

Freesurfer Applications

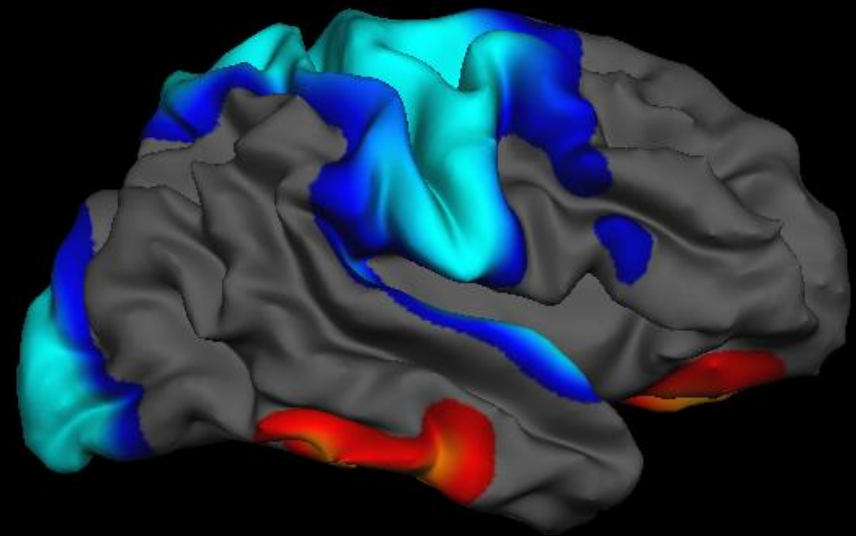
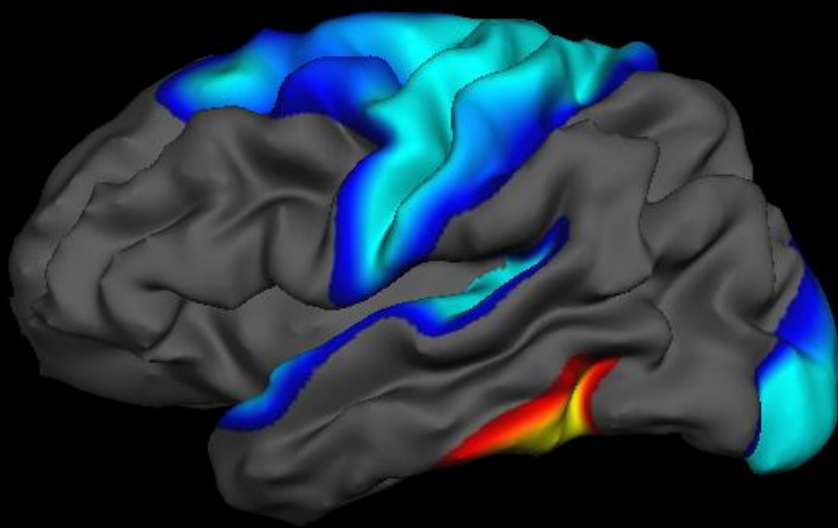


David H. Salat

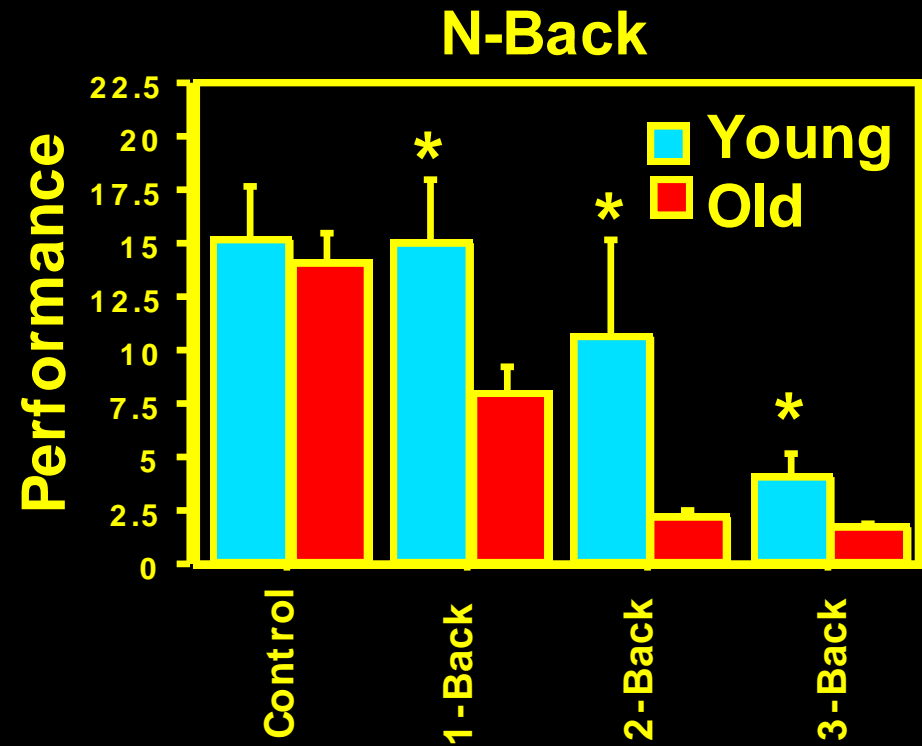
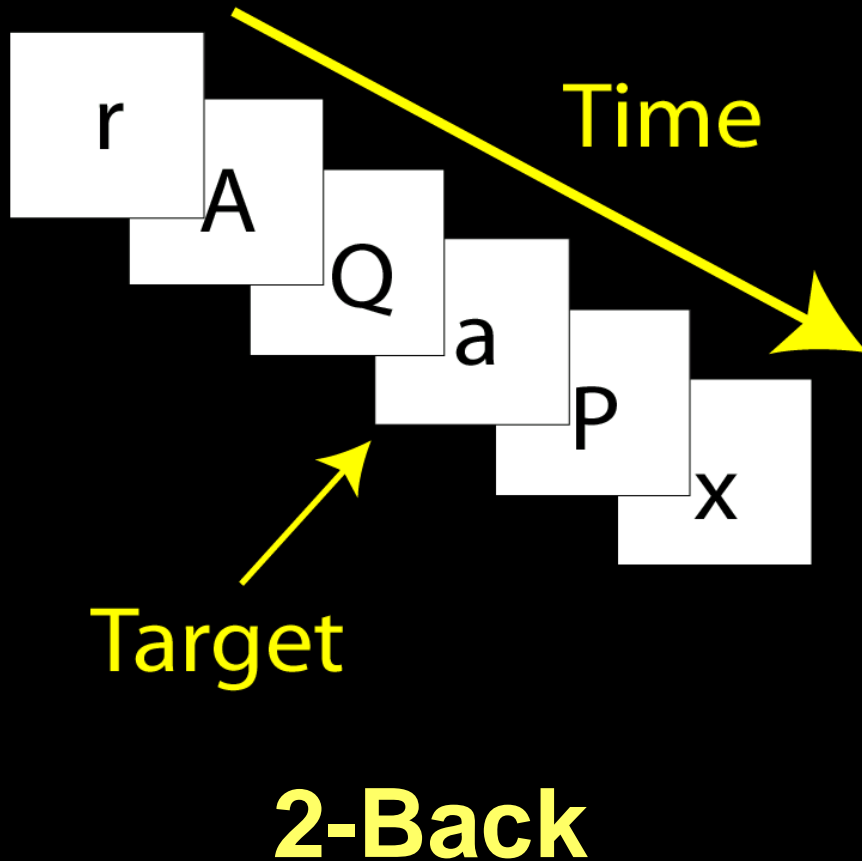
salat@nmr.mgh.harvard.edu



