Neuroimaging and mathematical modelling

Lesson 2: Voxel Based Morphometry

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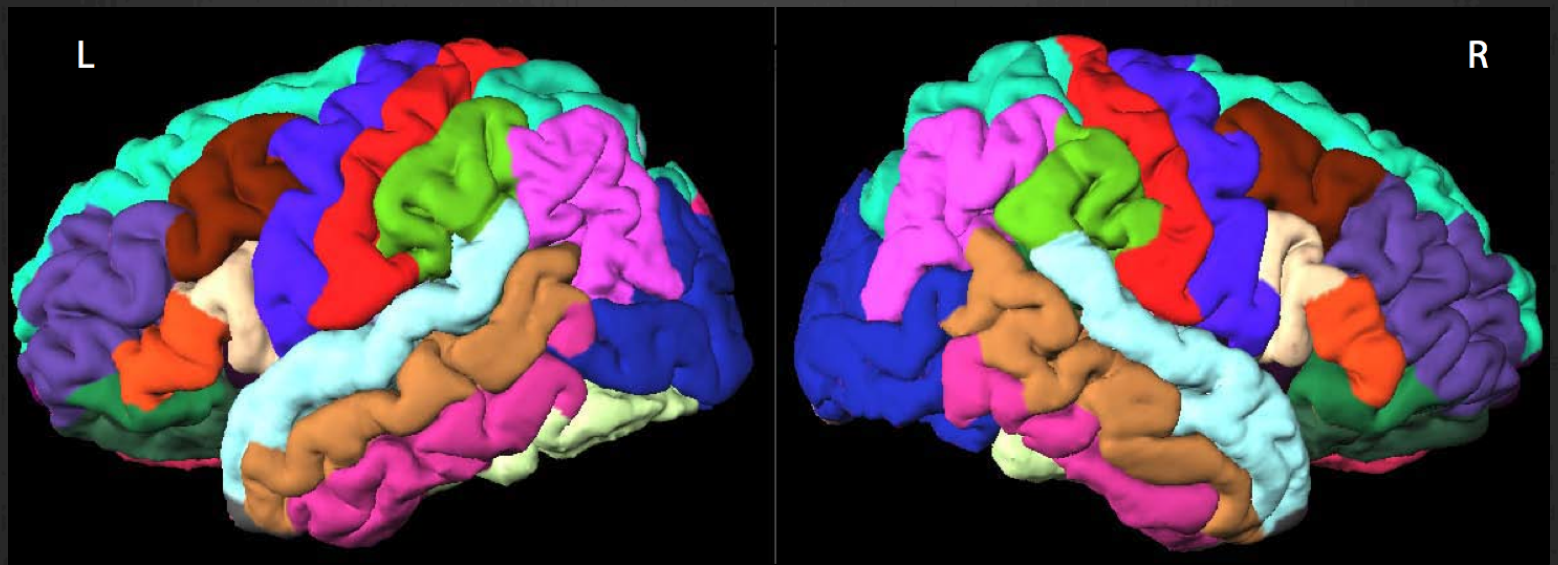
Volume and surface morphometry

Brain volume
- White matter
- Grey matter
- Volume of specific brain structures
  - hippocampus (Alzheimer's disease, memory loss states)
  - frontal lobe (intelligence!, analytical brain)
  - basal ganglia (Parkinson's disease, metabolic disorders)



Examples applications of VBM

- Many scientifically or clinically interesting questions might relate to the local volume of regions of the brain
- For example, whether (and where) local patterns of brain morphometry help to:
  - Distinguish groups (e.g. schizophrenics and healthy controls)
  - Explain the changes seen in development and aging
  - Understand plasticity, e.g. when learning new skills
  - Find structural correlates (scores, traits, genetics, etc.)

Volume and surface morphometry

This is where mathematicians and physicists come in to the scene!

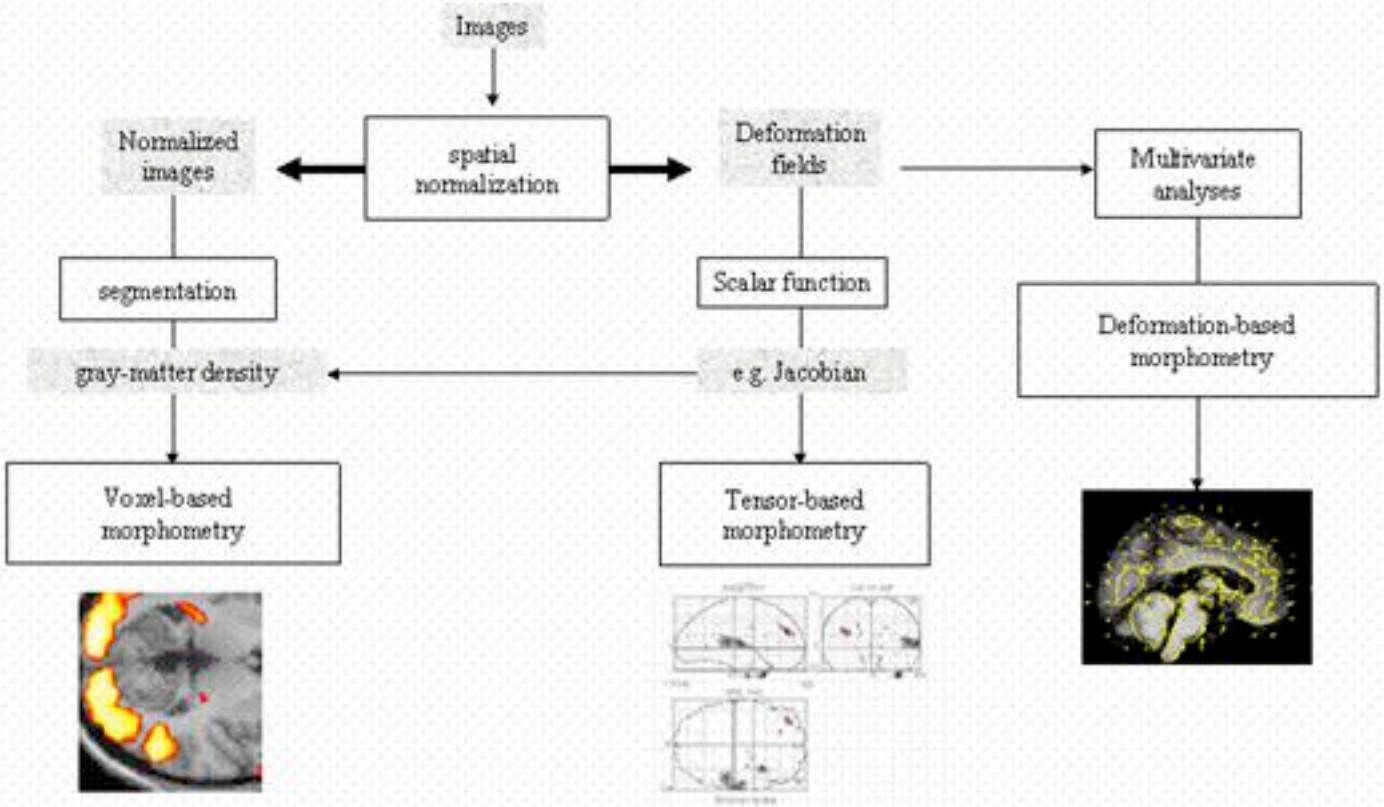
Lots of online free tools to study volume of brain structures and identify surface anatomy

