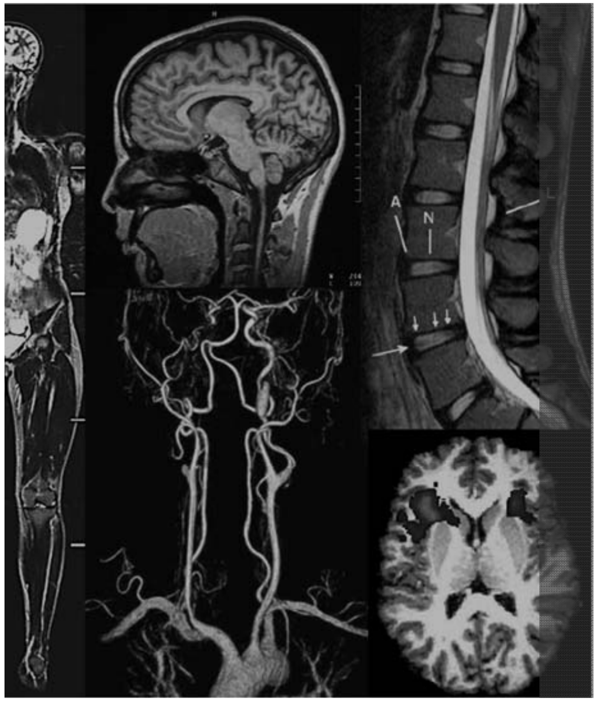

腦部結構影像
A Course of MRI

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本週課程內容

- 腦部結構影像
  - 空間標準化(Spatial normalization)
  - 均勻度校正(Bias correction)
  - 組織分割(Segmentation)
  - 體素形態學分析(Voxel-based morphometry, VBM)
  - 影像平滑化(Smoothing)

  - 腦影像分區(Atlasing)
  - 皮質厚度與皺褶(Cortical thickness and folding)

Analysis Softwares

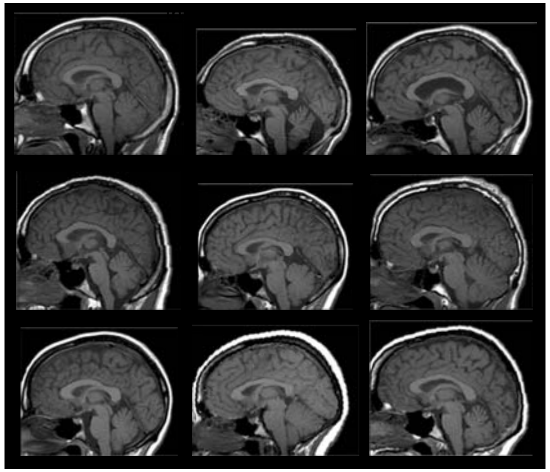
- Statistical Parametric Mapping (SPM), SPM8/ SPM12b
  - http://www.fil.ion.ucl.ac.uk/spm/
- Voxel-based Morphometry (VBM) toolbox, VBM8
  - http://dbm.neuro.uni-jena.de/vbm/download/
- FMRIB Software Library (FSL), FSL5.0
  - http://dbm.neuro.uni-jena.de/vbm/download/
- FreeSurfer 5.3
  - http://surfer.nmr.mgh.harvard.edu/

標準化、組織分割、體素型態

Normalization, Segmentation, and VBM

Spatial normalization

- Adjust the differences in
  - Head position/orientation in scanner
  - Global brain shape/size
- Normalized to standard stereotactic space
  - Affine step: translation, rotation, scaling, shearing
  - Nonlinear step



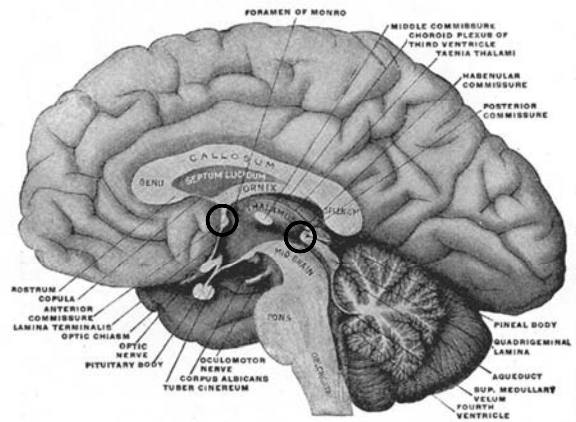
Ged Ridgway, slides of "spatial preprocessing" 2013, http://www.fil.ion.ucl.ac.uk/spm/course/