**MGH/MIT/HMS Athinoula A. Martinos Center for
Biomedical Imaging**

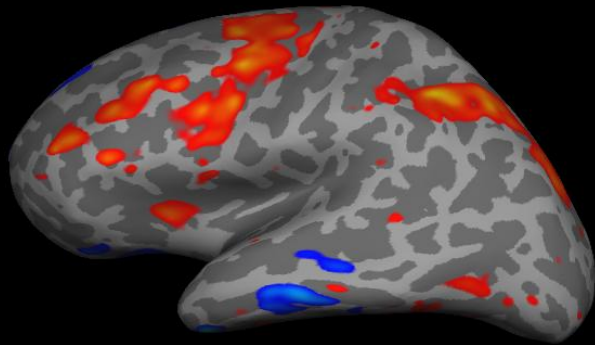


fMRI: Working Memory: N-Back

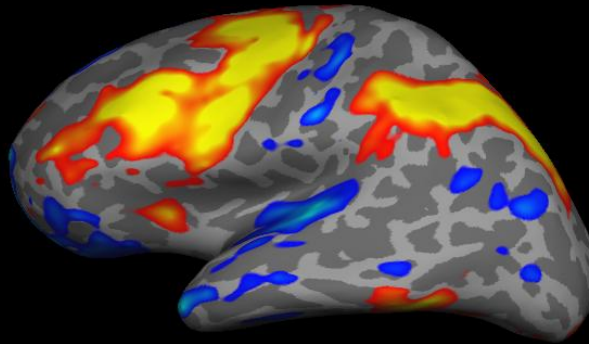


Working Memory: fMRI

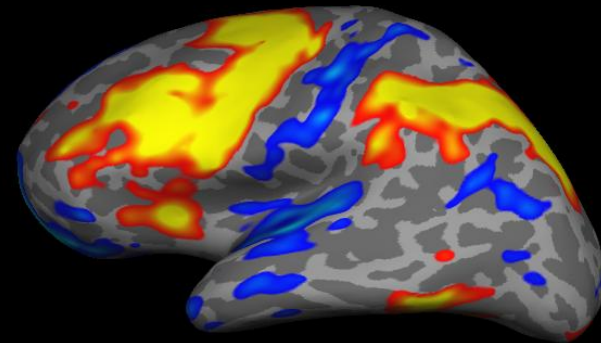
One Back



Two Back

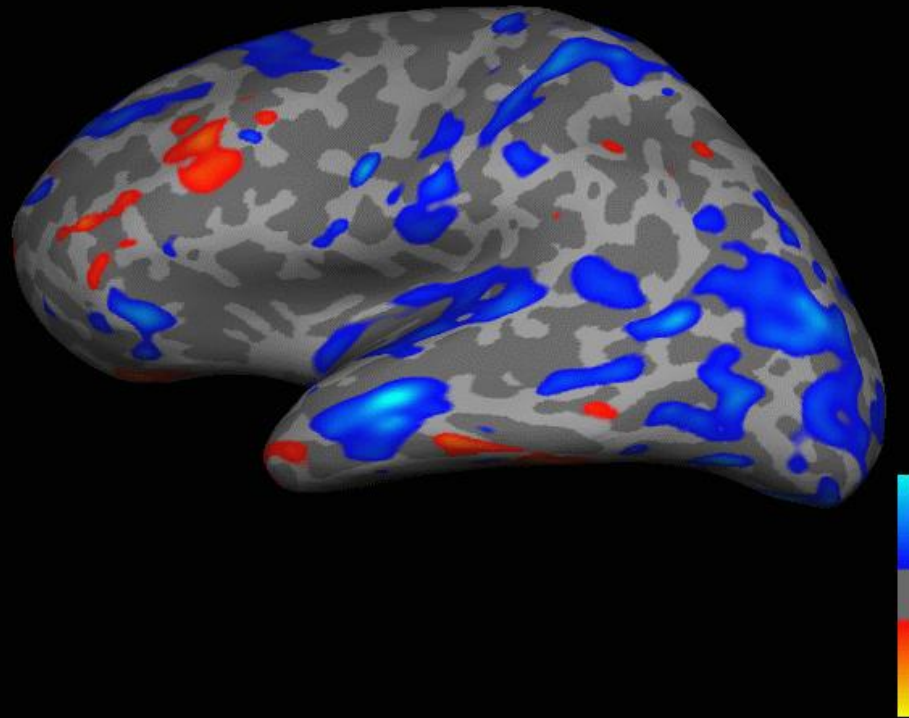


Three Back



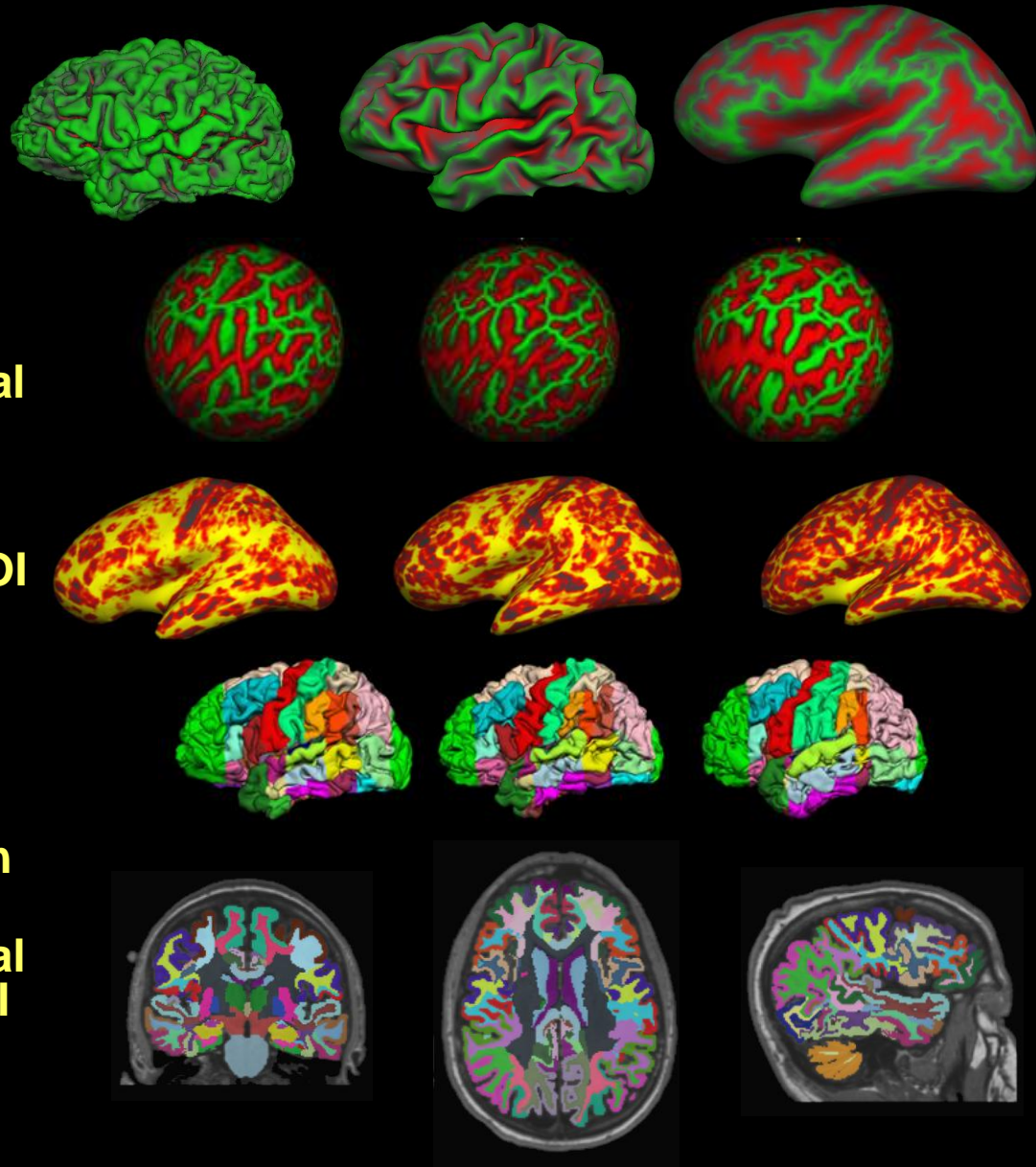
N-Back Working Memory Load

One Back → Two Back → Three Back

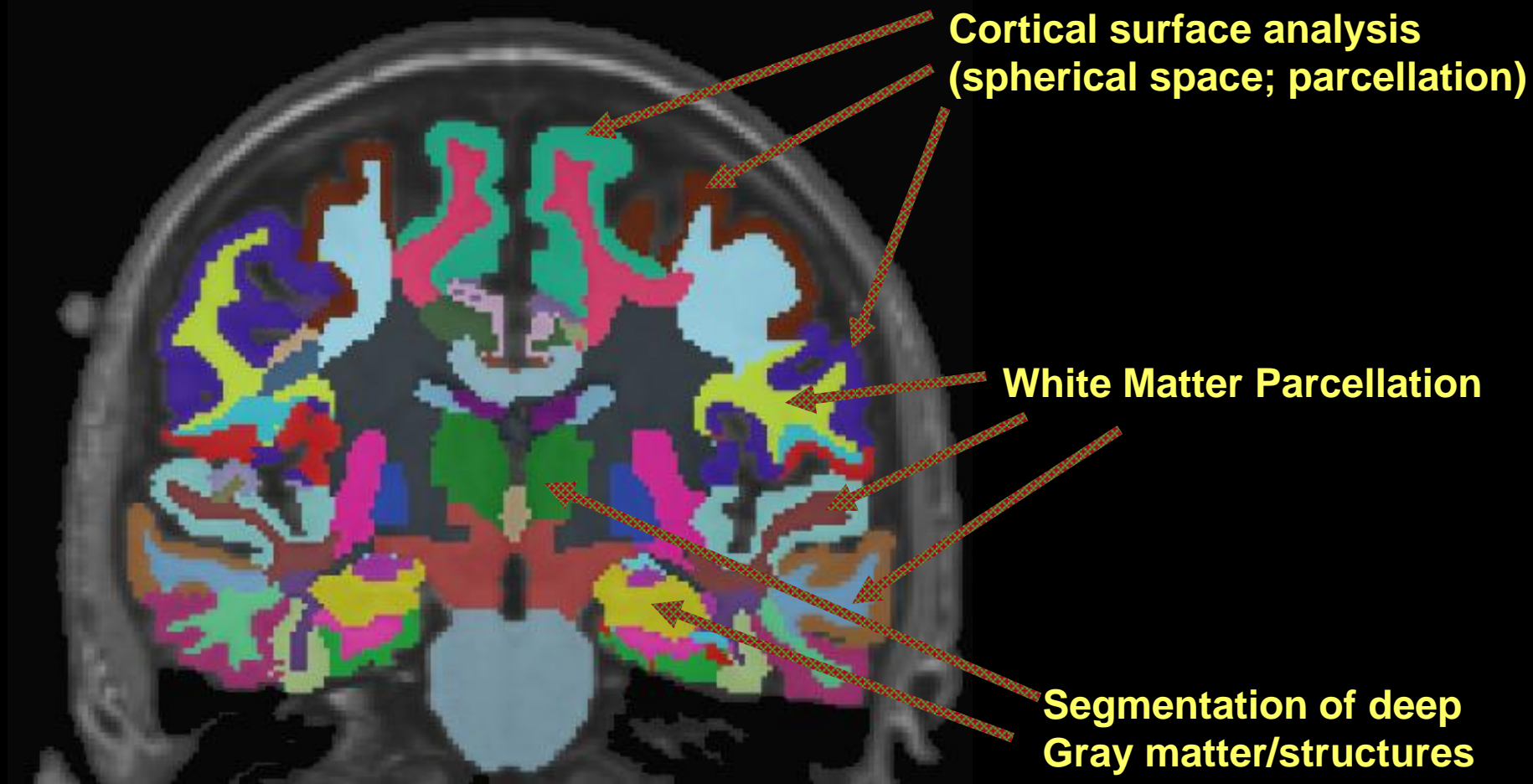


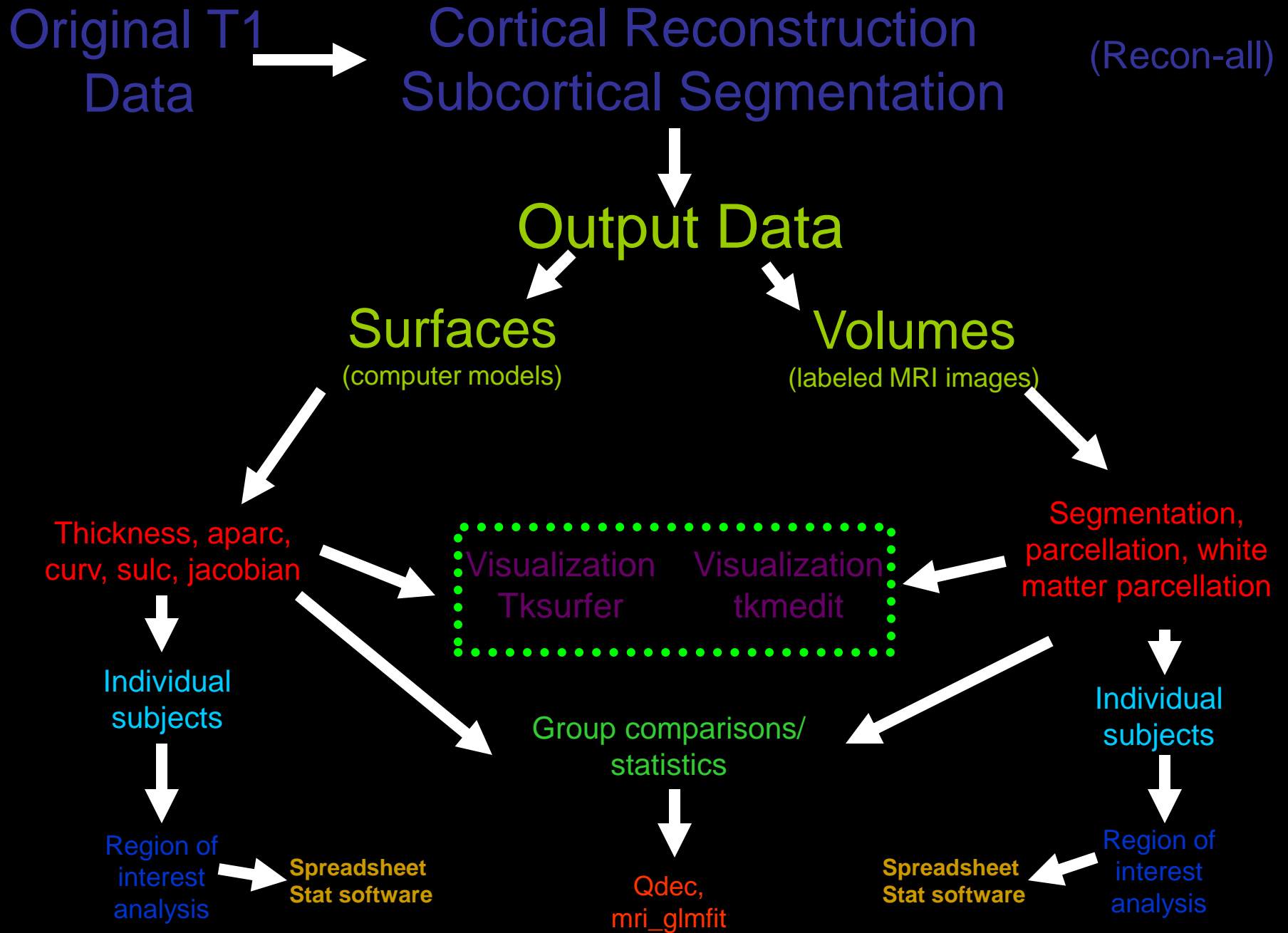
What can we do with Freesurfer?

- **Surface inflation and manipulation:** Visualize structural and functional data; reveal data in sulcal depths
- **Intersubject registration:** Alternate spatial normalization
- **Morphometric analysis:** Cortical thickness; analysis of folding patterns
- **Cortical Parcellation:** Analysis of cortical subregions; fMRI ROI analysis
- **Subcortical segmentation:** Volumetric analysis; fMRI ROI analysis
- **White matter parcellation:** Volumetric analysis; DTI region of interest analysis
- **Integrate with FSL tools:** Spatial normalization of fMRI data; ROI analyses



Post Reconstruction Levels of Analysis/Anatomy





Segmentation of deep Gray matter/structures

Original T1 Data **Cortical Reconstruction Subcortical Segmentation** (Recon-all)

Output Data

Surfaces
(computer models)

Volumes
(labeled MRI images)

**Thickness, aparc,
curv, sulc, jacobian**

Visualization
Tksurfer

Visualization
tkmedit

**Segmentation,
parcellation, white
matter parcellation**

Individual
subjects

Individual
subjects

Region of
interest
analysis

Region of
interest
analysis

Spreadsheet
Stat software

Group comparisons/
statistics

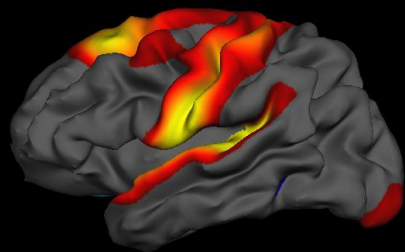
Qdec,
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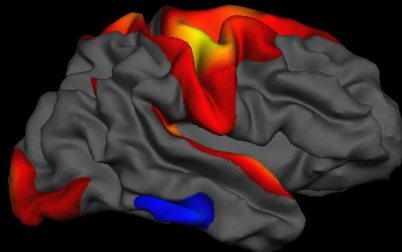
What do we mean by cortical surface?

- Cortical mantle
- These surface based procedures can not be used to examine certain structures such as the hippocampus, amygdala, etc. (use volume segmentation for that)

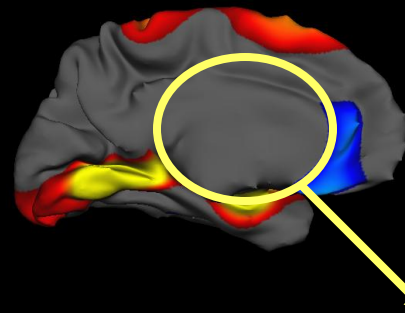
Left-Lateral



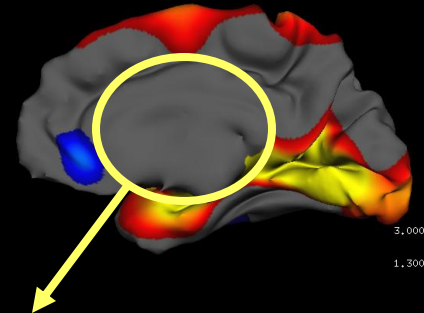
Right-Lateral



Left-Medial



Right-Medial



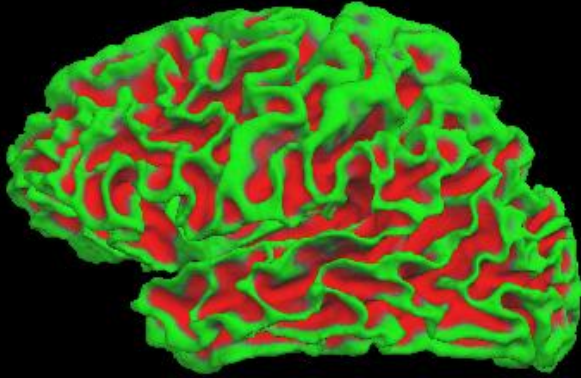
Medial regions that are not part of the cortical mantle are masked from analysis: corpus callosum, thalamus, ventricles



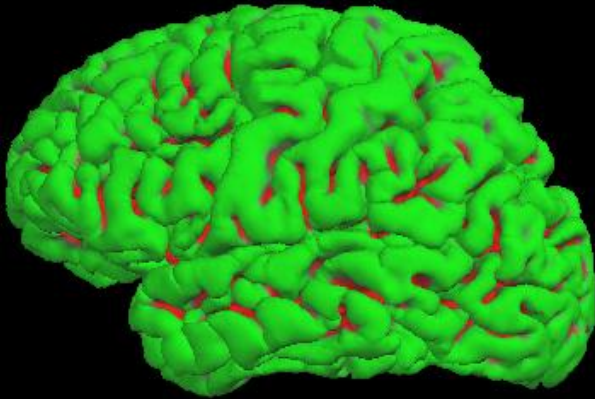
Optimal Surface Placement: Critical for Thickness Accuracy