http://surfer.nmr.mgh.harvard.edu/fswiki/FreeSurferAnalysisPipelineOverview

http://surfer.nmr.mgh.harvard.edu/fswiki/Slicer

http://afni.nimh.nih.gov/

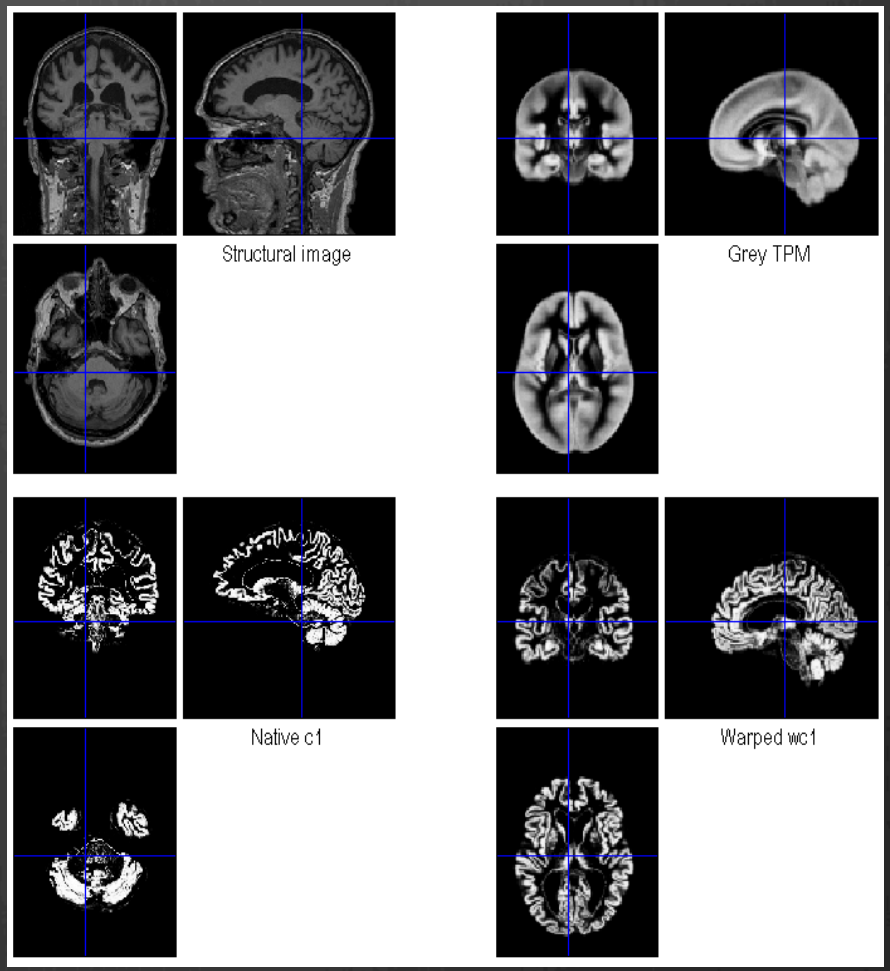
Computational neuroanatomy



VBM in pictures

Segment

Normalise



VBM i

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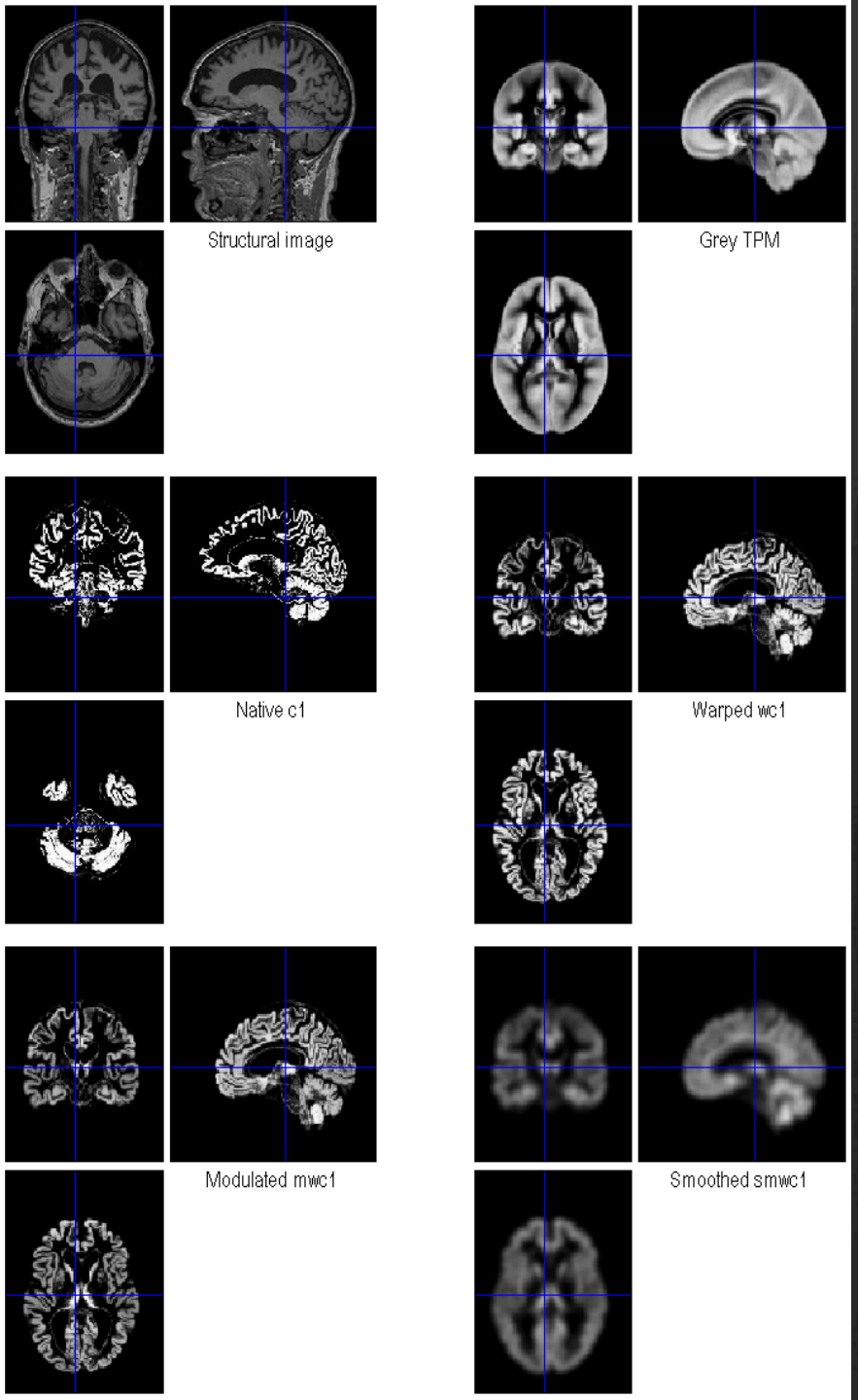
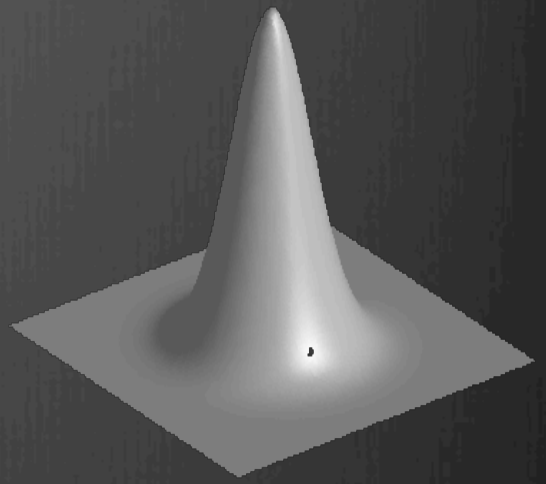
Modulate