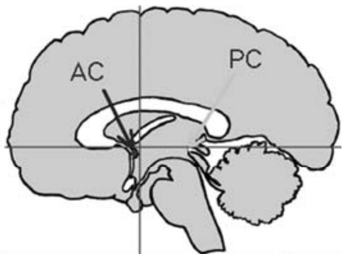
Standard stereotactic space

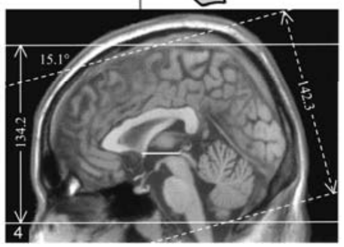
- Talairach atlas
  - First proposed as a standardized grid for neurosurgery in 1967, and modified based on single post-mortem dissection in 1988.
  - Use Brodmann areas as the labels.
- Montreal Neurological Institute (MNI) coordinates
  - ICBM 152: the average of 152 normal MRI scans that matched to the MNI coordinates (used in SPM99 and later).
  - Single_subj_T1: 27 repetitive scans of one brain were coregistered and averaged to yield a high detail T1 dataset.

AC-PC line

- The anterior commissure (AC) – posterior commissure (PC) line

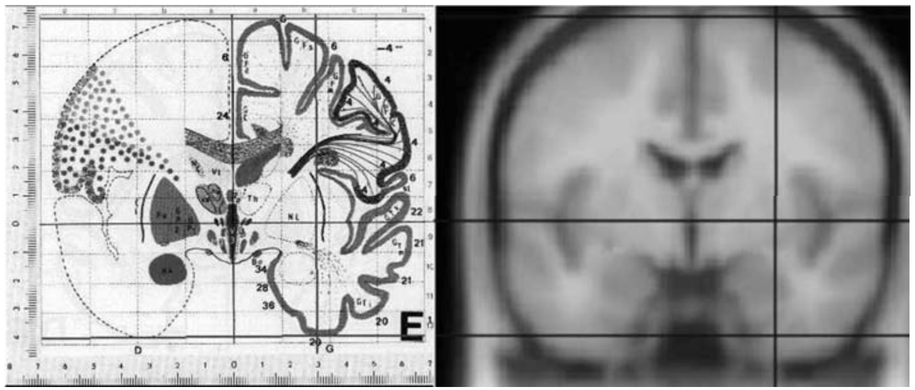






MNI vs. Talairach atlas

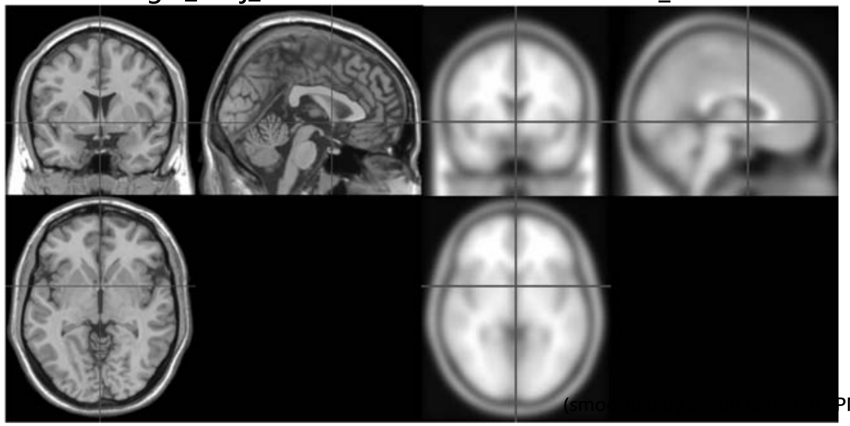
- MNI brains are slightly larger than the Talairach brain.



