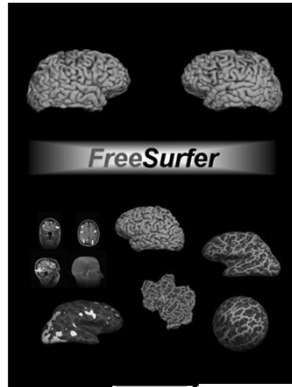


Surface-based Analysis: Intersubject Registration and Smoothing



Slides prepared by:
Douglas Greve



Outline

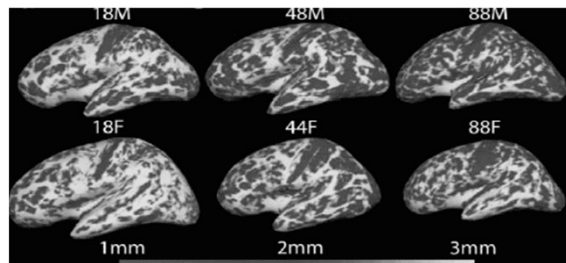
- Exploratory Spatial Analysis
- Coordinate Systems
 - 3D (Volumetric)
 - 2D (Surface-based)
- Intersubject registration
 - Volume-based
 - Surface-based
- Surface-based smoothing
- Surface-based clustering

Exploratory Spatial Analysis

- Don't know where effect is going to be
- vs ROI analysis
- Analyze each voxel separately
- Create a map
- Find clusters

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Aging Exploratory Analysis

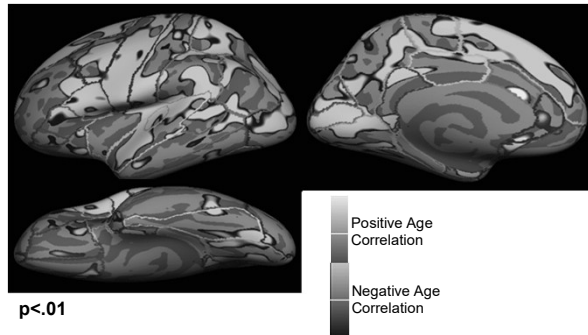
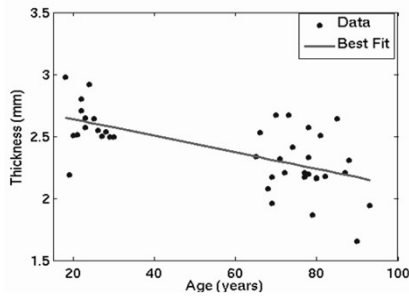
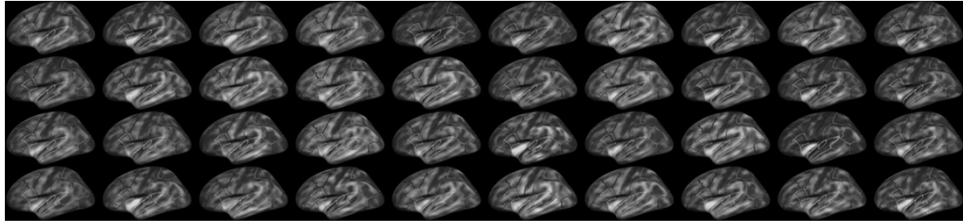


Cortical Thickness vs Aging
Salat, et al, 2004, Cerebral Cortex

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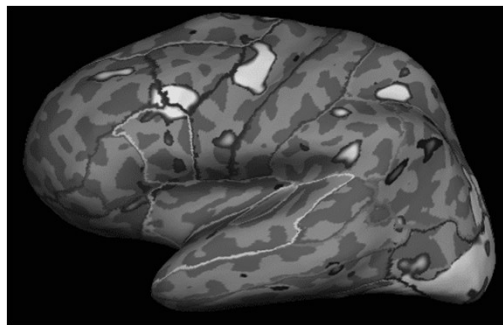
Aging Thickness Study

N=40



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Individual Exploratory Analysis



- fMRI Words-vs-Fixation
- Single subject (eg, presurgical planning or functional ROI)
- Outlines are FreeSurfer cortical ROIs
- Yellow and blue blobs are functional activation
- Activation does not lie cleanly within a predefined ROI