Smooth

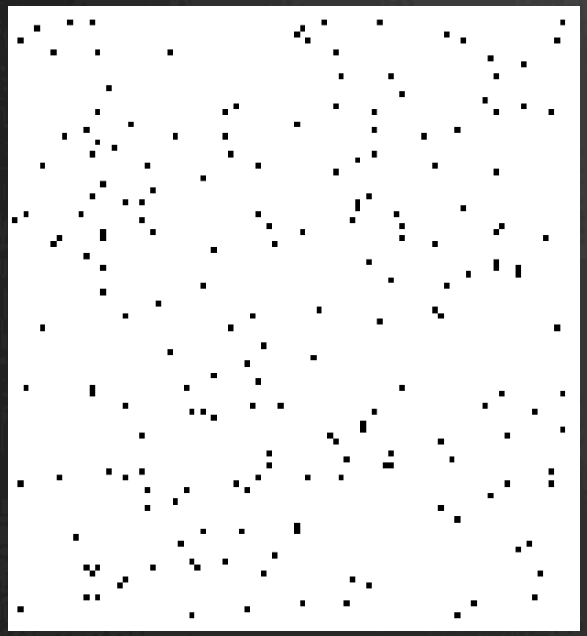


Smoothing

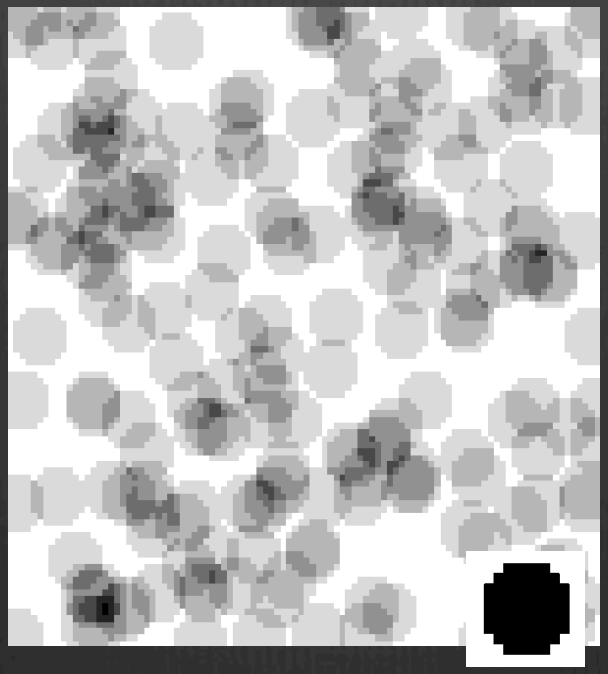
Each voxel after smoothing effectively becomes the result of applying a weighted region of interest (ROI).