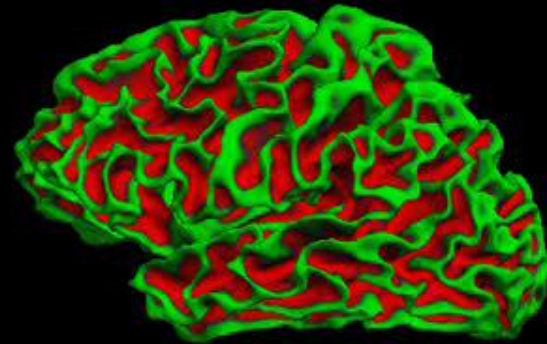
Gray/CSF Deformation



Gray-White Boundary

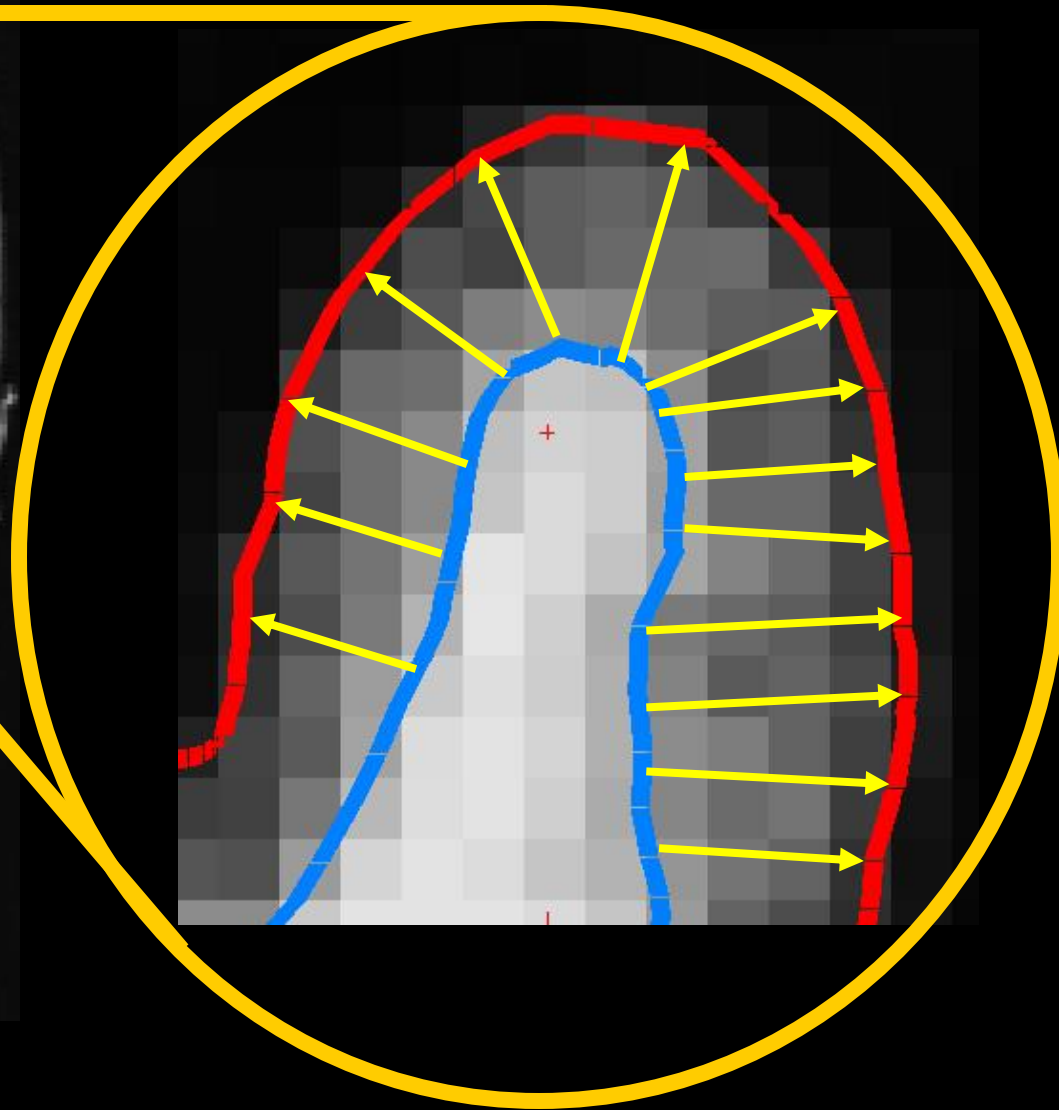
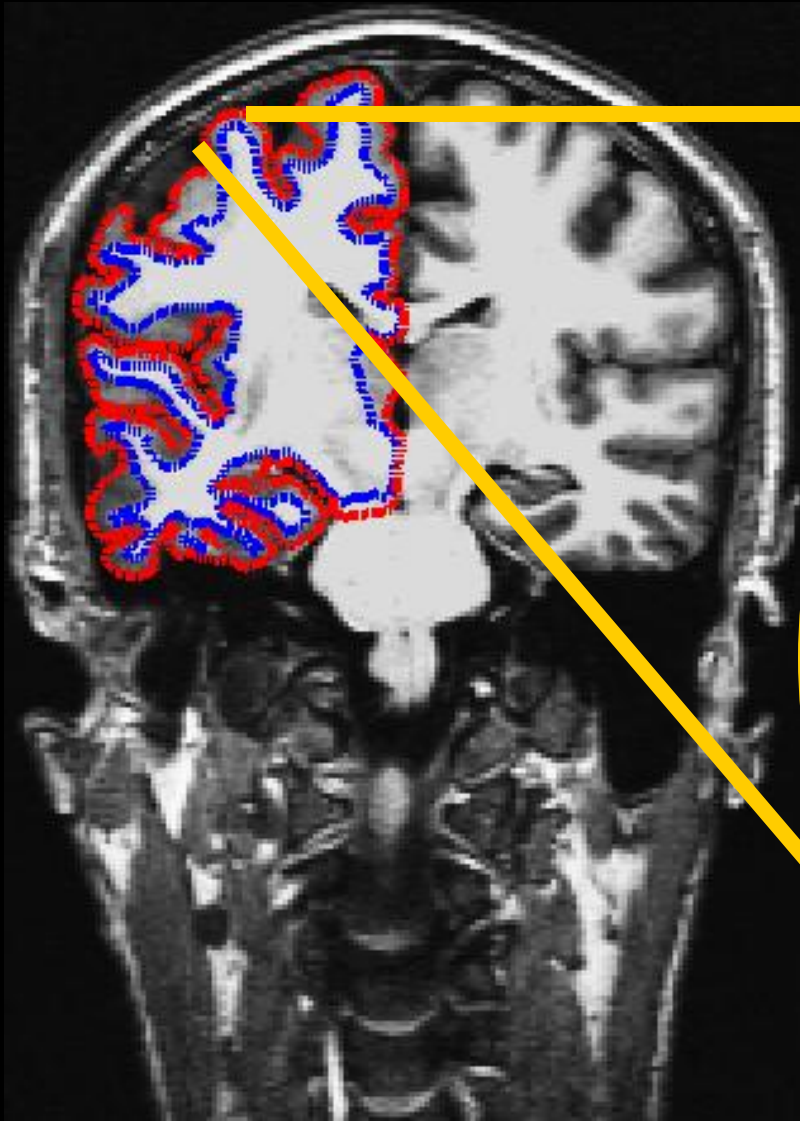


Outer Cortical Surface



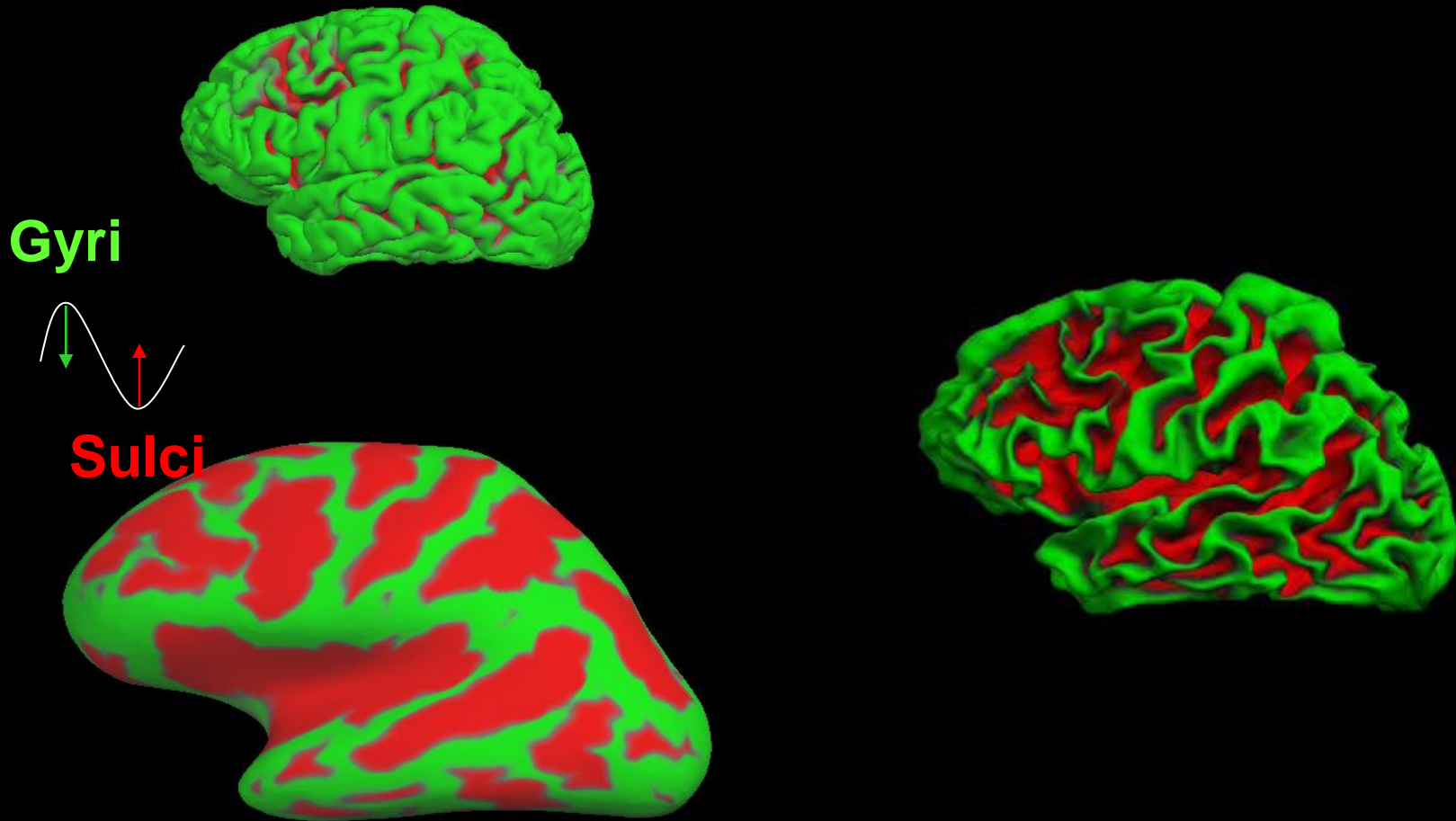
Dale and Sereno, 1993; Dale et al., 1999; Fischl et al., 1999;
Fischl et al., 2000; Fischl et al., 2001

Cortical Thickness



Shown slice here, but this is a whole ribbon process

Visualization: Surface Inflation



Dale and Sereno, 1993; Dale et al., Dale et al., 1999; Fischl et al., 1999;
Fischl et al., 2000; Fischl et al., 2001

Cortical thinning in aging and AD

Questions:

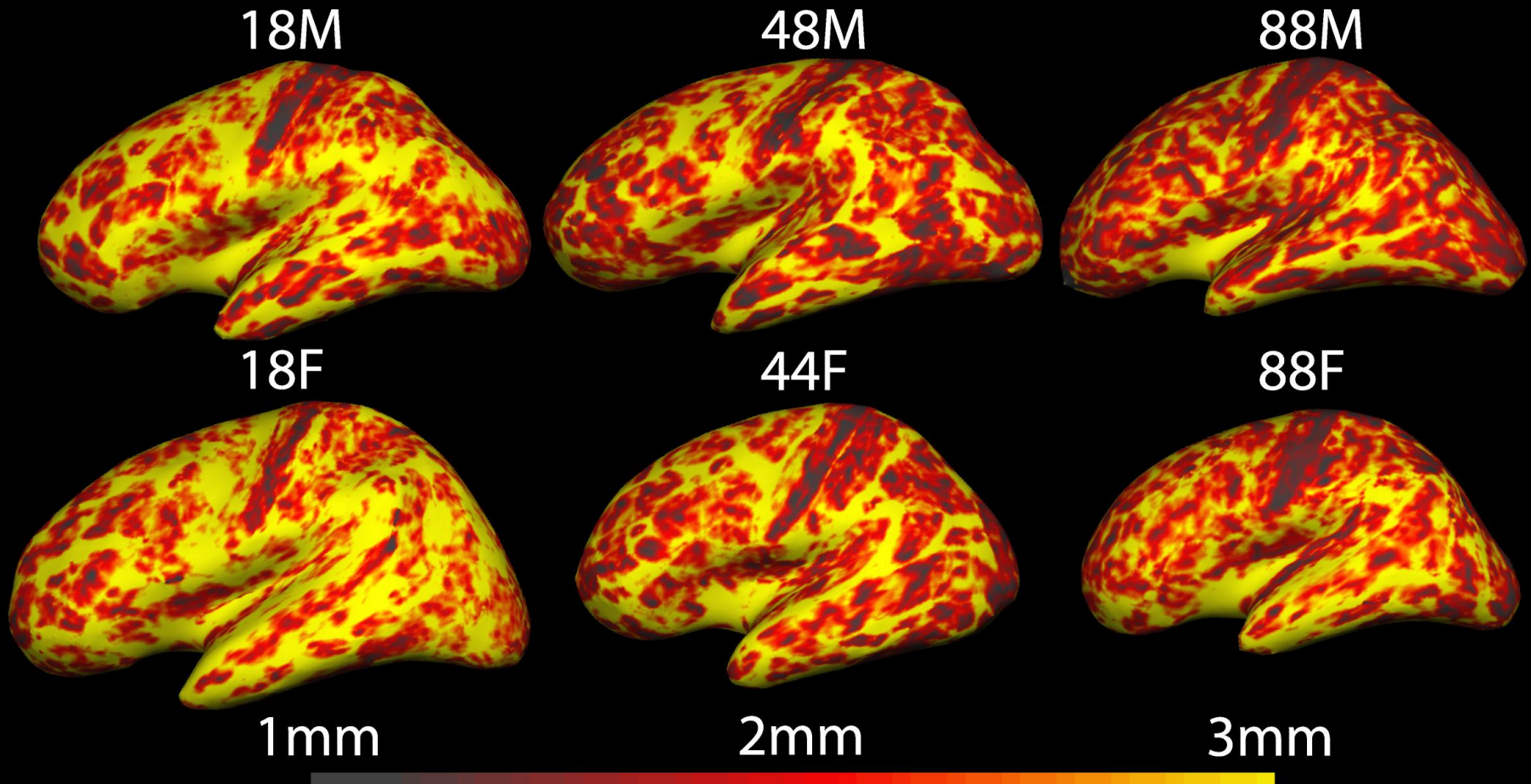
How early can age-related cortical atrophy be detected?