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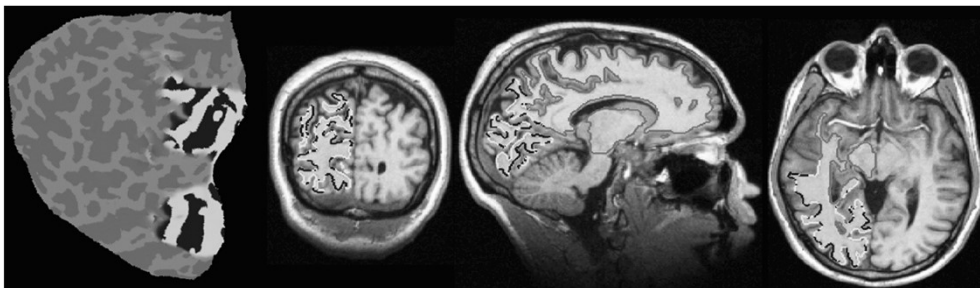
Exploratory Spatial Analysis

- Generally requires spatial smoothing of data to increase SNR
- For group analysis, requires that subjects' brains be aligned to each other on a voxelwise basis.
- Neither needed for an ROI analysis
- Smoothing and intersubject registration can be performed in the volume or surface.

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Why Is a Model of the Cortical Surface Useful?

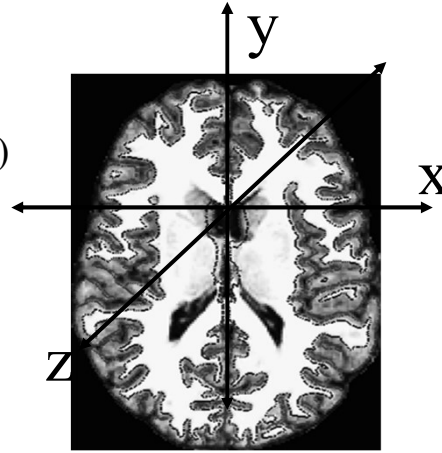
Local functional organization of cortex is largely 2-dimensional! Eg, functional mapping of primary visual areas:



From (Serenio et al, 1995, Science).

Coordinate Systems: 3D (Volumetric)

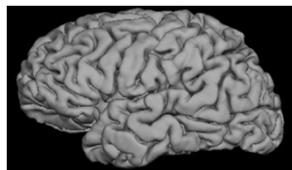
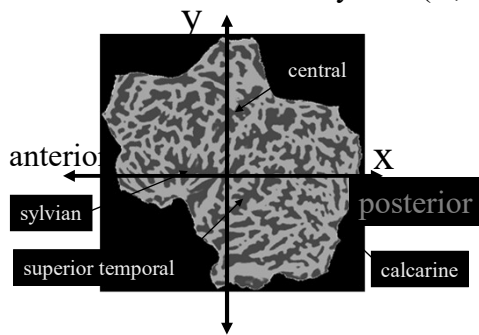
- 3D Coordinate System
 - XYZ
 - RAS (Right-Anterior-Superior)
 - CRS (Column-Row-Slice)
 - Origin (XYZ=0, eg, AC)
 - MR Intensity at each XYZ



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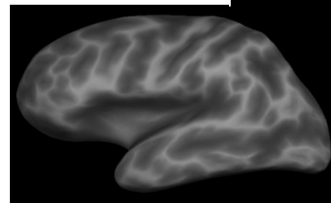
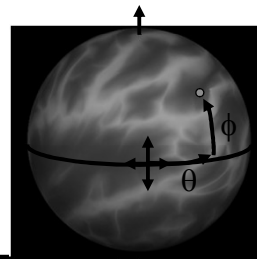
Coordinate Systems: 2D (Surface)

Sheet: 2D Coordinate System (X,Y)



Sphere: 2D Coordinate System

- Latitude and Longitude (θ, ϕ)
- Continuous, no cuts
- Value at each point (eg, thickness)



Curvature

- SULCUS (+)
- GYRUS (-)

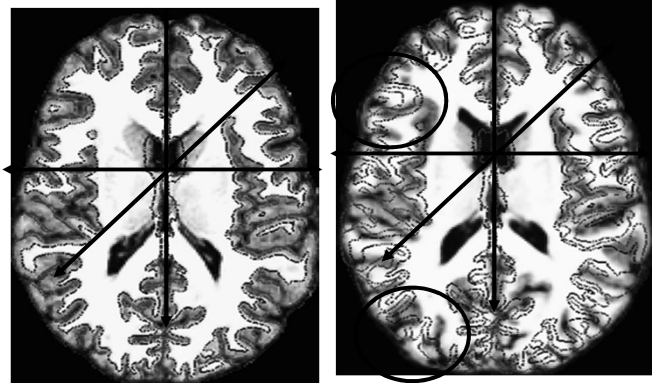
10

Intersubject Registration

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Volumetric Intersubject Registration