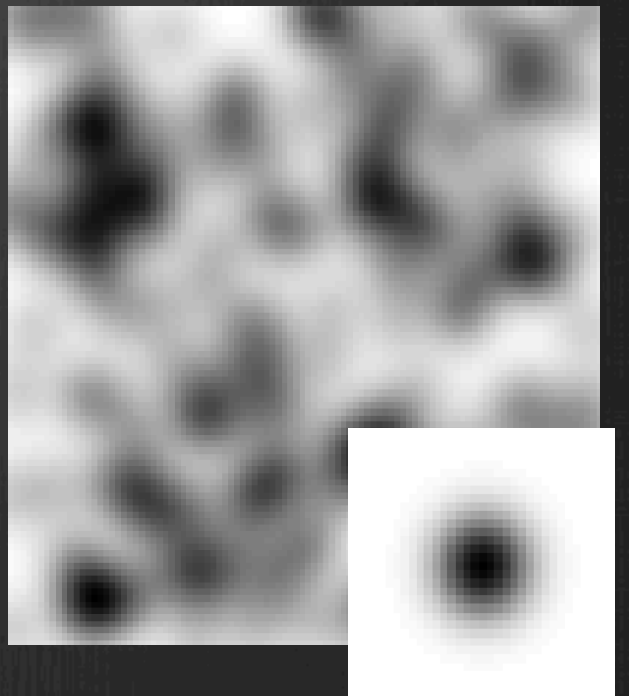
Before convolution



Convolved with a circle



Convolved with a Gaussian



VBM in pictures

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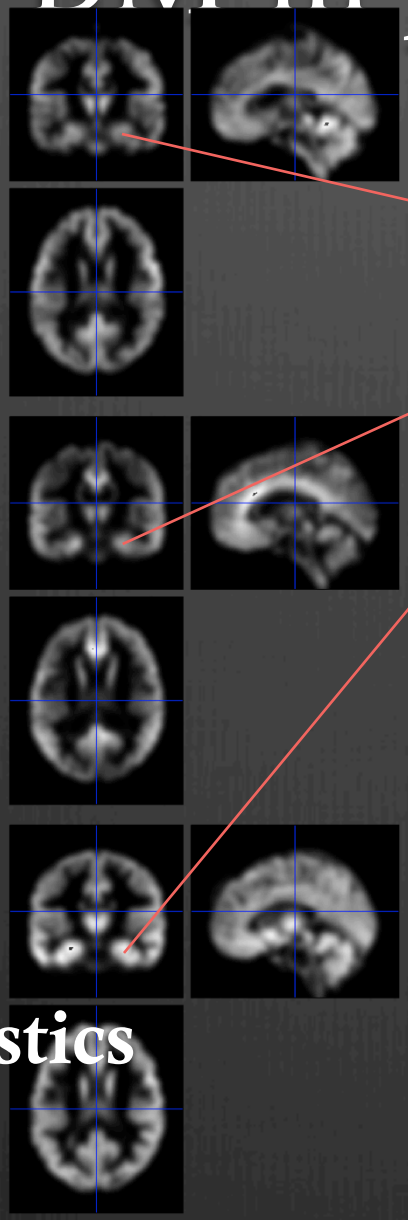

$$\begin{bmatrix} a1xyz \\ a2xyz \\ \vdots \\ aNxyz \end{bmatrix} = Y = X\beta_{xyz} + e_{xyz}$$

$$e_{xyz} \sim N(0, \sigma^2_{xyz} V)$$

$$X = \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ \vdots & \vdots \\ 0 & 1 \\ 0 & 1 \end{bmatrix}$$