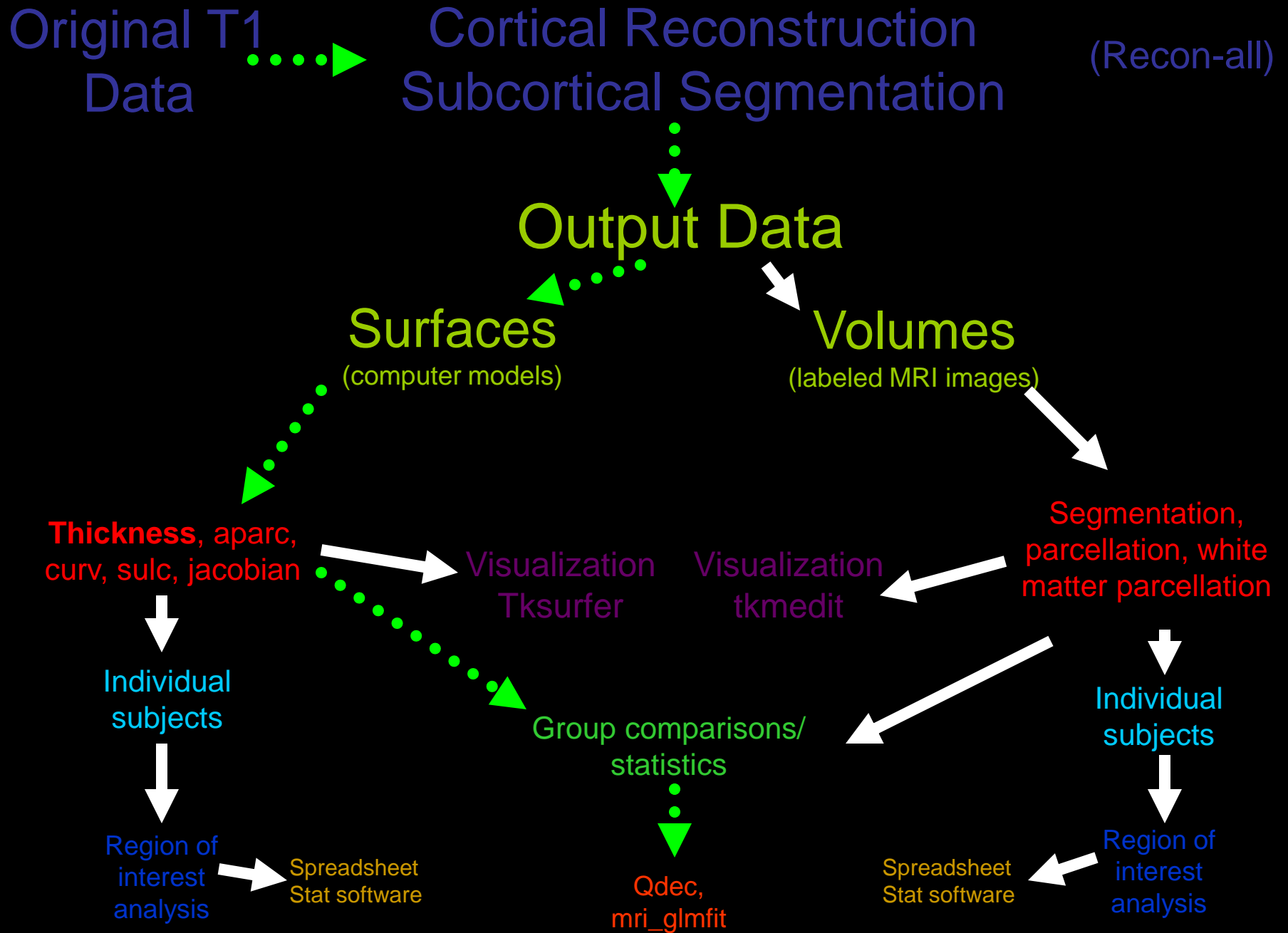
What are the regional patterns of age-related cortical atrophy?

Do patterns of cortical atrophy differ in AD compared to healthy aging?

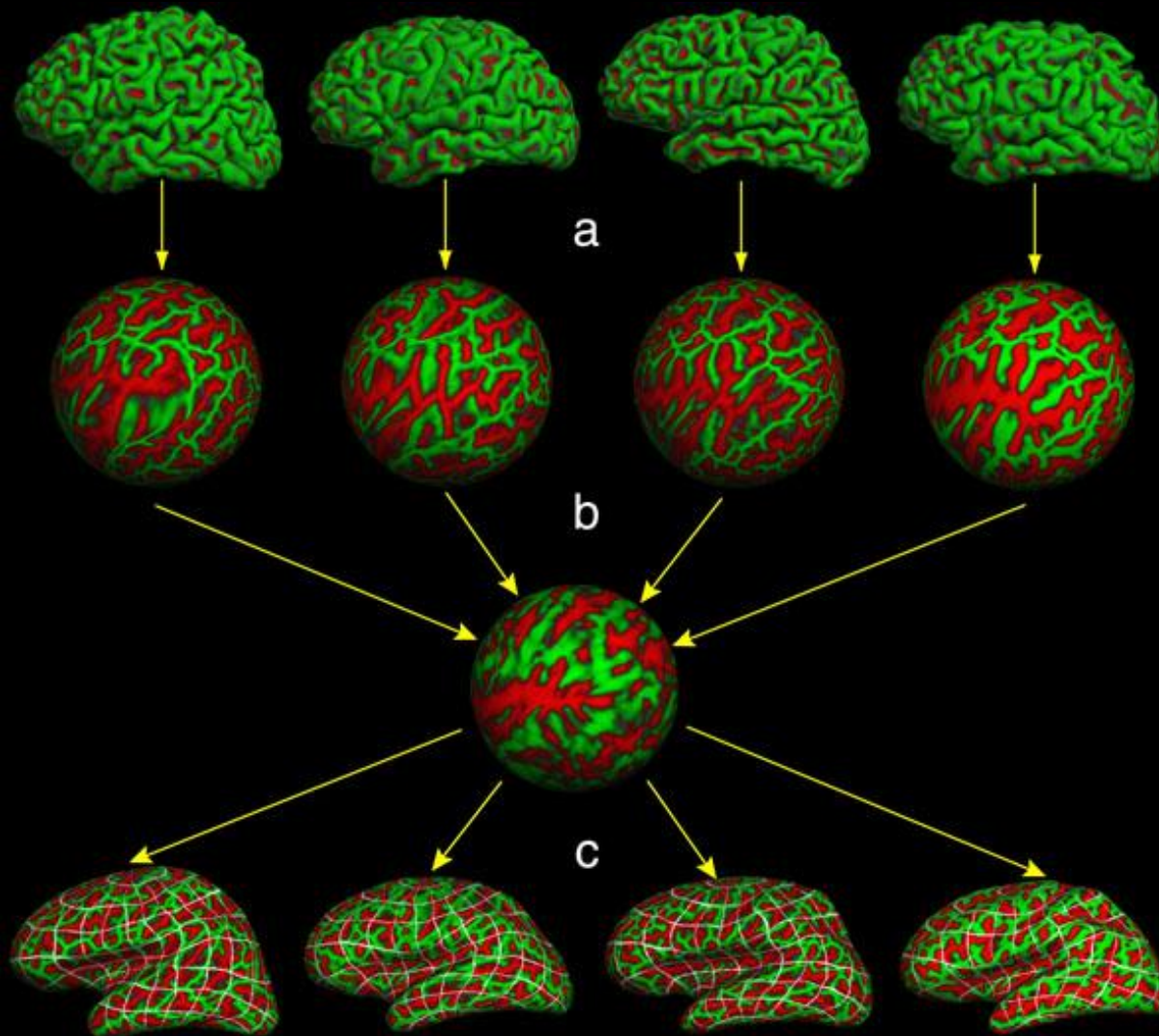
Inflated Thickness Maps in Six Individuals

- Yellow is thicker cortex, red is thinner cortex
- Thinner cortex in older adults (more red) visible on individual maps



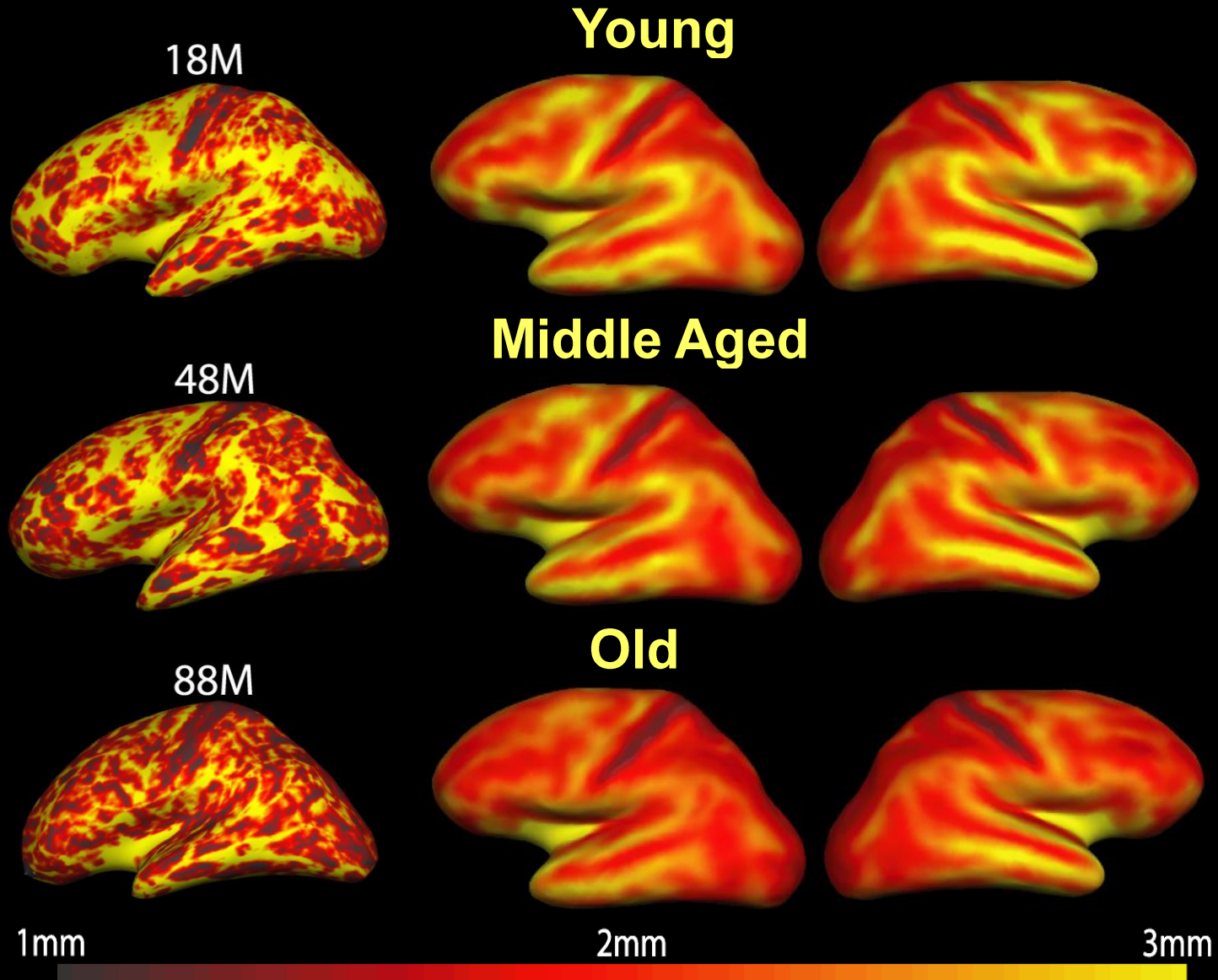


Inter-Subject Morphing



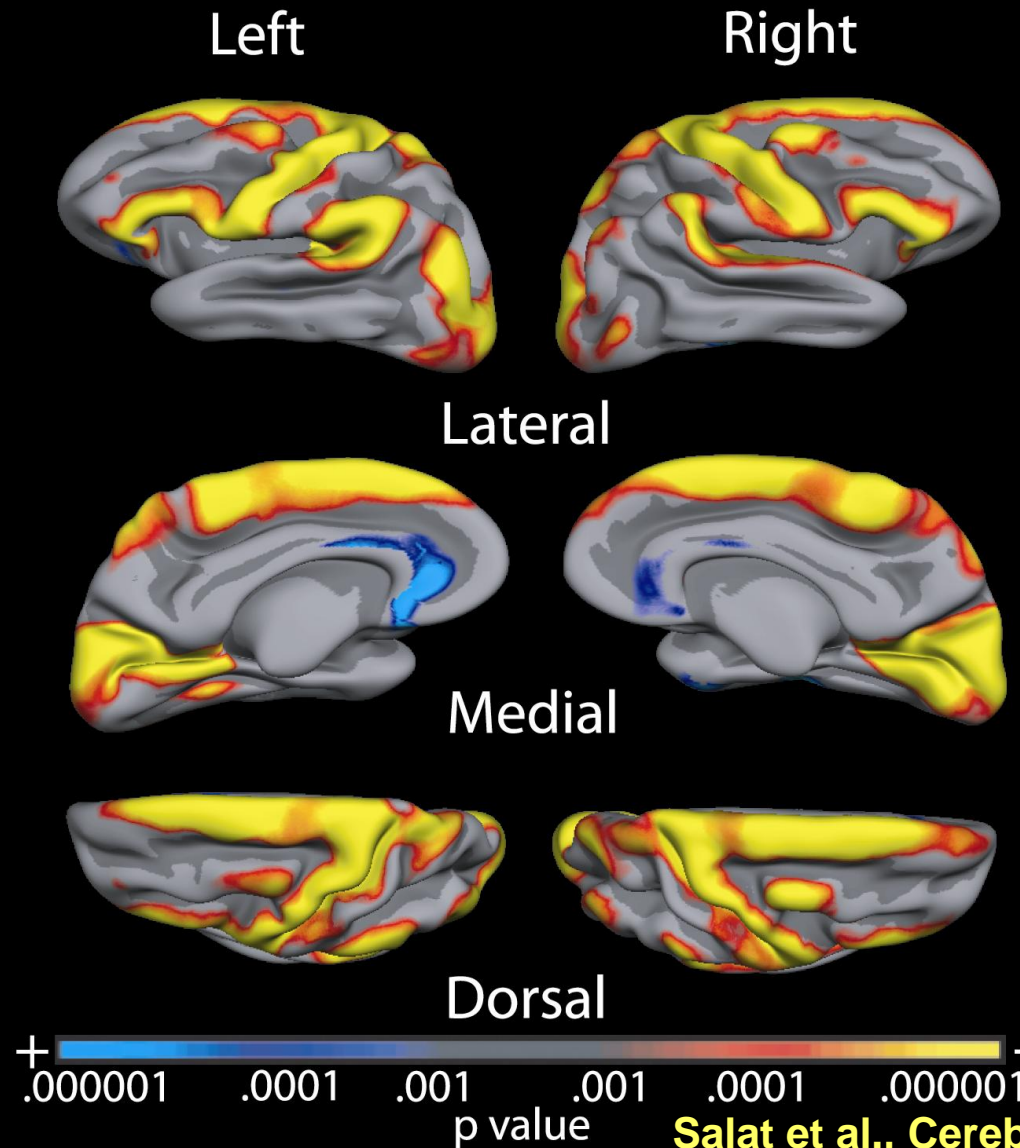
Fischl, Sereno, Dale, Neuroimage, 1999
Fischl et al., Human Brain Mapping, 1999