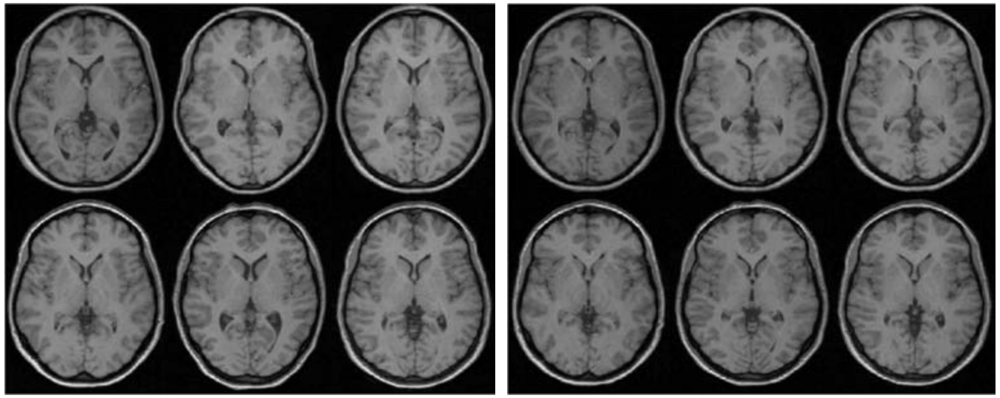
http://imaging.mrc-cbu.cam.ac.uk/imaging/MniTalairach

MNI coordinate

Single_subj_T1 | ICBM152 _T1



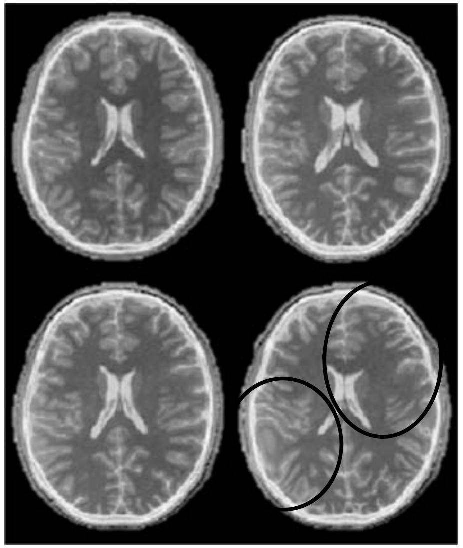
Normalization results



Affine registration | Affine+nonlinear registration

Karl J. Friston et al., Statistical Parametric Mapping, Academic Press, 2006.

Overfitting



T2W images

Template image

Subject image
Affine registration
(error = 472.1)

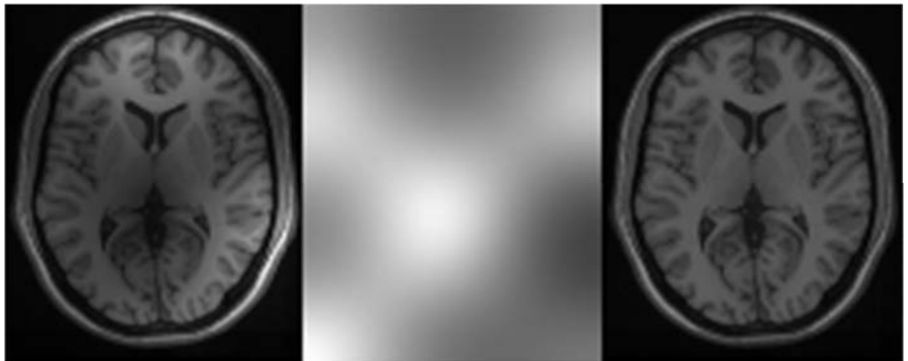
Nonlinear registration
with regularization
(error = 302.7)

Nonlinear registration
without regularization
(error = 287.3)

Ged Ridgway, slides of "spatial preprocessing" 2013, http://www.fil.ion.ucl.ac.uk/spm/course/

Bias correction

- A correction for image inhomogeneity



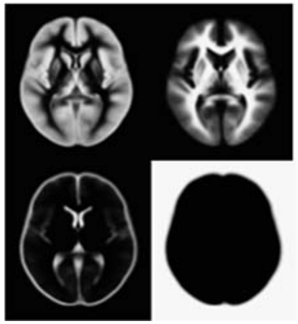
Corrupted image | Bias Field | Corrected image

Ged Ridgway, slides of "spatial preprocessing" 2013, http://www.fil.ion.ucl.ac.uk/spm/course/

Tissue Segmentation

- To segment out the images of GM, WM or CSF
- Two sources of information
  - Prior tissue probability maps (TPM)
  - Intensity information in the image itself