Voxel-wise statistics

VBM in

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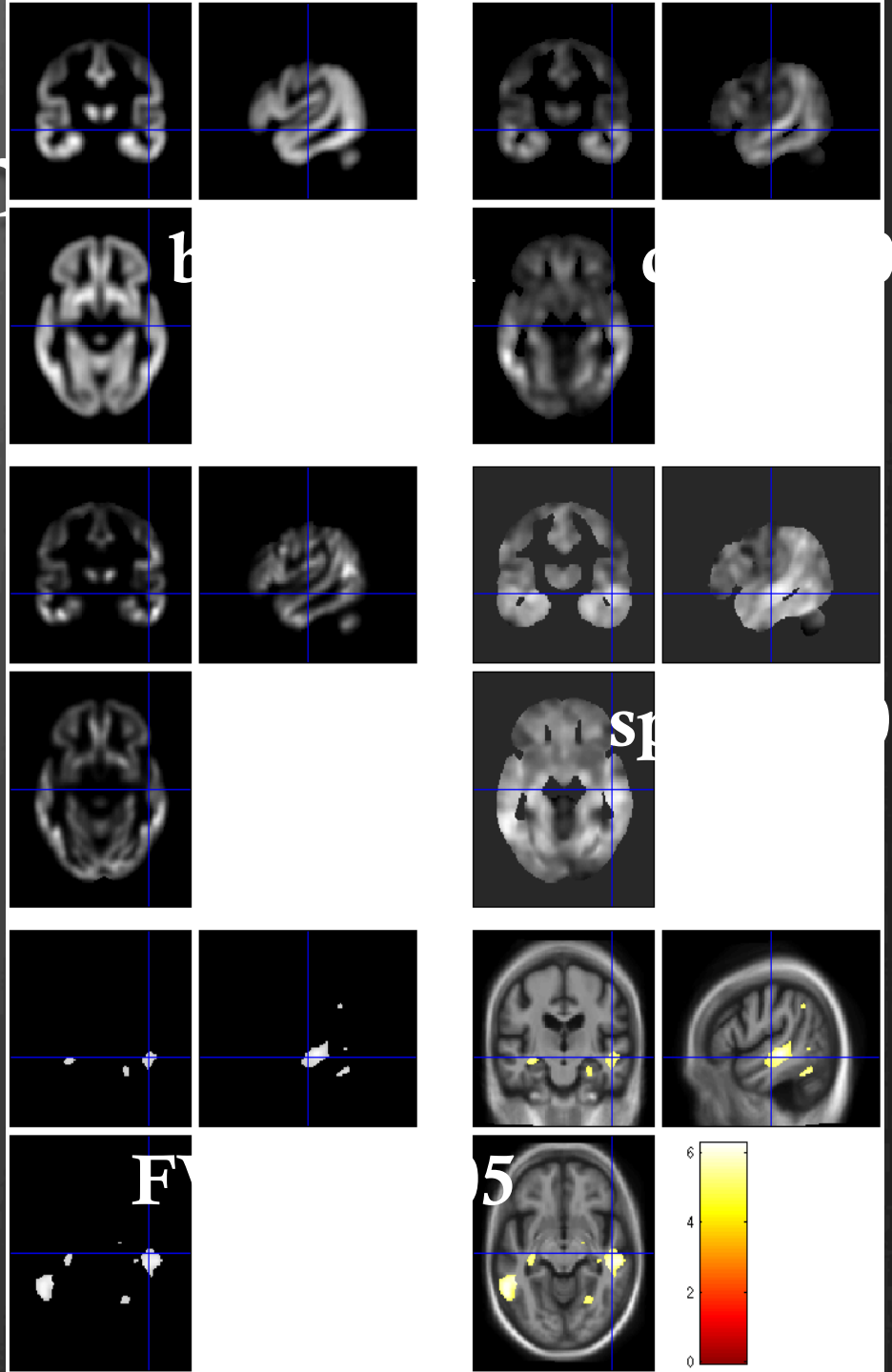
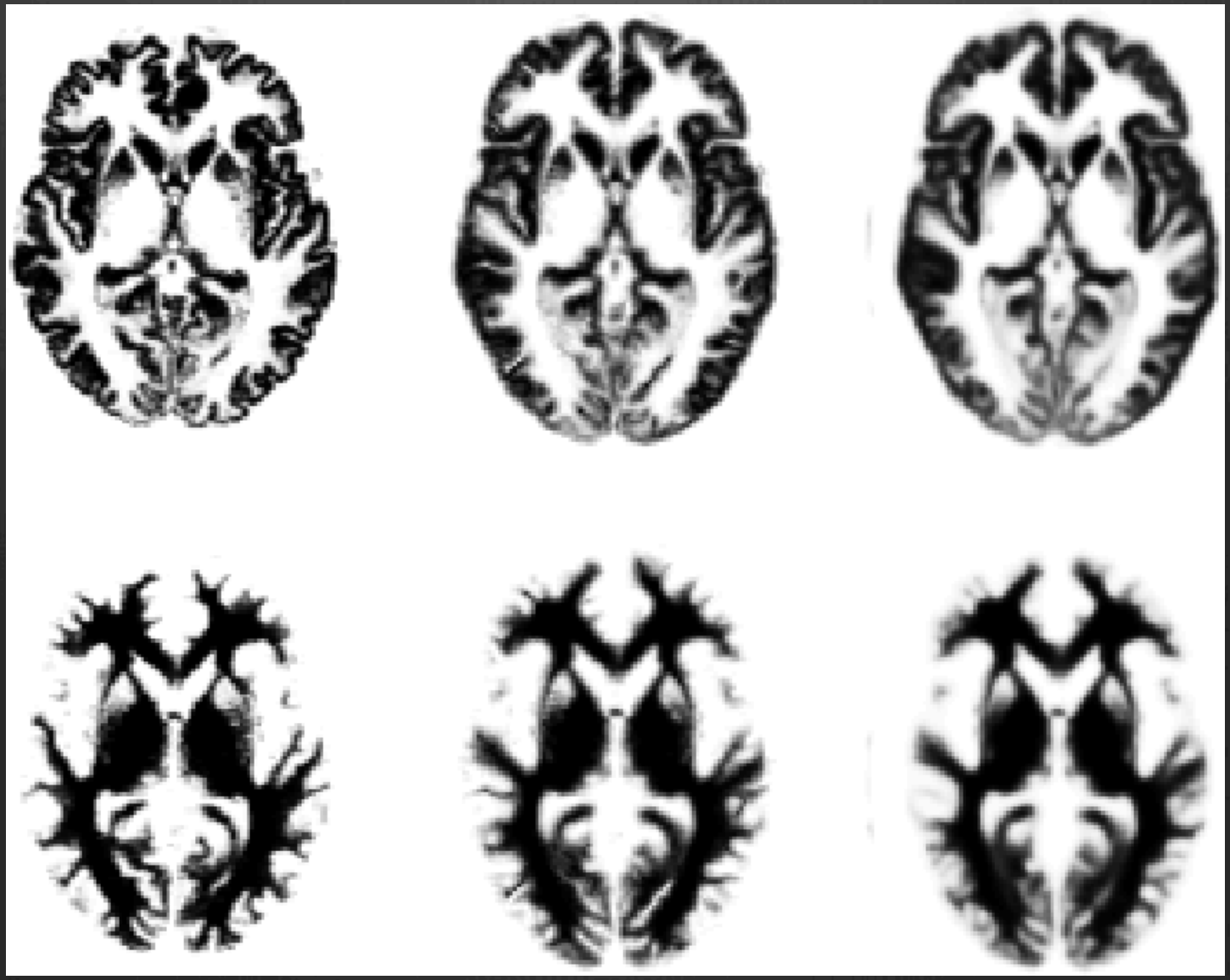
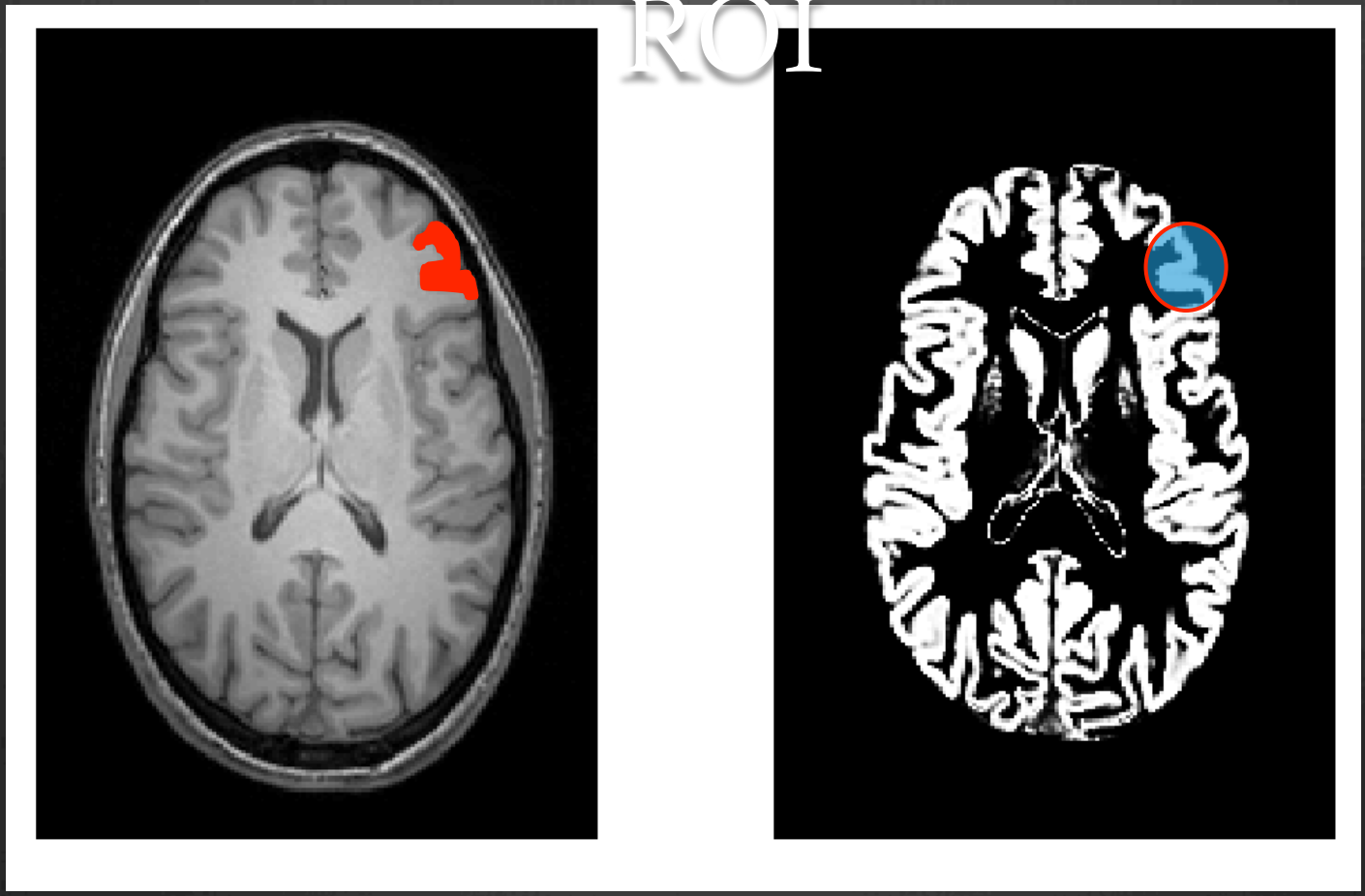
Voxel-wise statistics