Group Mean Thickness



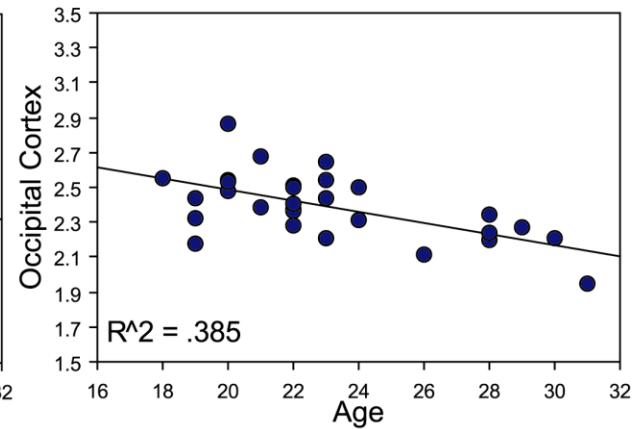
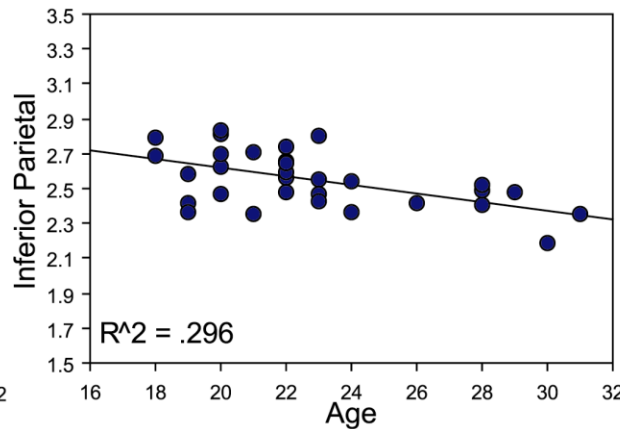
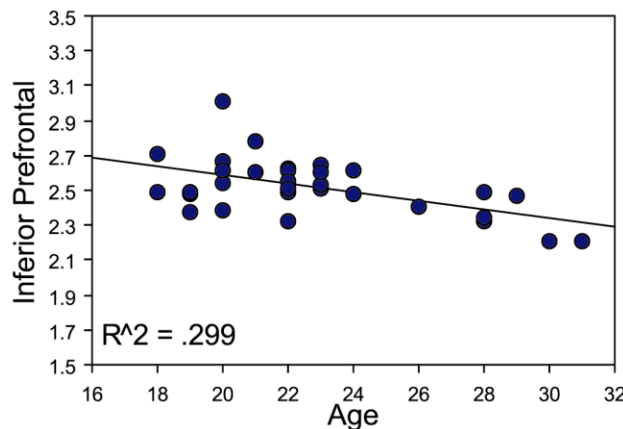
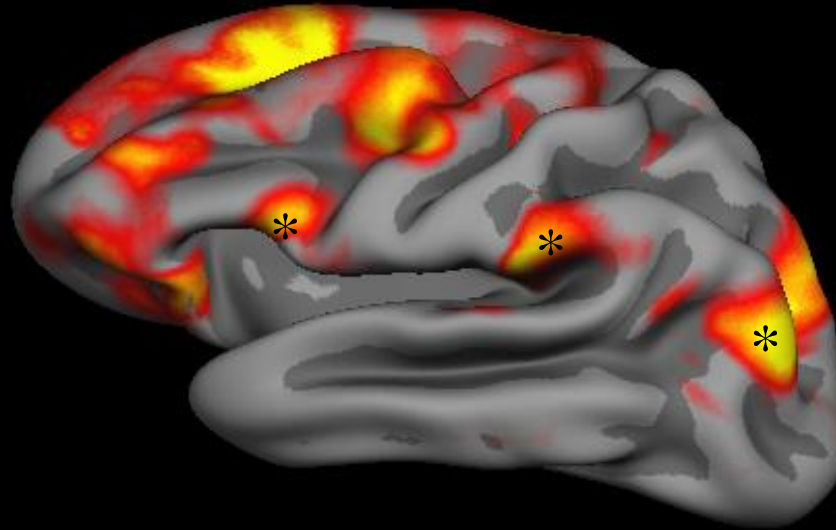
Thinning from Young to Old Age

Thinning in primary as well as association areas



Salat et al., Cerebral Cortex, 2004

Thinning in Young Adults



Confidence for whole sample analysis: e.g. motion, wm damage in OA; Development?

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Visualization Tksurfer

Visualization tkmedit

Segmentation, parcellation, white matter parcellation

Individual subjects

Region of interest analysis

Spreadsheet Stat software

Group comparisons/ statistics

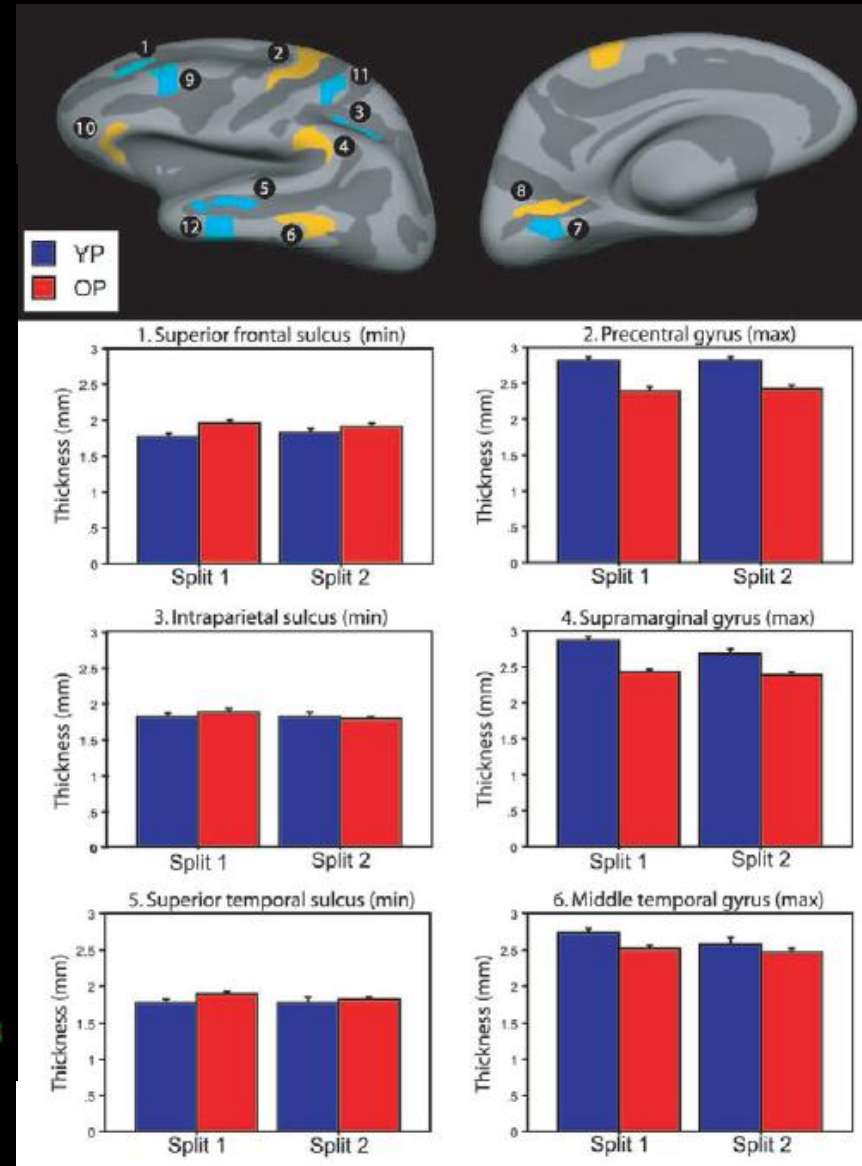
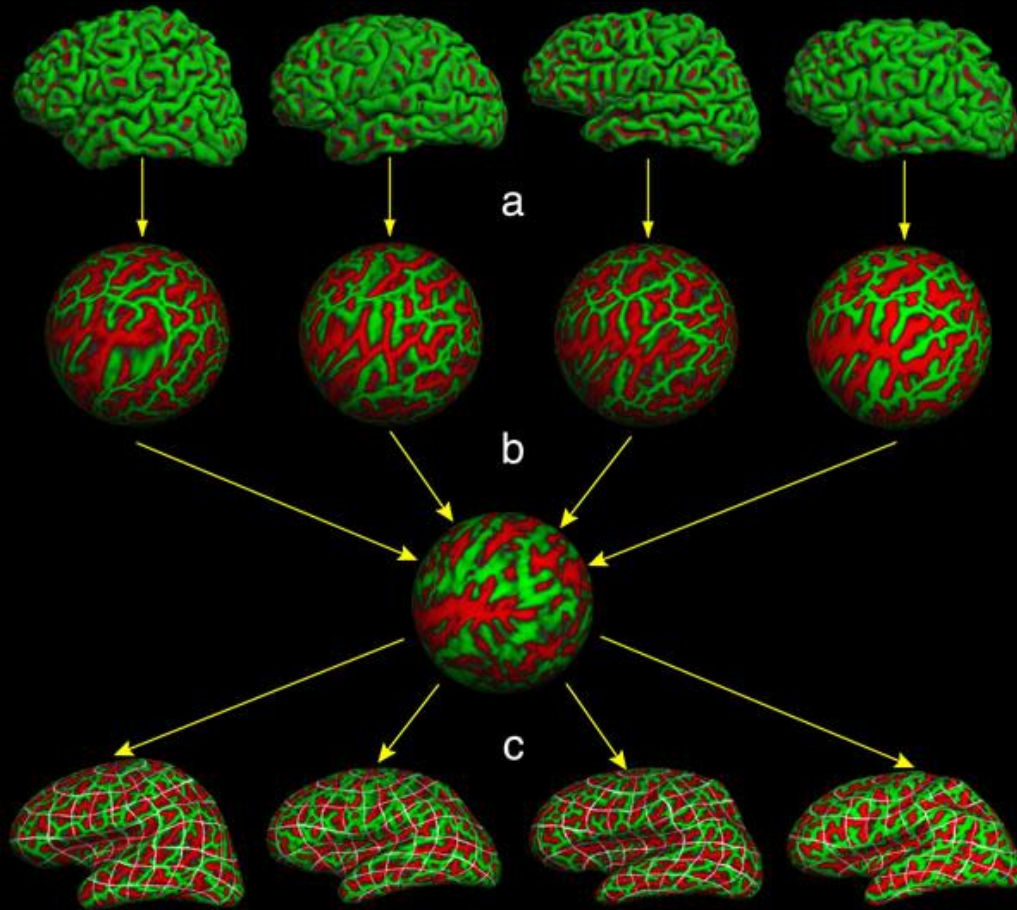
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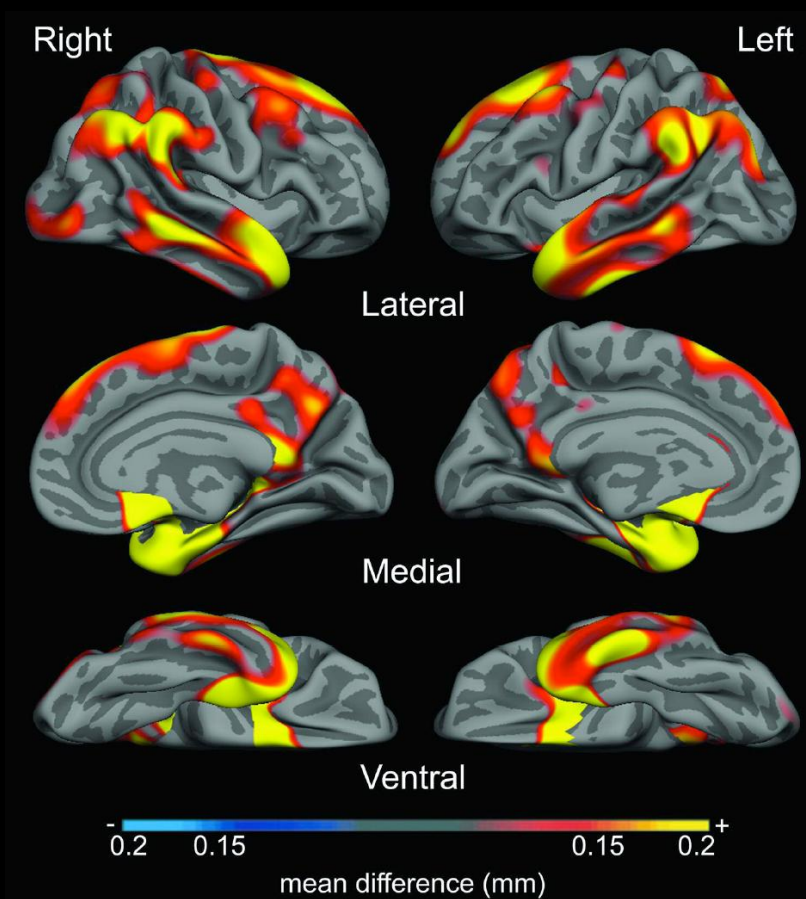
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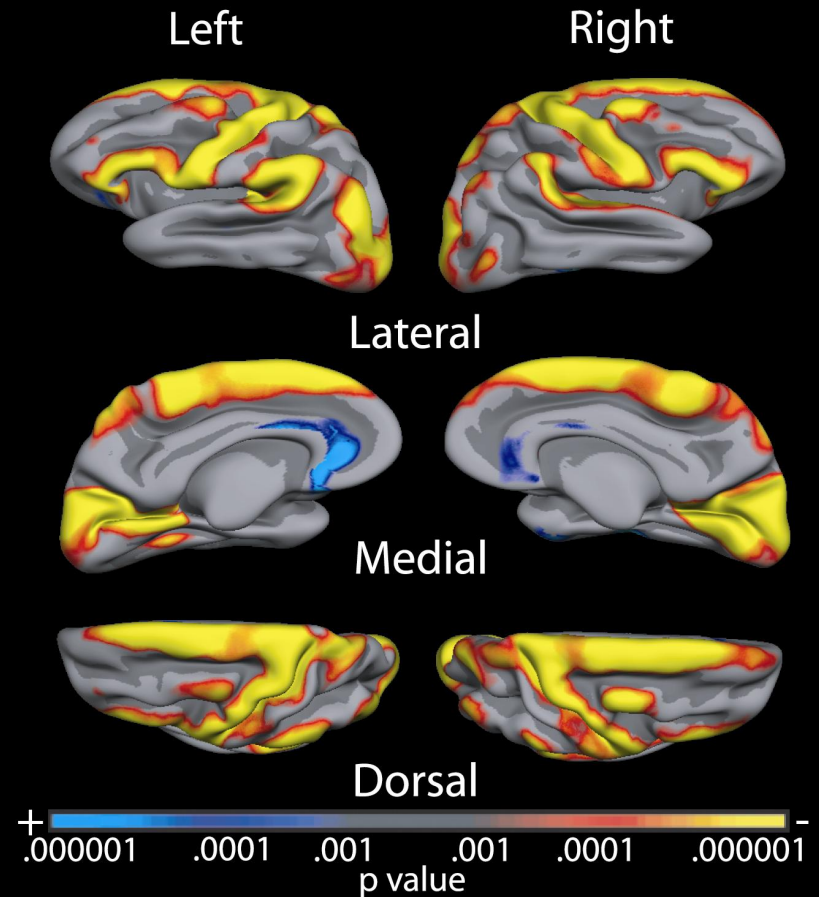
Replication of Effects: Label Mapping



'Cortical Signature of AD'