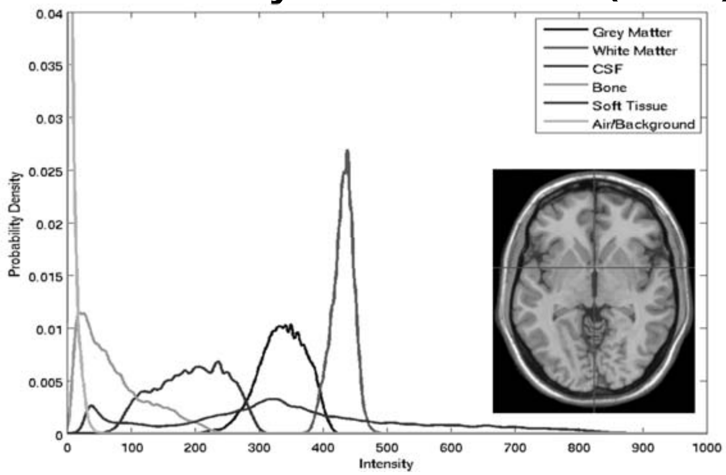
TPMs



Normalized image | GM | WM | CSF

Nicola Hobbs & Marianne Novak, slides of "voxel-based morphometry" 2008

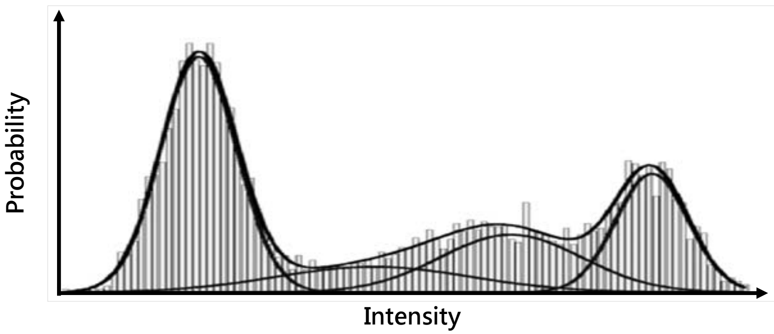
Tissue intensity distributions (T1W)



Ged Ridgway, slides of "spatial preprocessing" 2013, http://www.fil.ion.ucl.ac.uk/spm/course/

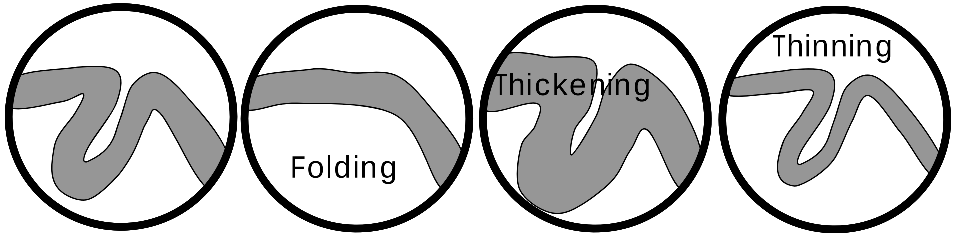
Mixture of Gaussians (MoG)

- The intensity probability density (black curve) can be represented by a number of Gaussian distributions (blue curves).