Original Warped Template

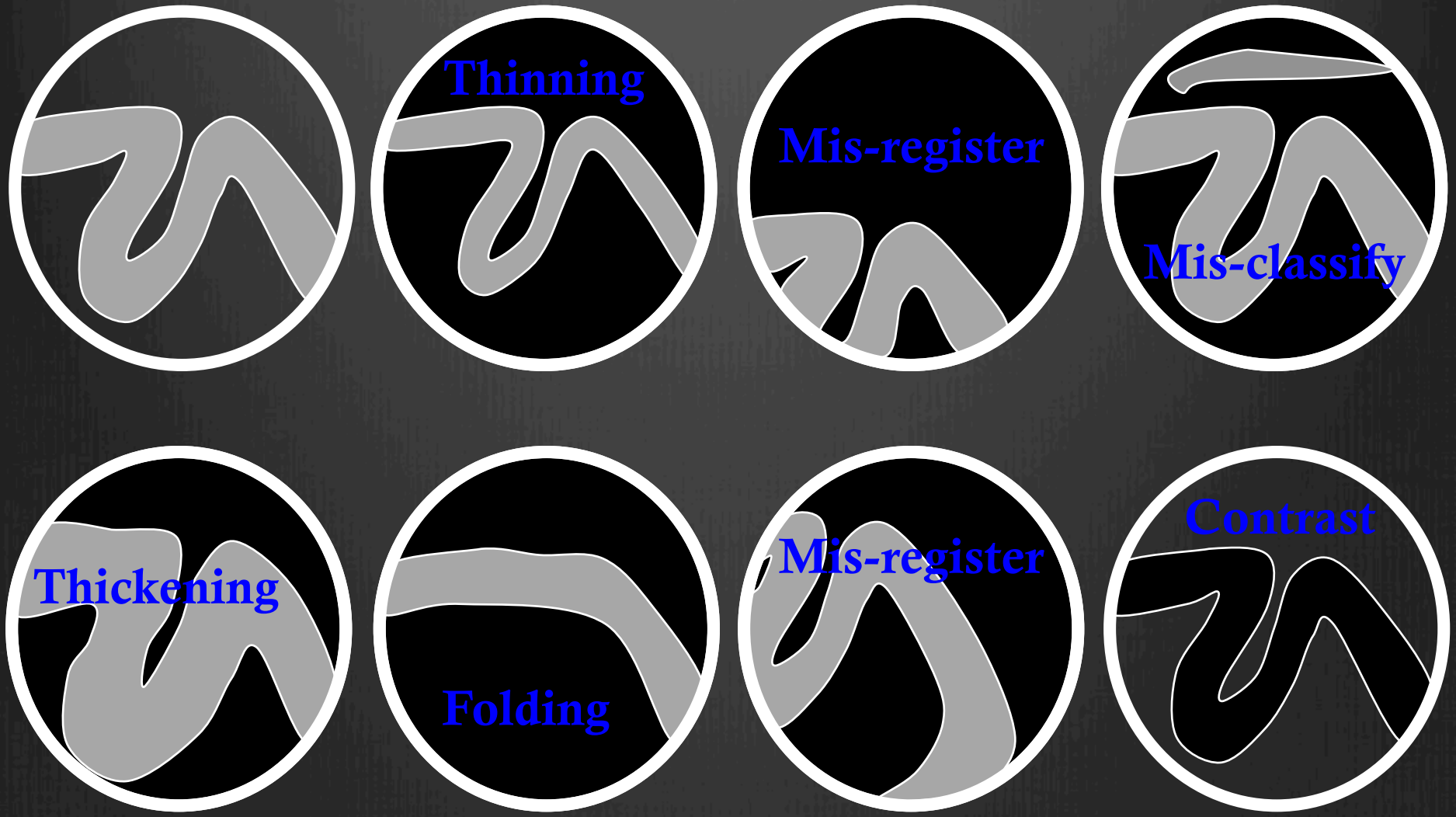


Smoothing as a locally weighted ROI

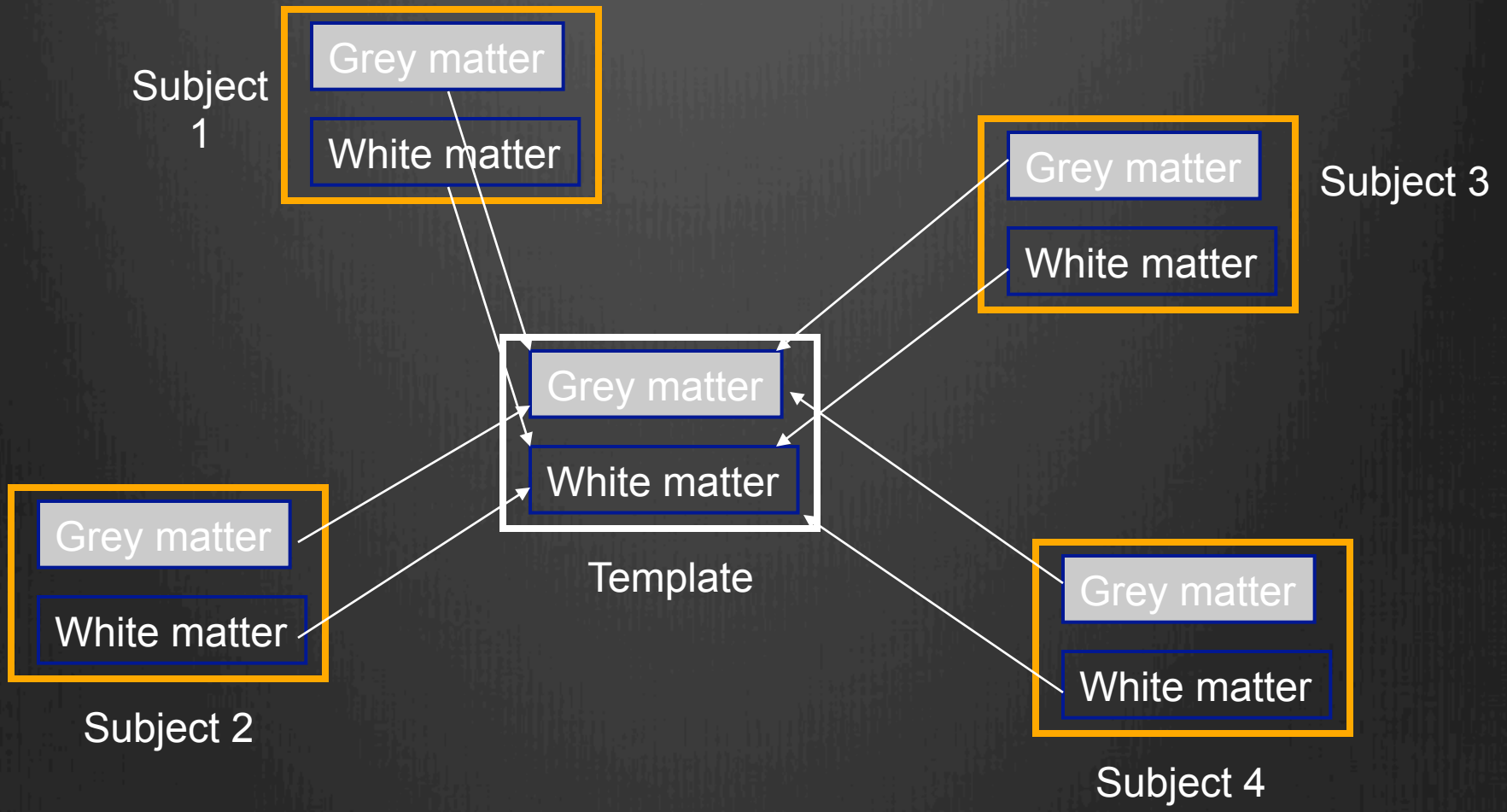


- VBM > ROI: no subjective (or arbitrary) boundaries
- VBM < ROI: harder to interpret blobs & characterise error