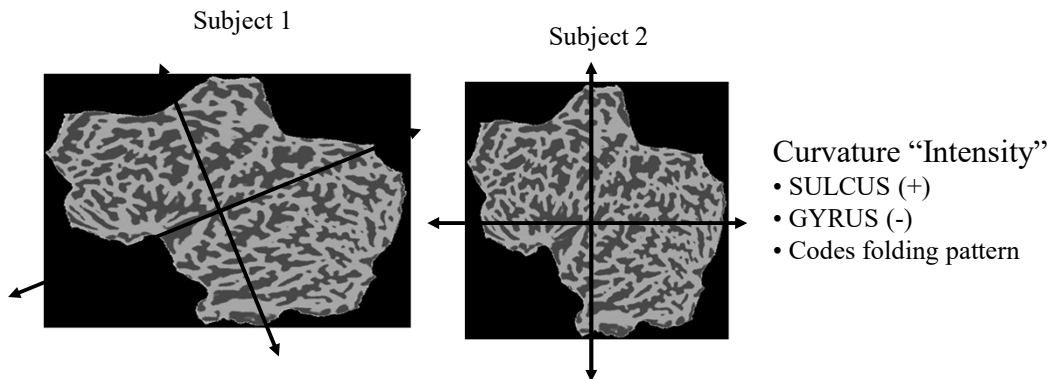
- Affine/Linear
 - Translate
 - Rotate
 - Stretch
 - Shear
 - (12 DOF)



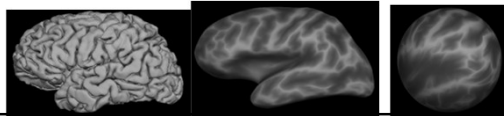
- Match Intensity, Voxel-by-Voxel
- Problems
- Can use nonlinear volumetric (cf CVS)

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Surface-based Intersubject Registration

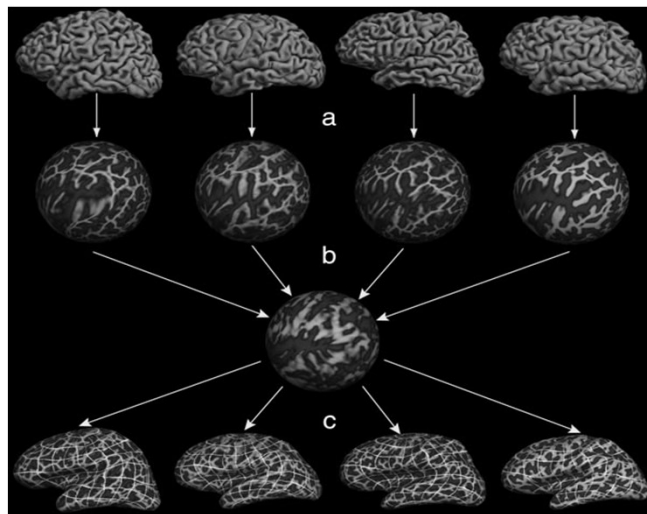


- Translate, Rotate, Stretch, Shear (12 DOF)
- Match Curvature, Vertex-by-Vertex
- Nonlinear Stretching (“Morphing”) allowed (area regularization)
- Actually done on sphere
- “Spherical Morph”



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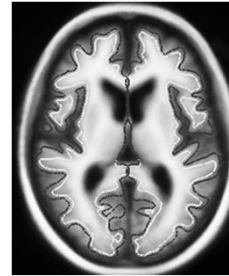
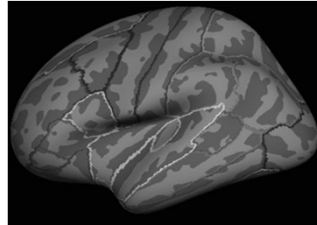
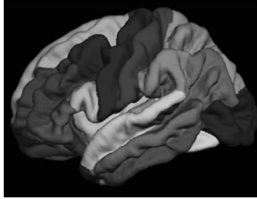
A Surface-Based Coordinate System



Common space for group analysis (like Talairach)

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fsaverage



- Has “subject” folder like individual FS subjects
- “Buckner 40” subjects
- Default registration space
- MNI305 coordinates

?h.average.curvature.filled.buckner40.tif

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Surface-based Intersubject Registration

- Gray Matter-to-Gray Matter (it’s all gray matter!)
- Gyrus-to-Gyrus and Sulcus-to-Sulcus
- Some minor folding patterns won’t line up
- Fully automated, no landmarking needed
- Atlas registration is probabilistic, most variable regions get less weight.
- Done automatically in recon-all
- fsaverage

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Spatial Smoothing

Why should you smooth?