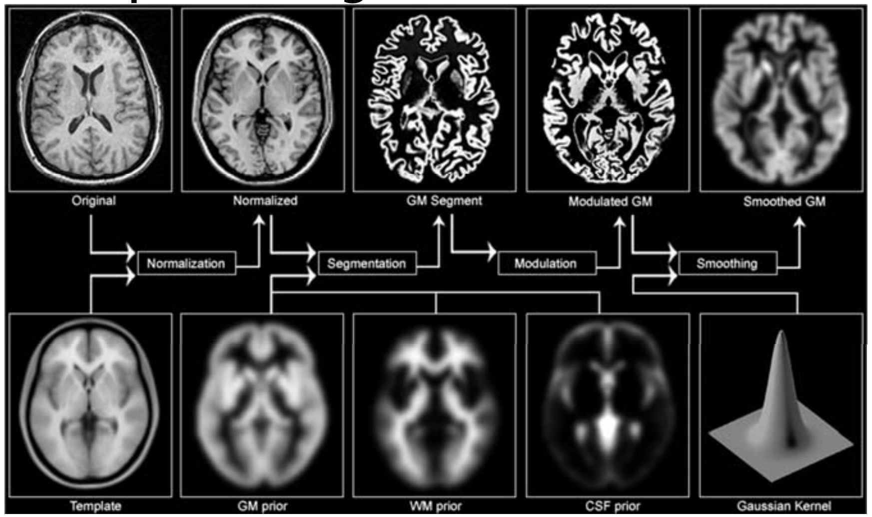


Voxel-based morphometry, VBM

- VBM is a voxel-wise comparison of local tissue volumes within a group or across groups
- Whole-brain analysis, does not require *a priori* assumptions about ROIs; unbiased way of localizing structural changes
- Can be automated, requires little user intervention compared with manual ROI tracing.



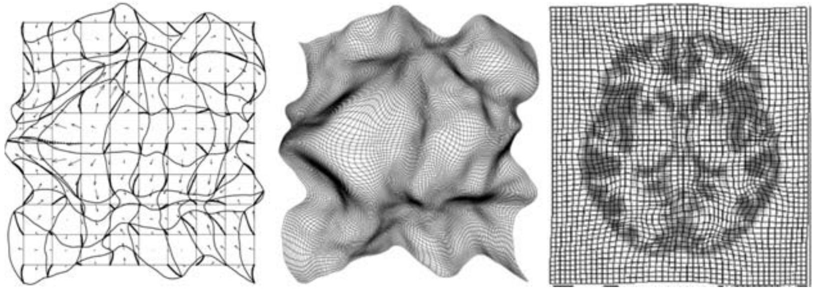
Pre-processing flow of VBM



Nicola Hobbs & Marianne Novak, slides of "voxel-based morphometry" 2008

Modulation in VBM

- Correction for changes in volume induced by spatial normalization
- Voxel intensities are multiplied by the local value in the deformation field (Jacobian determinants) from normalization.
- Intensity now represents the relative volume at that voxel.



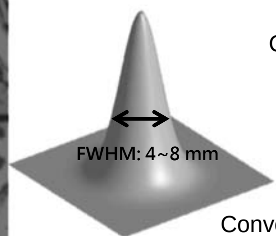
Karl J. Friston et al., Statistical Parametric Mapping, Academic Press, 2006.

Modulation in VBM

- Gray matter "density" vs. Gray matter "concentration" ??
- "GM segments were scaled by the Jacobian determinants of the deformations to account for local compression and expansion during linear and nonlinear registrations."
- Expansion during registration
  - lower voxel concentration
  - smaller volume
- Compression during registration
  - Higher voxel concentration
  - larger volume

Ashburner et al., Voxel-based morphometry – the methods, NeuroImage, 2000.

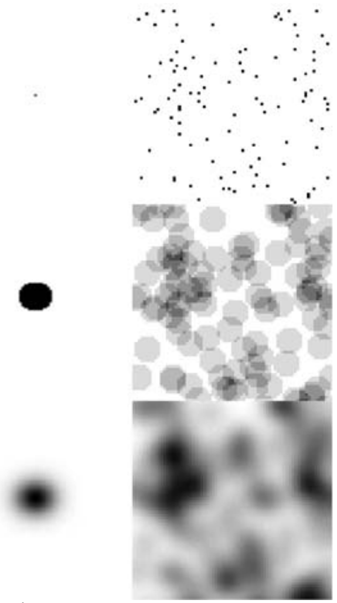
Gaussian smoothing



Before convolution

Convolved with a circle

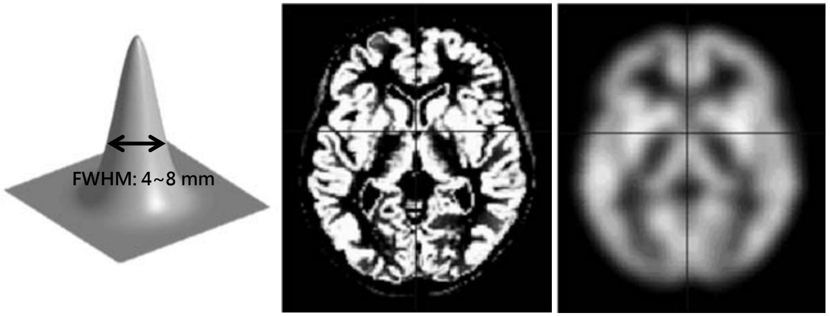
Convolved with a Gaussian



Karl J. Friston et al., Statistical Parametric Mapping, Academic Press, 2006.