Interpreting findings



Simultaneous registration of GM to GM and WM to WM



Template

Iteratively generated from 471 subjects

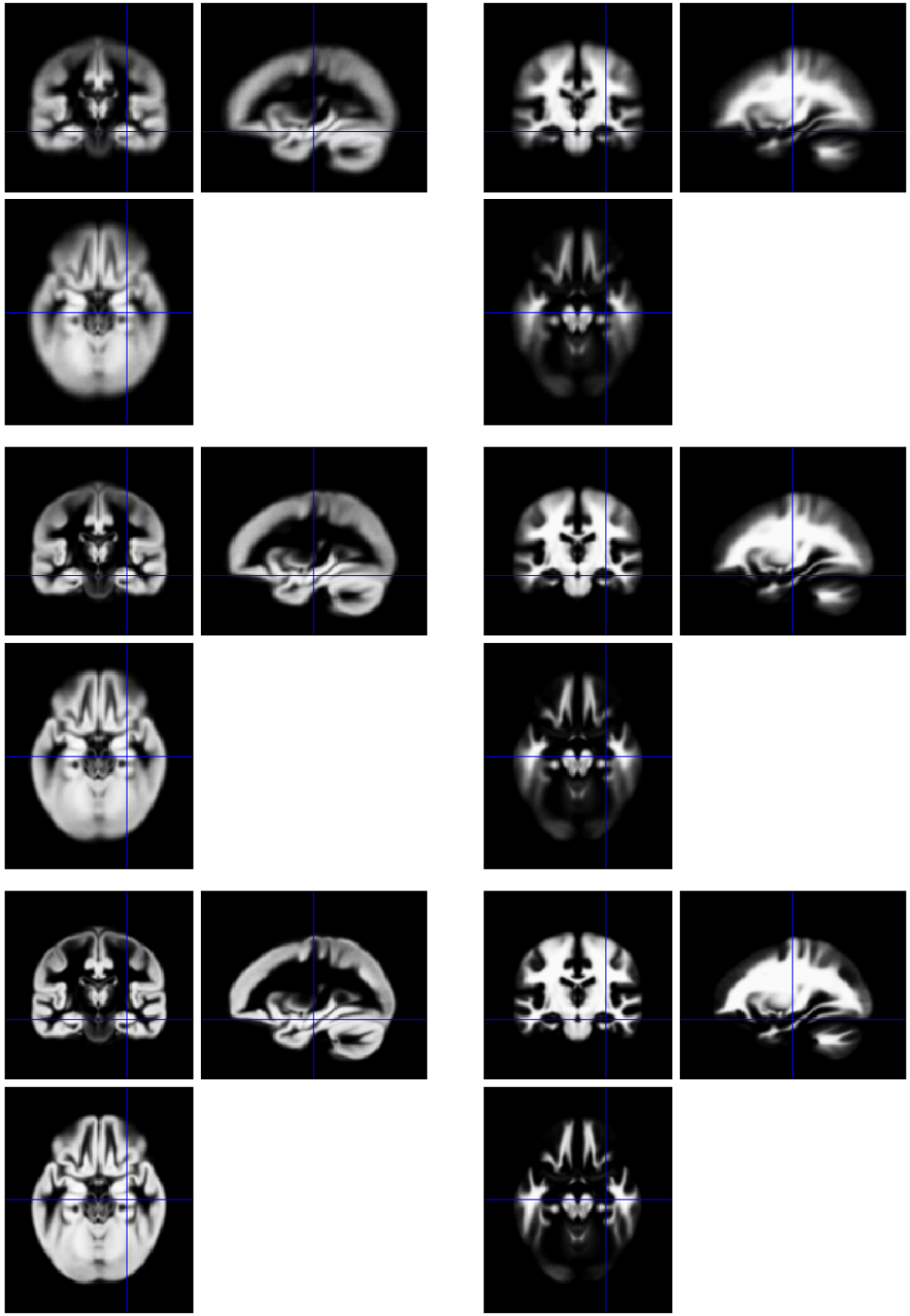
Began with rigidly aligned tissue probability maps