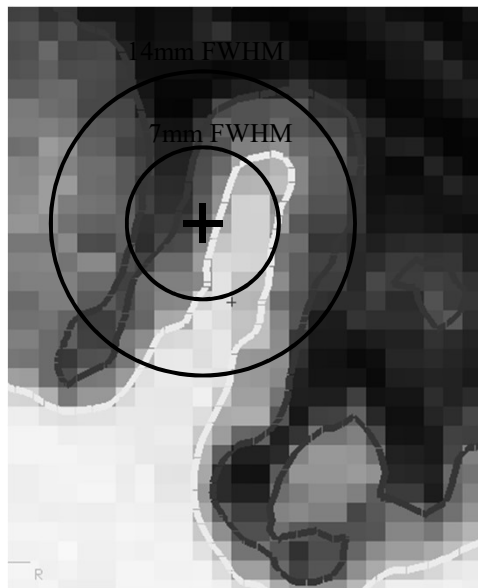
- Might Improve CNR/SNR
- Improve intersubject registration

How much smoothing?

- Blob-size
- Typically 5-20 mm FWHM
- Surface smoothing more forgiving than volume-based

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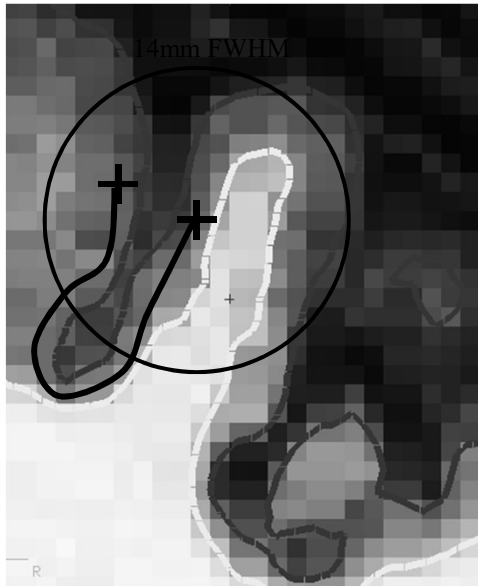
Volume-based Smoothing



- Smoothing is averaging of “nearby” voxels

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Volume-based 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

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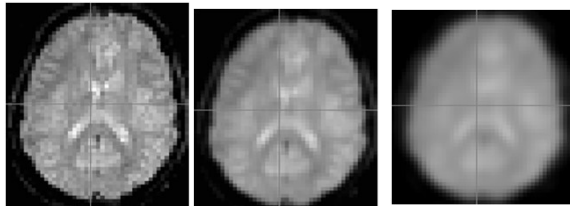
Spatial Smoothing

- Spatially convolve image with Gaussian kernel.
 - Kernel sums to 1
 - Full-Width/Half-max: $FWHM = \sigma / \sqrt{\log(256)}$
- σ = standard deviation of the Gaussian

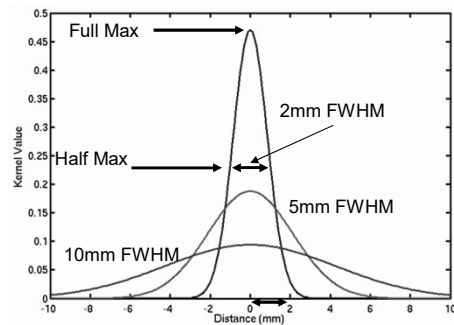
0 FWHM

5 FWHM

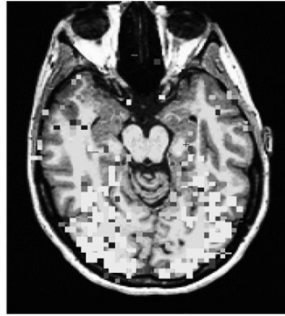
10 FWHM



Full-Width/Half-max



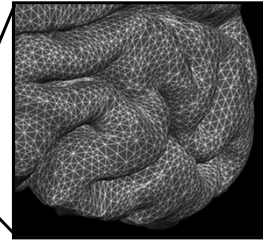
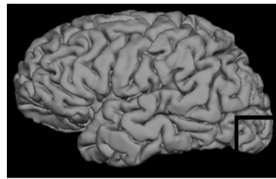
Effect of Smoothing on Activation



- Working memory paradigm
- FWHM: 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20