Gaussian smoothing

- Each voxel becomes weighted average of surrounding voxels.
- Render the data more normally distributed.
- Compensate for inaccuracies in normalization.

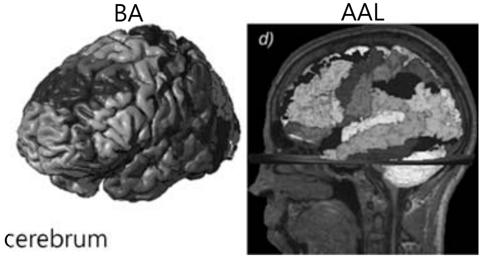


Ged Ridgway, slides of "spatial preprocessing" 2013, http://www.fil.ion.ucl.ac.uk/spm/course/

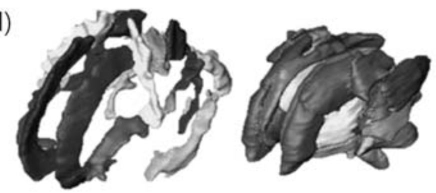
分區與皮質結構

Atlasing, cortical structure

Image Atlas



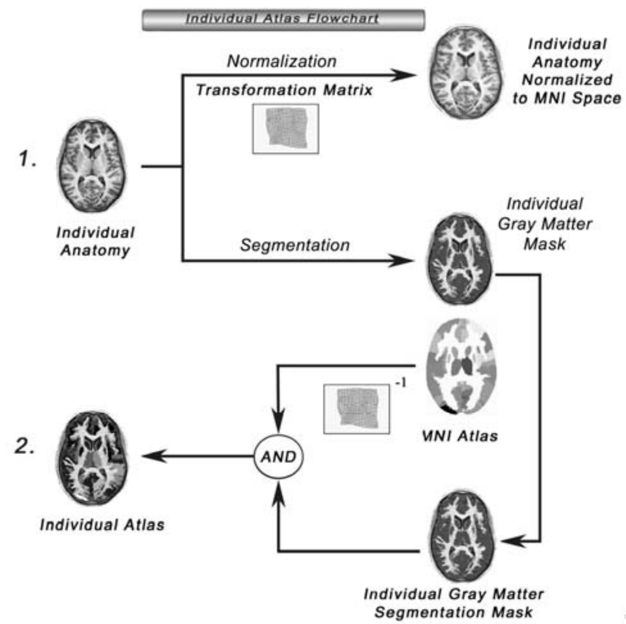
- For GM
  - Brodmann areas (BA)
    - Superficial cortex in cerebrum
  - Anatomical Automatic Labeling (AAL) atlas
    - Superficial cortex, subcortical area in cerebrum, and cerebellum
- For WM
  - WM parcellation map (WMPM)
    - Superficial WM, deep WM



Tzourio-Mazoyer et al., NeuroImage, 2002.
Mori et al., NeuroImage, 2008; Oishi et al., NeuroImage, 2008.