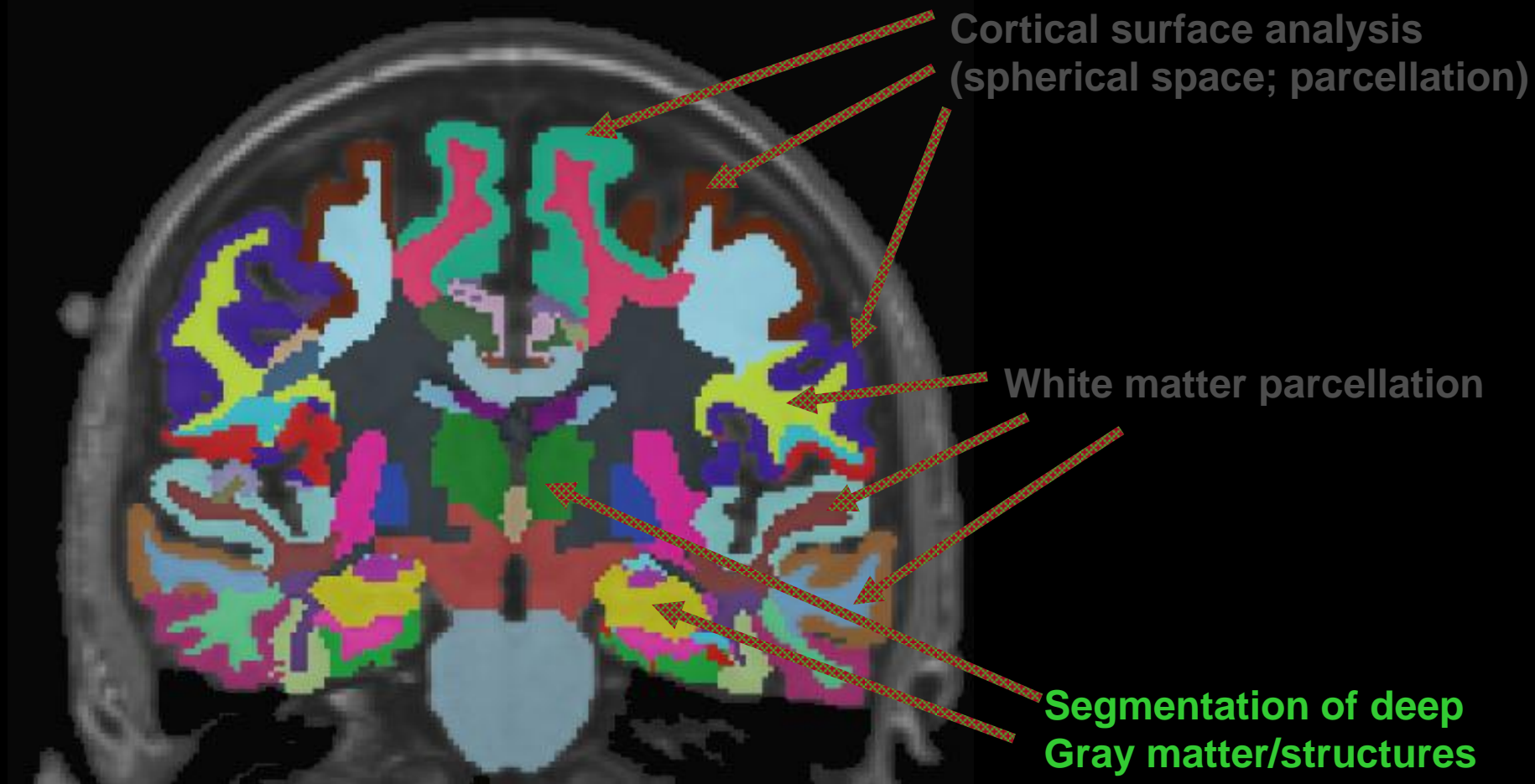


Dickerson et al., Cerebral Cortex, 2008



Salat et al., Cerebral Cortex, 2004

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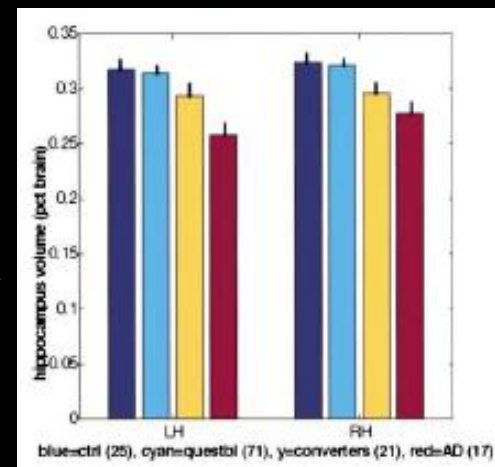
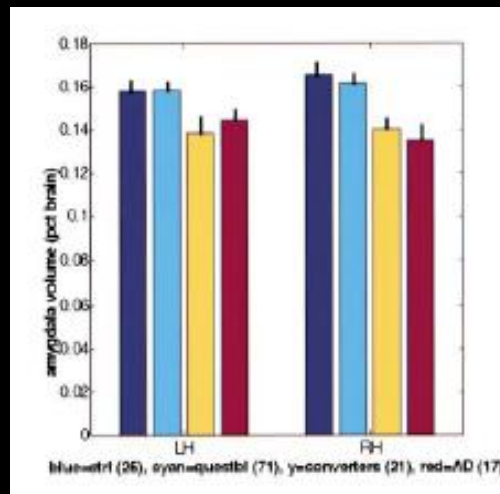
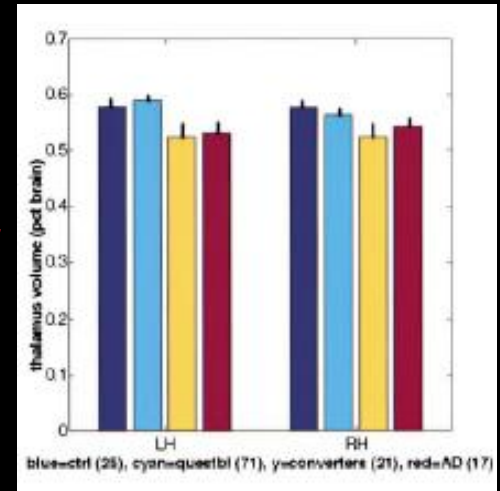
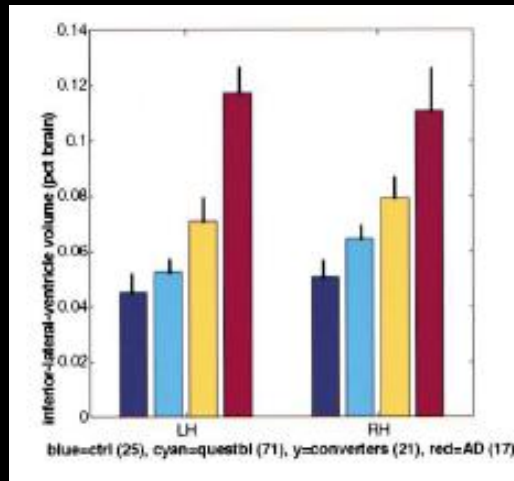
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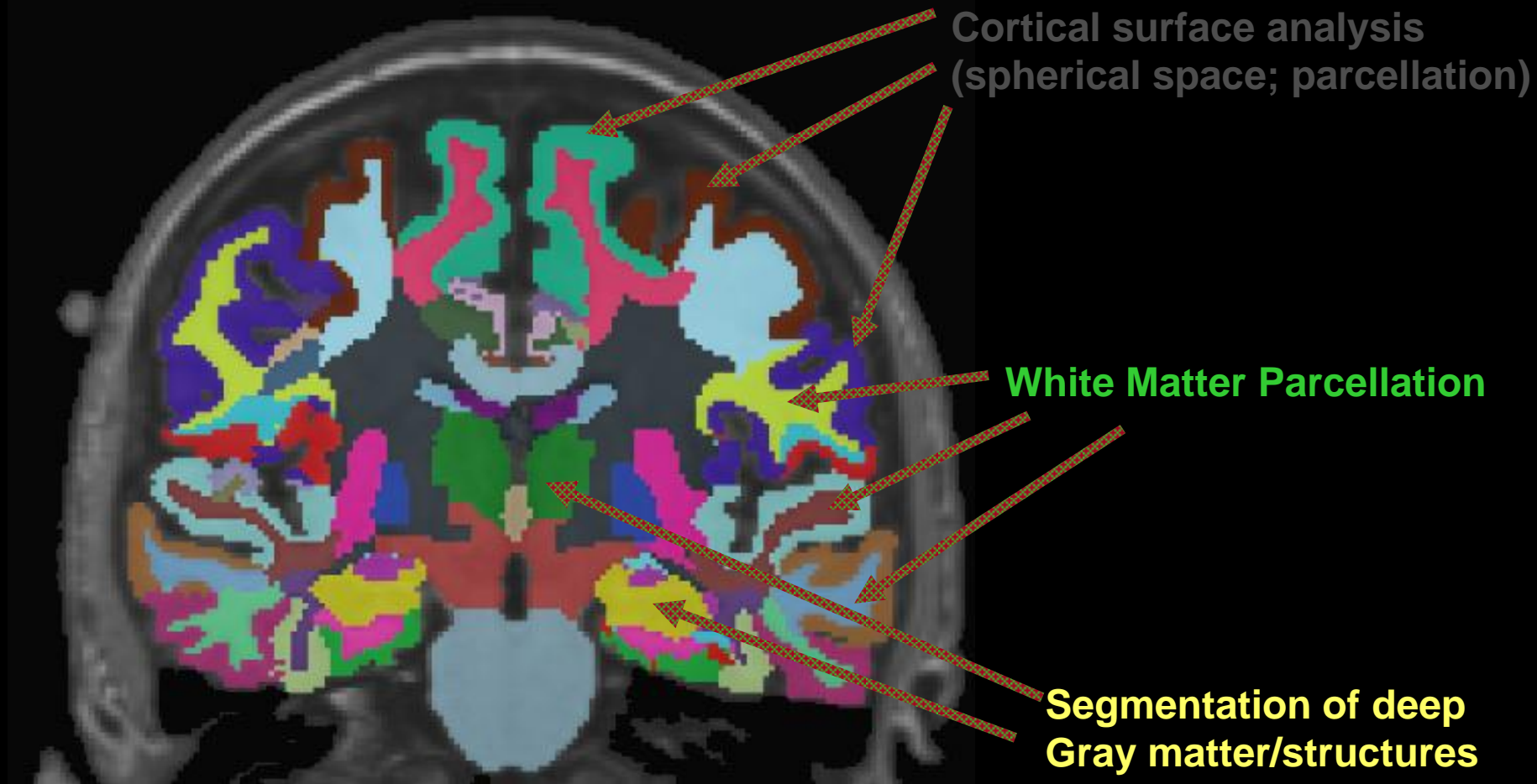
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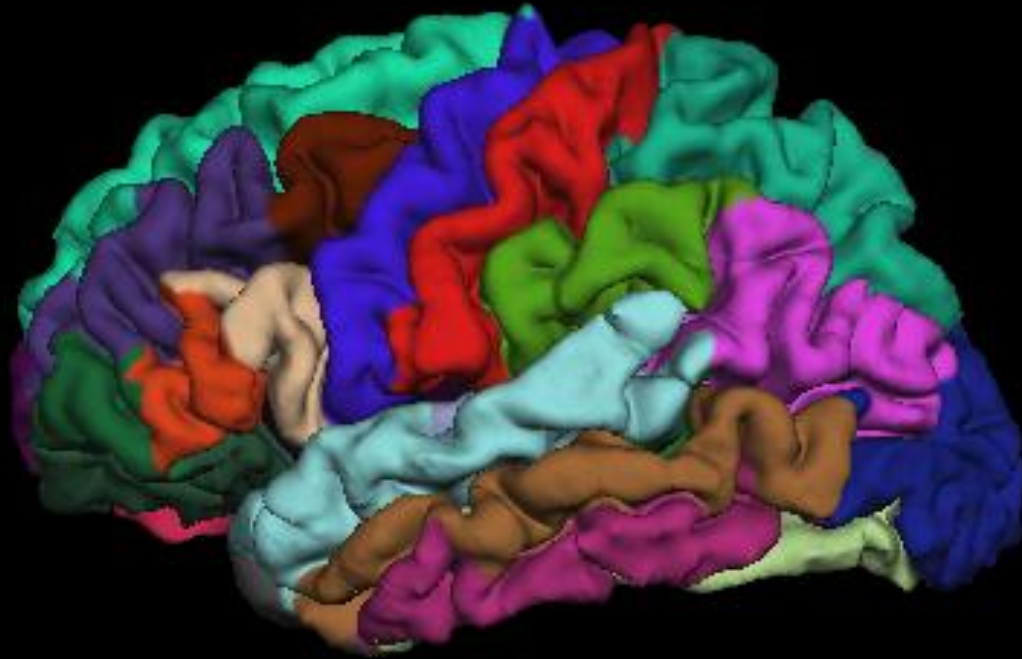
Volumetric Differences in Individuals Prior to Conversion to AD



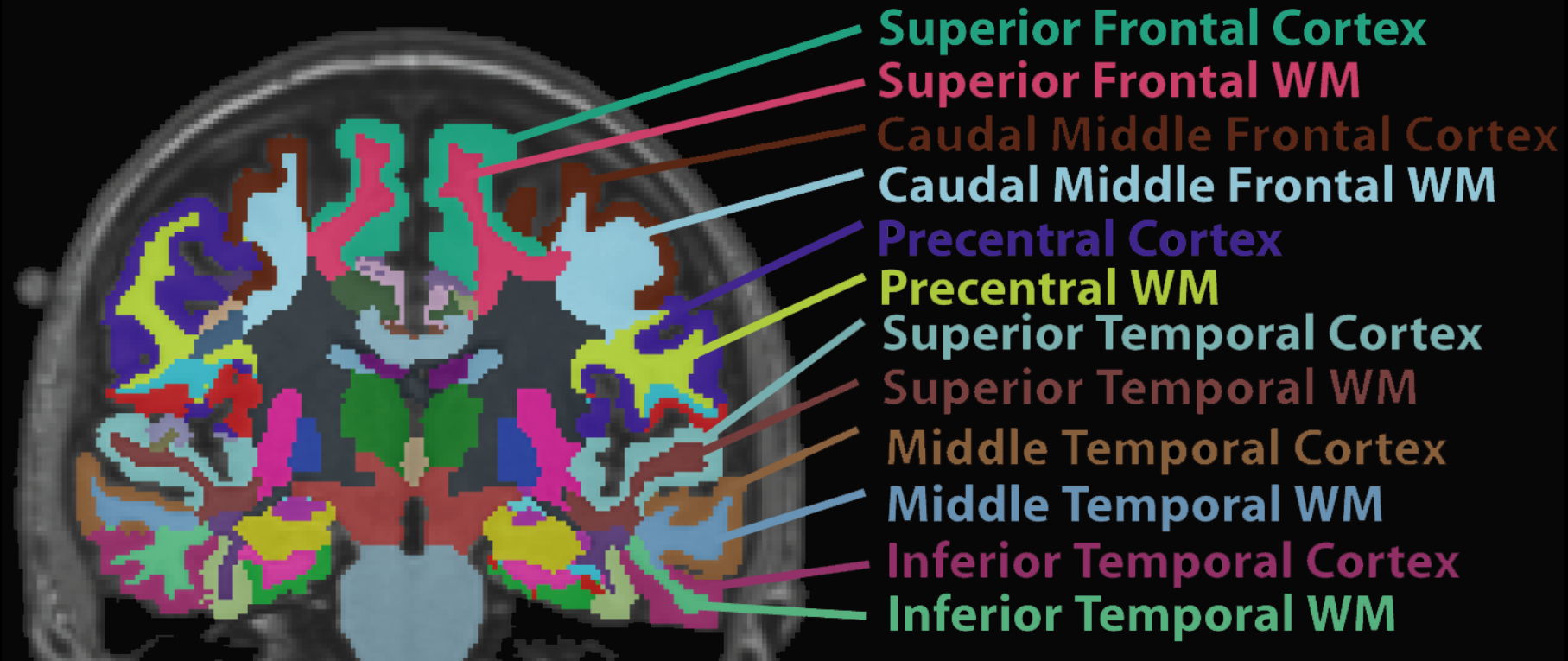
Post Reconstruction Levels of Analysis/Anatomy



