-Human Primates



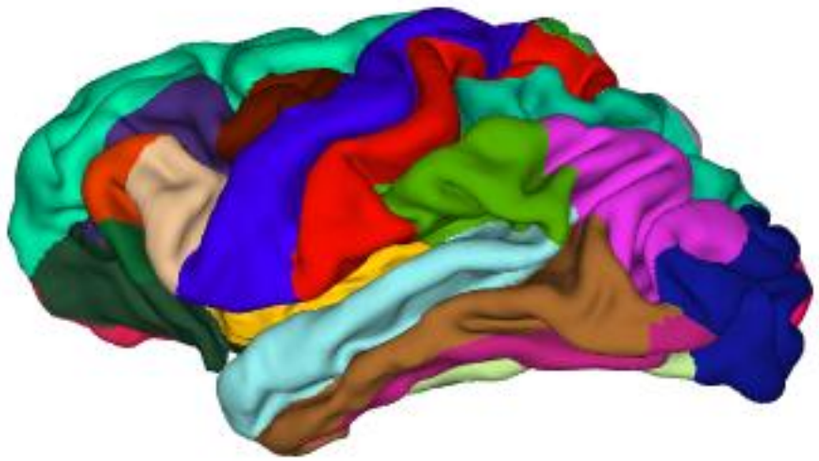
Baboon



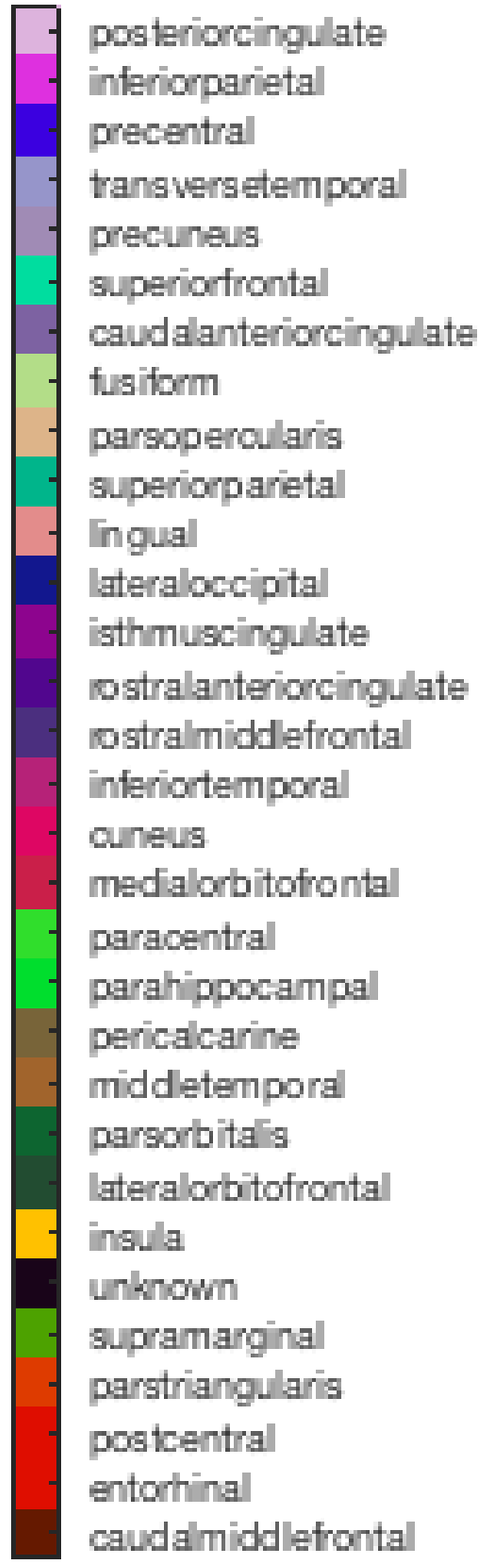
Chimpanzee



Mangabey



Gibbon



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