Individual brain atlas

- Sofware
  - IBASPM for MNI
  - http://www.thomaskoenig.ch/Lester/ibaspm.htm



Number labeling – AAL116 example

1=Precentral_L
2=Precentral_R
3=Frontal_Sup_L
4=Frontal_Sup_R
5=Frontal_Sup_Orb_L
6=Frontal_Sup_Orb_R
7=Frontal_Mid_L
8=Frontal_Mid_R
9=Frontal_Mid_Orb_L
10=Frontal_Mid_Orb_R
11=Frontal_Inf_Oper_L
12=Frontal_Inf_Oper_R
13=Frontal_Inf_Tri_L
14=Frontal_Inf_Tri_R
15=Frontal_Inf_Orb_L
16=Frontal_Inf_Orb_R
17=Rolandic_Oper_L
18=Rolandic_Oper_R
19=Supp_Motor_Area_L
20=Supp_Motor_Area_R
21=Olfactory_L
22=Olfactory_R
23=Frontal_Sup_Medial_L
24=Frontal_Sup_Medial_R
25=Frontal_Mid_Orb_L
26=Frontal_Mid_Orb_R
27=Rectus_L
28=Rectus_R
29=Insula_L
30=Insula_R
31=Cingulum_Ant_L
32=Cingulum_Ant_R
33=Cingulum_Mid_L
34=Cingulum_Mid_R
35=Cingulum_Post_L
36=Cingulum_Post_R
37=Hippocampus_L
38=Hippocampus_R
39=ParaHippocampal_L
40=ParaHippocampal_R
41=Amygdala_L
42=Amygdala_R
43=Calcarine_L
44=Calcarine_R
45=Cuneus_L
46=Cuneus_R
47=Lingual_L
48=Lingual_R
49=Occipital_Sup_L
50=Occipital_Sup_R
51=Occipital_Mid_L
52=Occipital_Mid_R
53=Occipital_Inf_L
54=Occipital_Inf_R
55=Fusiform_L
56=Fusiform_R
57=Postcentral_L
58=Postcentral_R
59=Parietal_Sup_L
60=Parietal_Sup_R
61=Parietal_Inf_L
62=Parietal_Inf_R
63=SupraMarginal_L
64=SupraMarginal_R
65=Angular_L
66=Angular_R
67=Precuneus_L
68=Precuneus_R
69=Paracentral_Lobule_L
70=Paracentral_Lobule_R
71=Caudate_L
72=Caudate_R
73=Putamen_L
74=Putamen_R
75=Pallidum_L
76=Pallidum_R
77=Thalamus_L
78=Thalamus_R
79=Heschl_L
80=Heschl_R
81=Temporal_Sup_L
82=Temporal_Sup_R
83=Temporal_Pole_Sup_L
84=Temporal_Pole_Sup_R
85=Temporal_Mid_L
86=Temporal_Mid_R
87=Temporal_Pole_Mid_L
88=Temporal_Pole_Mid_R
89=Temporal_Inf_L
90=Temporal_Inf_R
91=Cerebelum_Crus1_L
92=Cerebelum_Crus1_R
93=Cerebelum_Crus2_L
94=Cerebelum_Crus2_R
95=Cerebelum_3_L
96=Cerebelum_3_R
97=Cerebelum_4_5_L
98=Cerebelum_4_5_R
99=Cerebelum_6_L
100=Cerebelum_6_R
101=Cerebelum_7b_L
102=Cerebelum_7b_R
103=Cerebelum_8_L
104=Cerebelum_8_R
105=Cerebelum_9_L
106=Cerebelum_9_R
107=Cerebelum_10_L
108=Cerebelum_10_R
109=Vermis_1_2
110=Vermis_3
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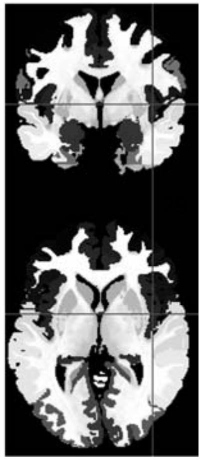
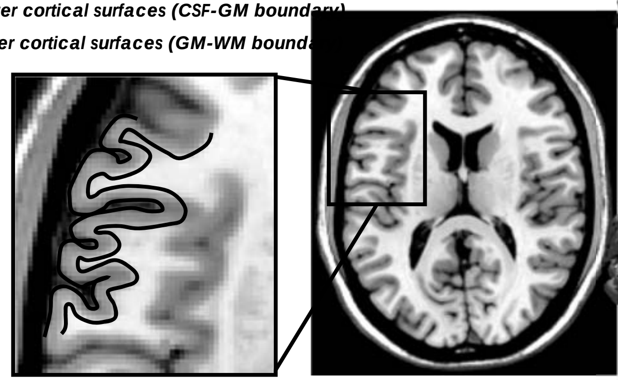
112=Vermis_6
113=Vermis_7
114=Vermis_8
115=Vermis_9
116=Vermis_10