Cortex → White matter

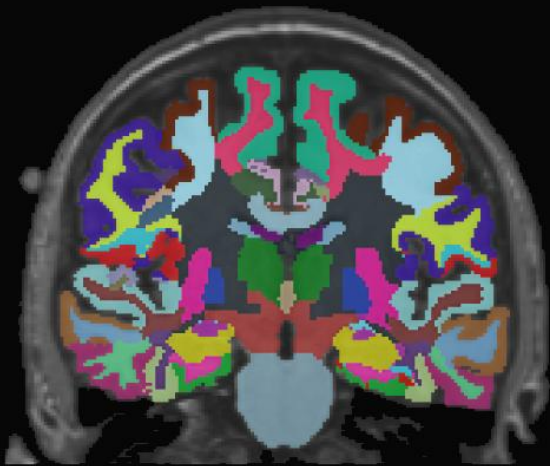


White Matter Parcellation

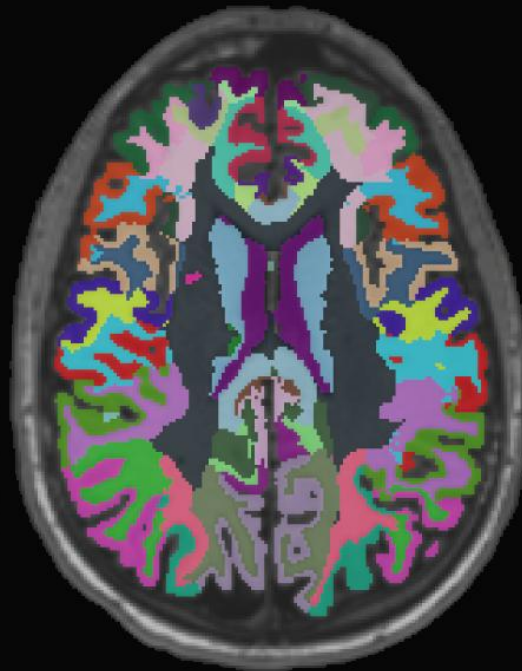


Volumetric Analysis/DTI ROI Analysis

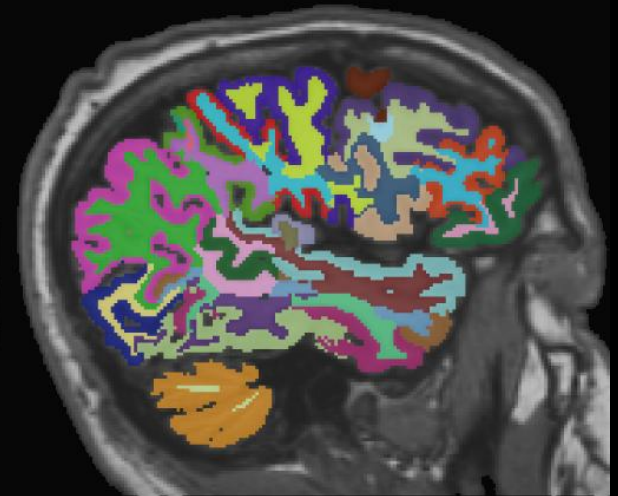
Coronal



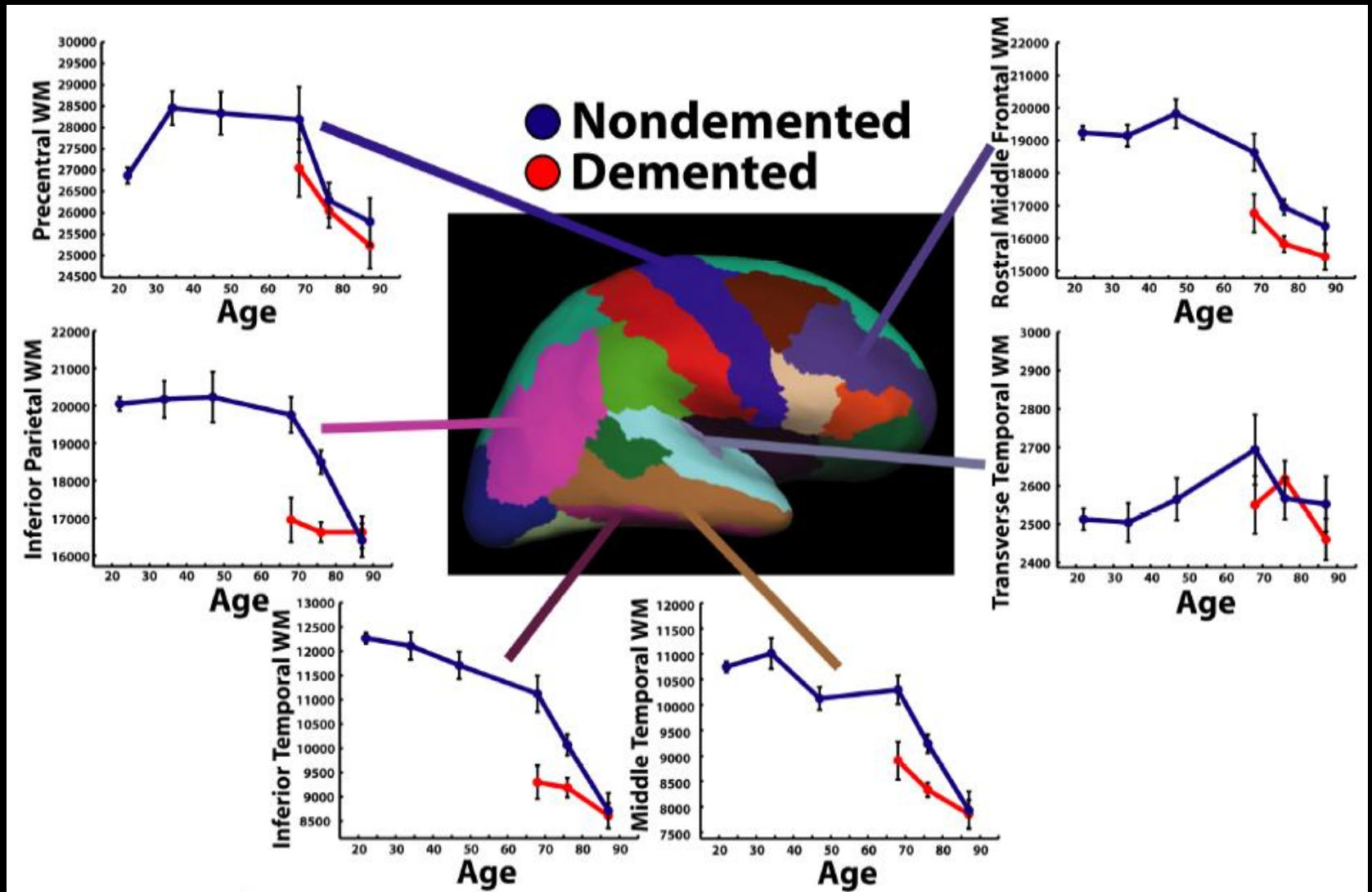
Axial



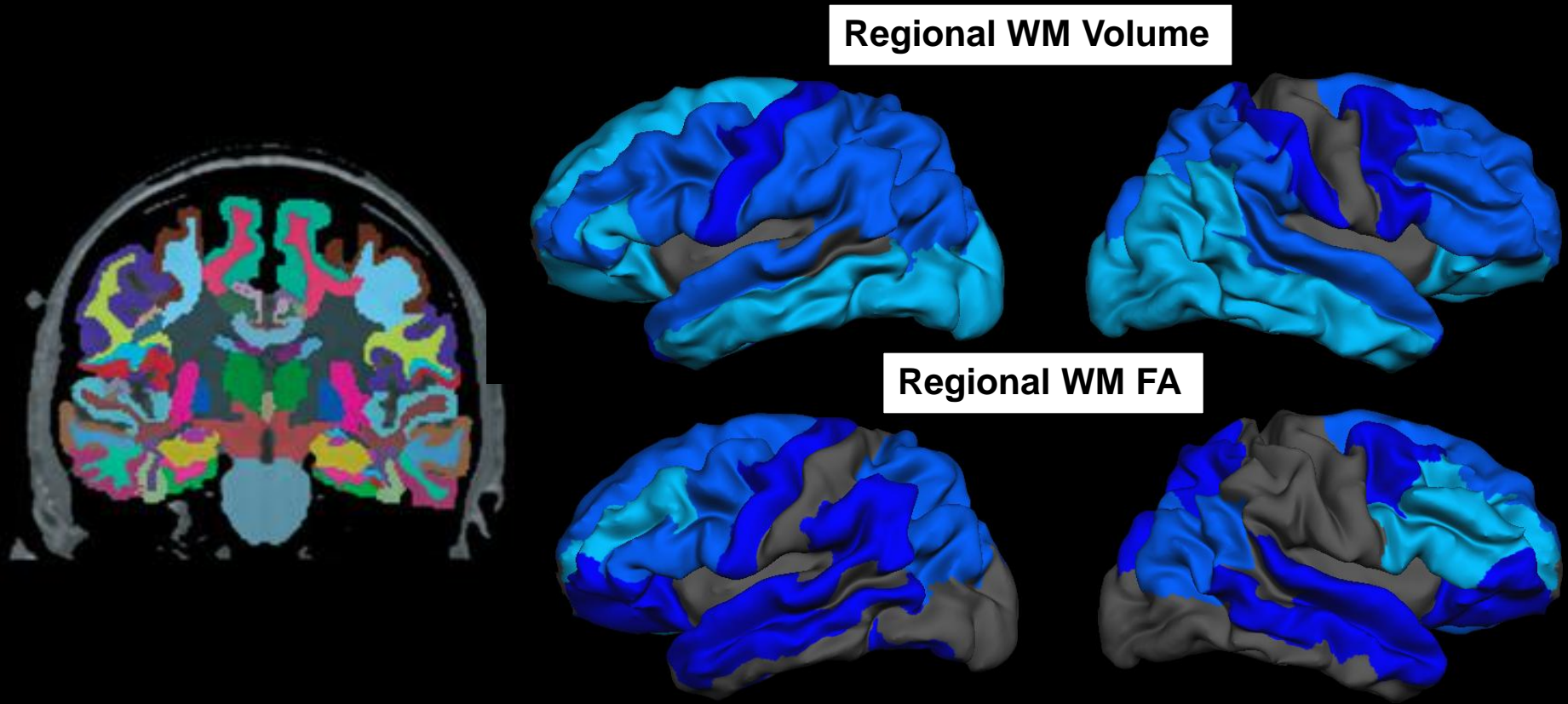
Sagittal



Effects of Age and AD on Regional White Matter

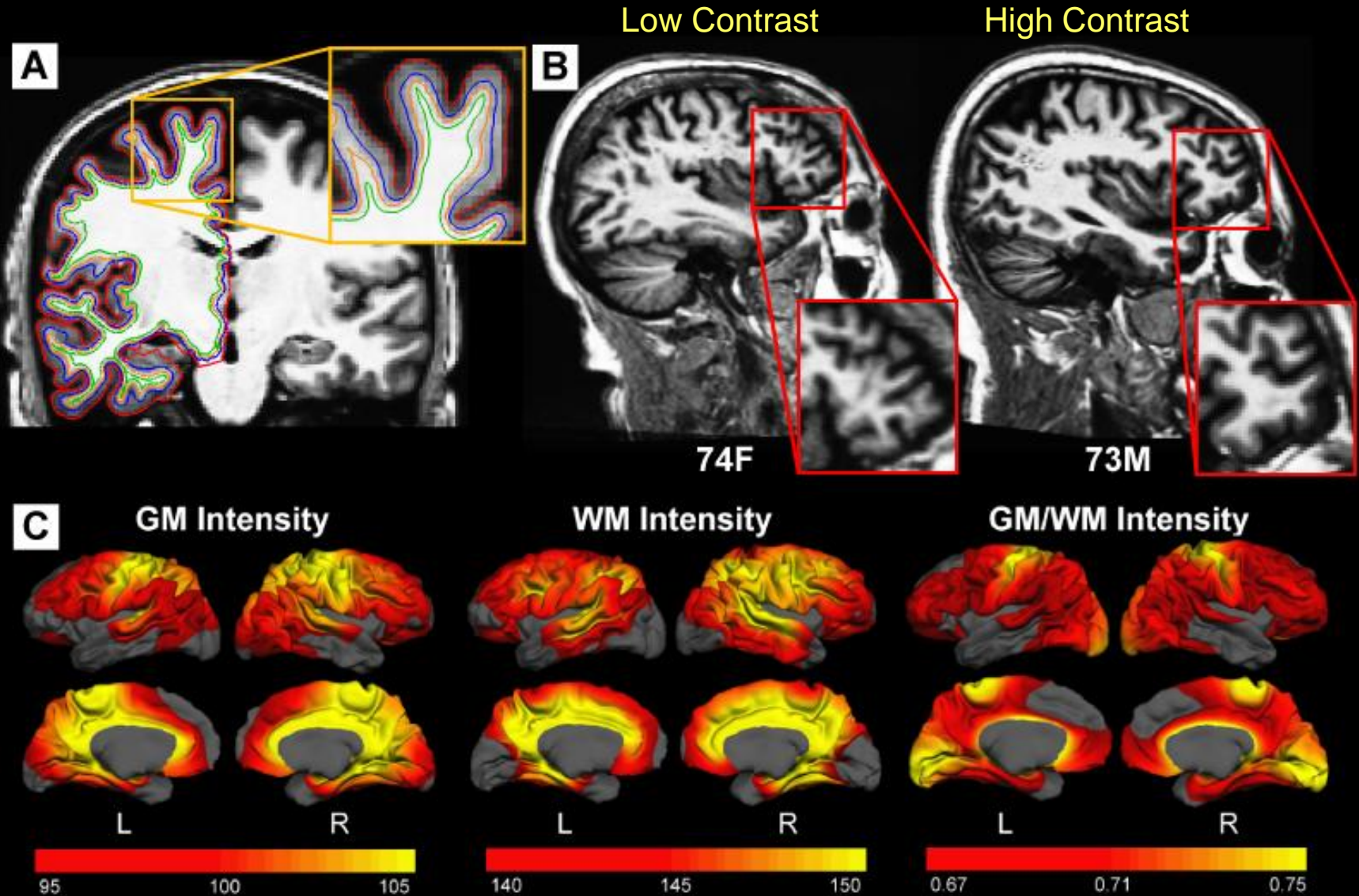


Gyral Changes in Volume and DTI FA

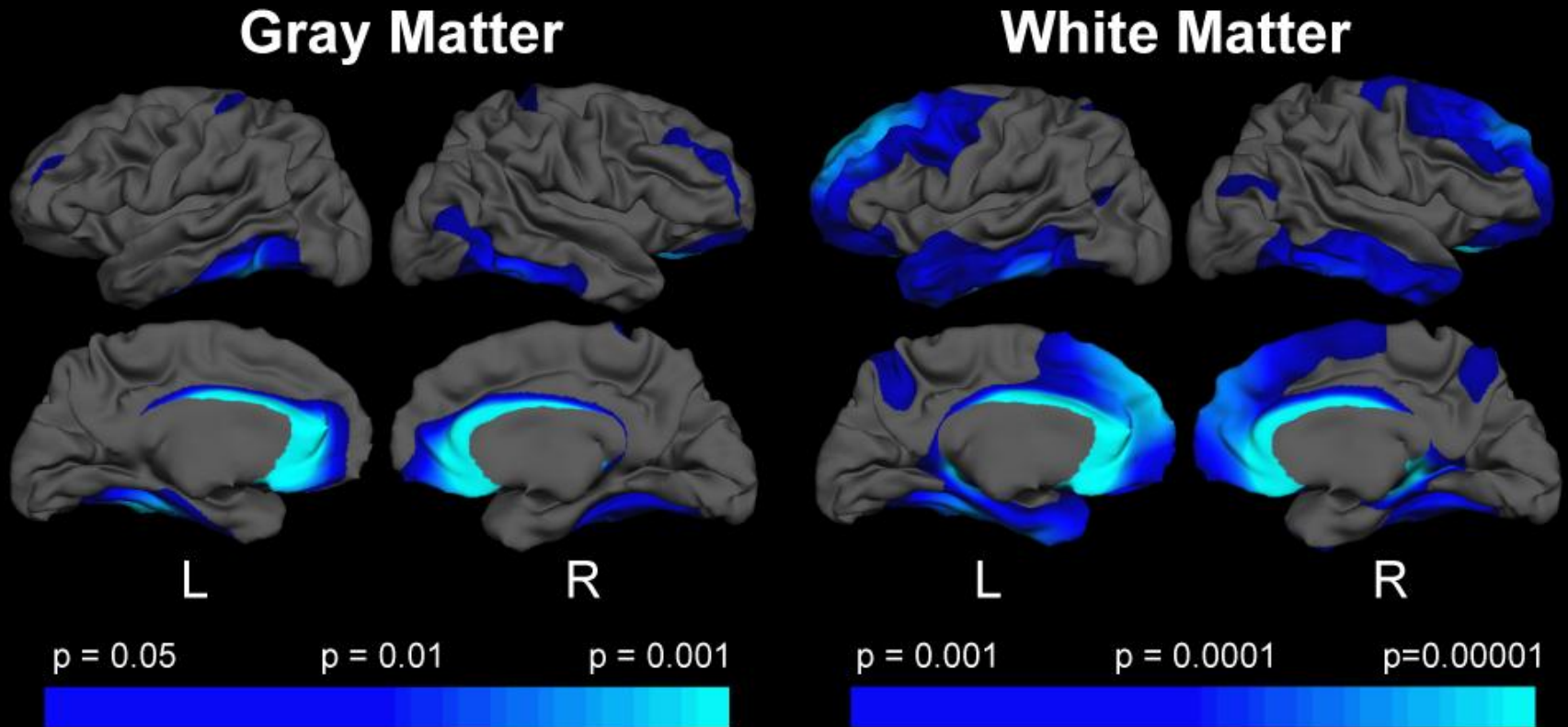


- FA/WM volume is strongly reduced throughout the brain (not necessarily along a clear theoretical definition)
- Procedures for measurement contribute to results (e.g. registration, etc).

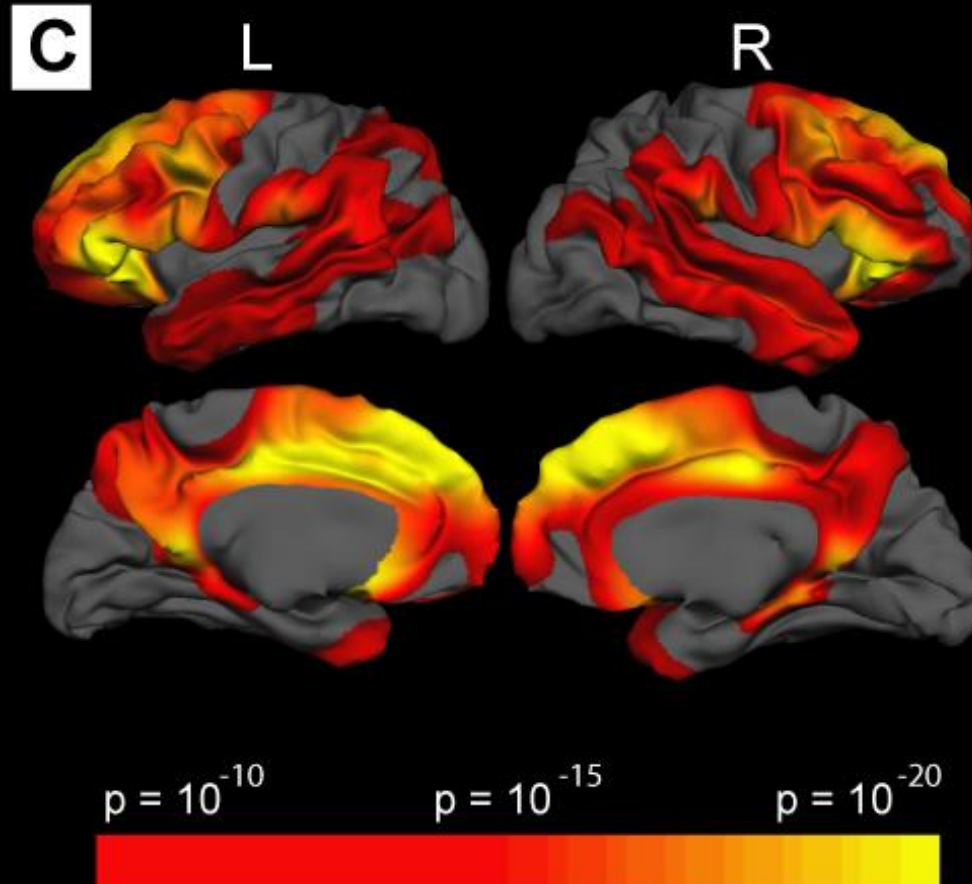
Intensity Sampling



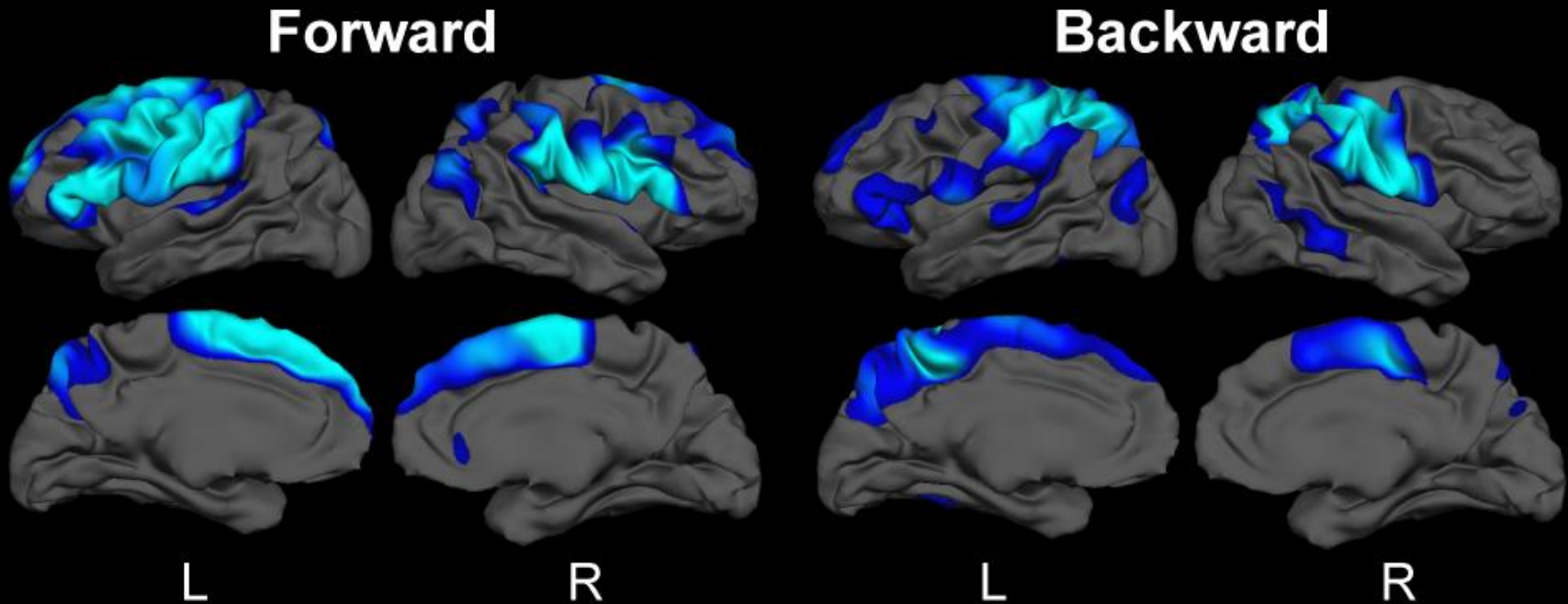
Effects of Age on Gray and White Matter Intensity



Changes in Contrast with Age (controlling for thickness)



Association with Cognition (digit span forward/backward)

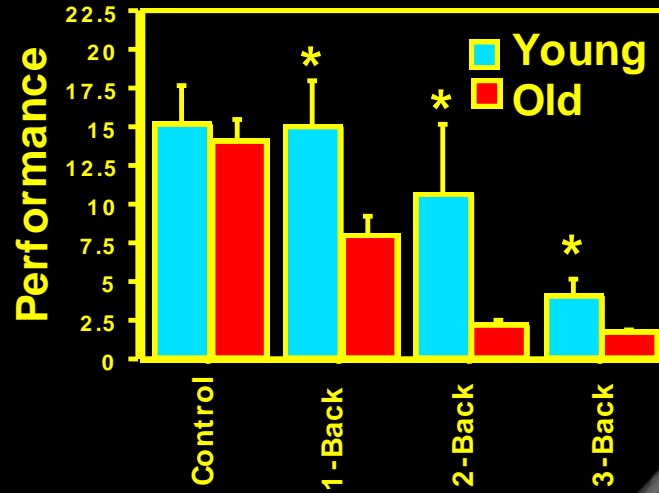


MR Anatomy Caveats

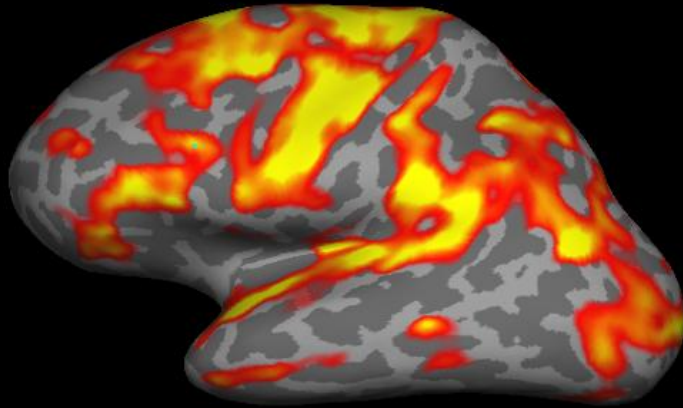
- **Reliability and validity of measures/effects dependent on several factors:**