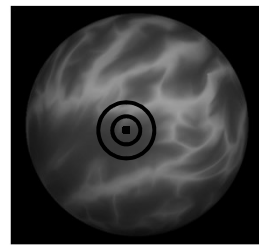
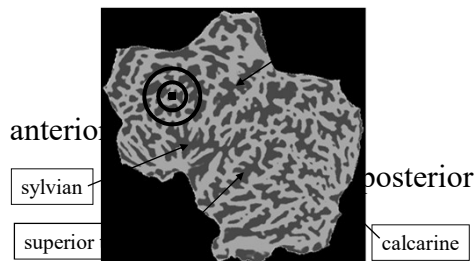
Surface-based Smoothing

- Smoothing is averaging of nearby vertices

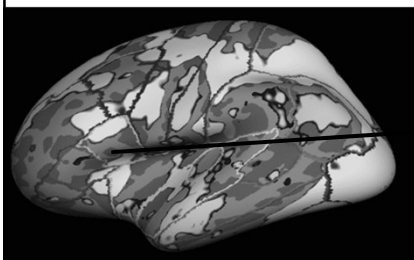


Sheet: 2D Coordinate System (X,Y)

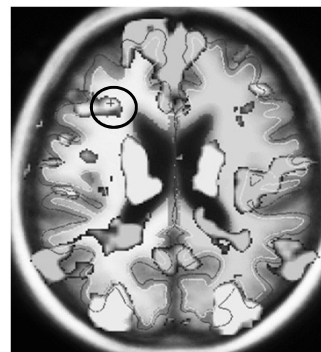
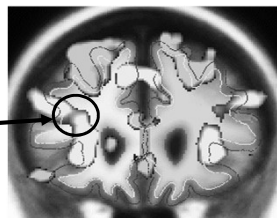
Sphere: 2D Coordinate System (θ, ϕ)



Group fMRI Analysis: Volume vs Surface



Surface-based Registration and smoothing

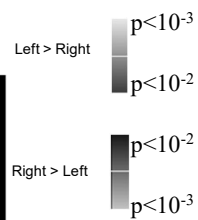
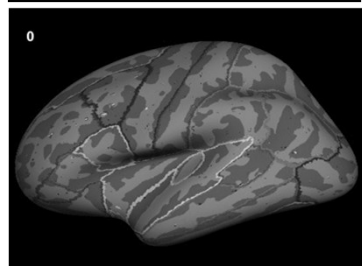
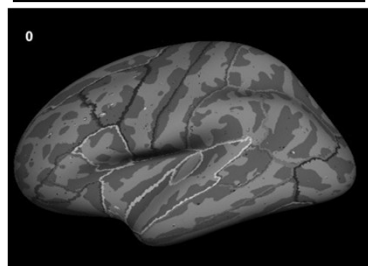
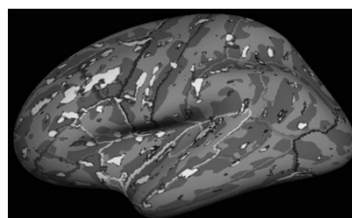
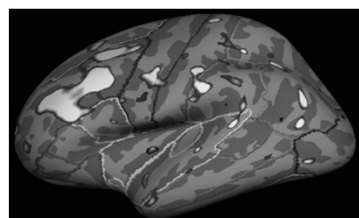


Affine registration to MNI305 with volume smoothing

Probe-vs-Fixation. Data from Functional Biomedical Informatics Research Network (fBIRN)

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5HT₄ BP Asymmetry Study (N=16)



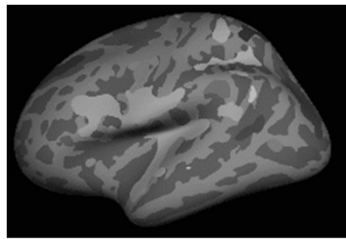
Surface Smoothing

Volume Smoothing

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Surface-based Clustering

- A cluster is a group of connected (neighboring) vertices above threshold
- Neighborhood is 2D, not 3D
- Cluster has a size (area in mm^2)
- Reduced search space (corrections for multiple comparisons)

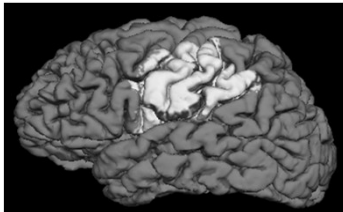


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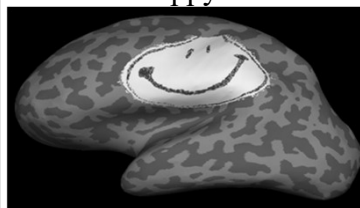
Summary

- Why Surface-based Analysis?
 - Function has surface-based organization
 - Inter-subject registration: anatomy, not intensity
 - Smoothing
 - Clustering
 - Like 3D, but 2D

Use FreeSurfer



Be Happy



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