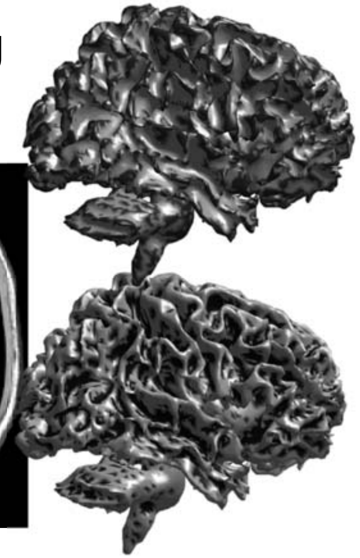


Cortical shape and folding

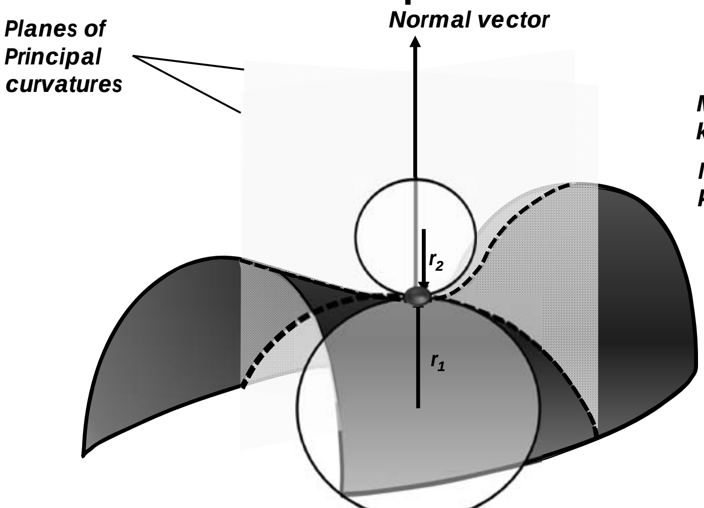
Outer cortical surfaces (CSF-GM boundary)

✓ *Inner cortical surfaces (GM-WM boundary)*





Curvature and shape index

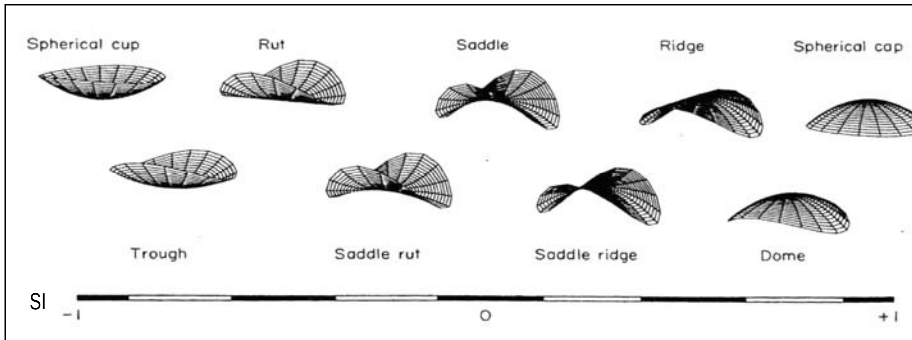


Maximal principal curvature
$k_1 = 1 / r_1$

Minimal principal curvature
$k_2 = -1 / r_2$

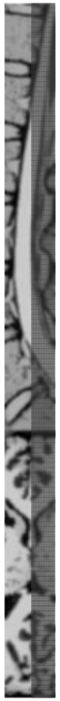
$$SI = \frac{2}{\pi} \arctan \frac{k_2 + k_1}{k_2 - k_1}$$

Shape Index and folding

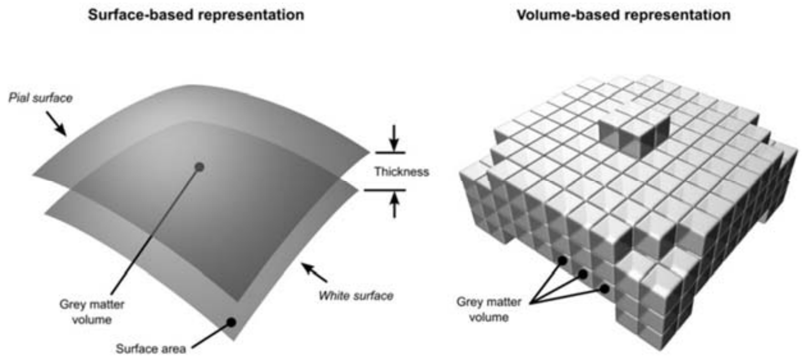


Koenderink JJ, van Doorn AJ (1992) Surface shape and curvature scales. *Image and Vision Computing* 10:557-564.

Sulcus ⟷ Gyrus



Cortical thickness & volume



Winkler et al. NeuroImage, 2009.

THE END

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