 - **Data quality**
 - **Contrast to noise**
 - **Signal to noise**
 - **Voxel resolution**
 - **MR Artifacts**
 - **MR susceptibility**
 - **MR distortions**
 - **Variations in MR tissue parameters across regions of the brain and are altered in different populations**
 - **Relevant Publications: Fischl et al., 2002; Rosas et al., 2002; Kuperberg et al., 2002; Salat et al., 2004; Han et al., 2004; Fischl et al., 2004; Jovicich et al., 2006; Dickerson et al., 2007**
 - **Most problems with decent data can be fixed through interactive options**
- **What are the biological bases of MR changes?**

Performance

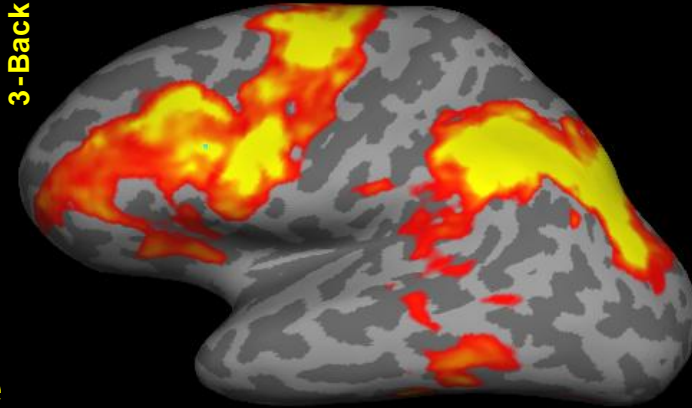
N-Back



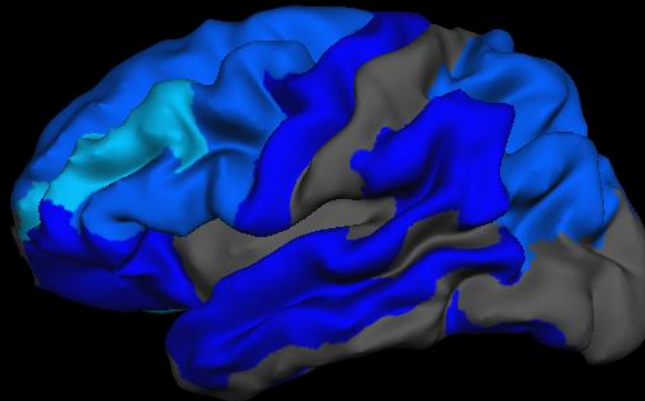
GM Structure



Brain Function



WM Structure



Acknowledgements

- **Freesurfer Team: Bruce, Doug, Andre, Nick, Allison, Krish, Sita, Jenni, Lilla**
- **Diana Rosas**
- **Anders Dale**
- **Marty Sereno**
- **Randy Buckner**
- **Stephanie Lee**
- **FSL Team**
- **This work was supported by NCRR P41RR14075, the MIND Institute, the MGH/MIT/HMS Athinoula A. Martinos Center for Biomedical Imaging, NIH AG024898 and NR010827**