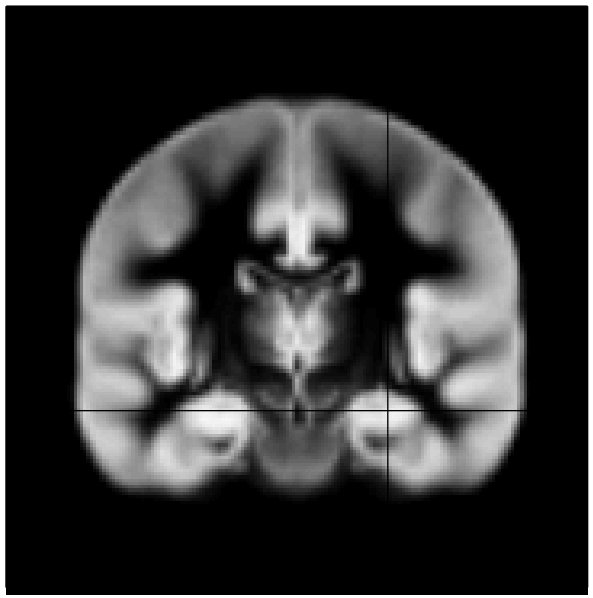
Used an inverse consistent formulation

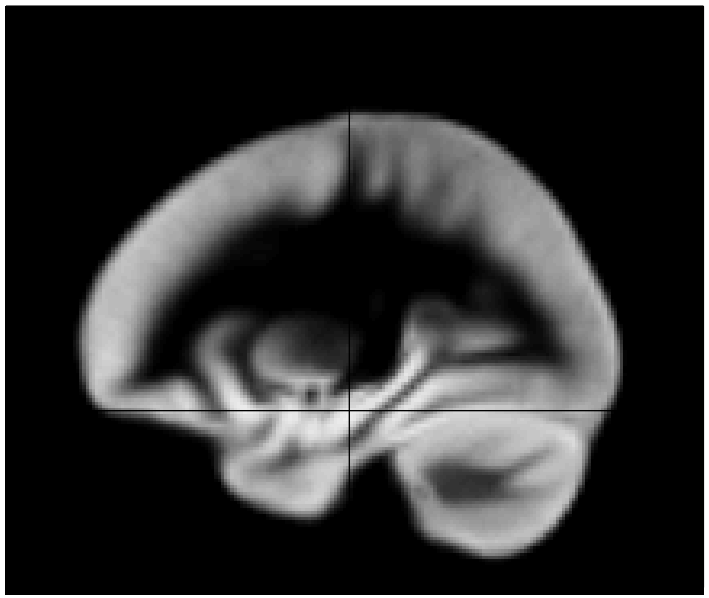
Initial Average

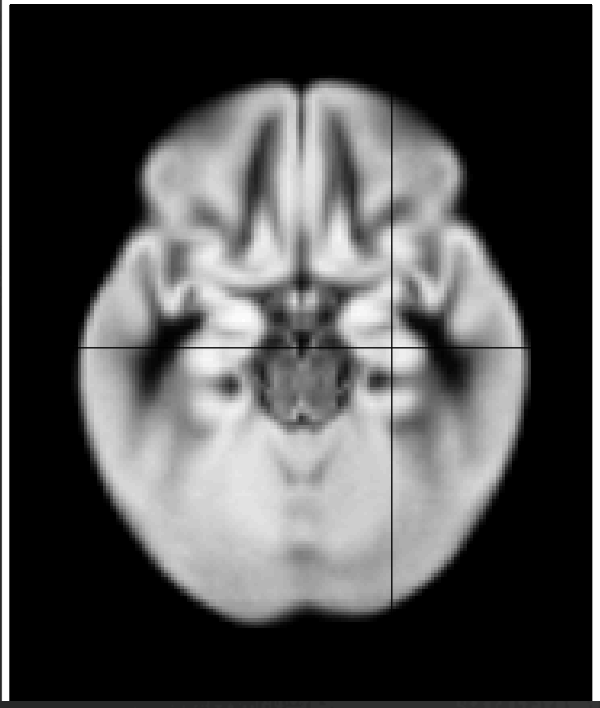
After a few iterations

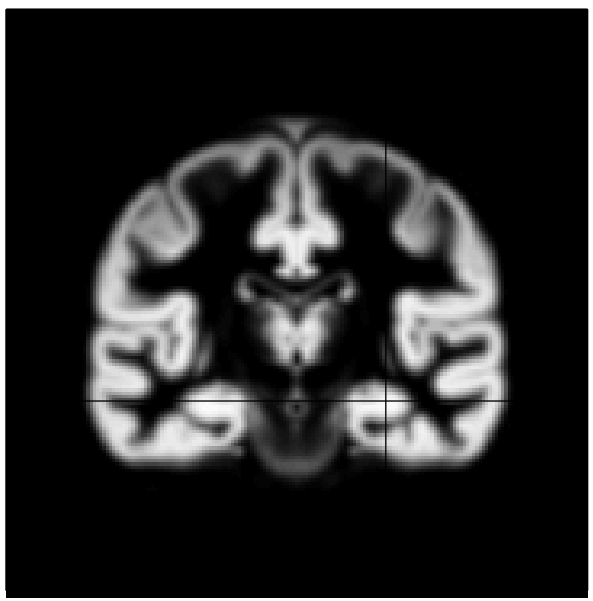
Final template

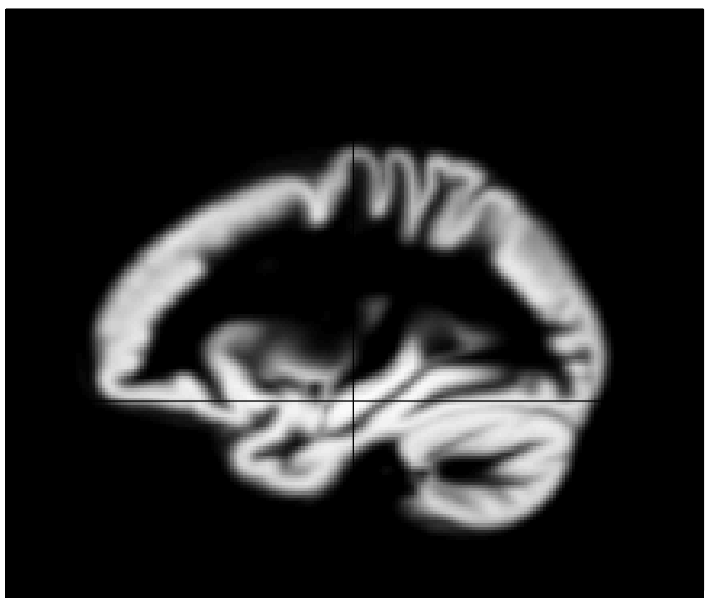


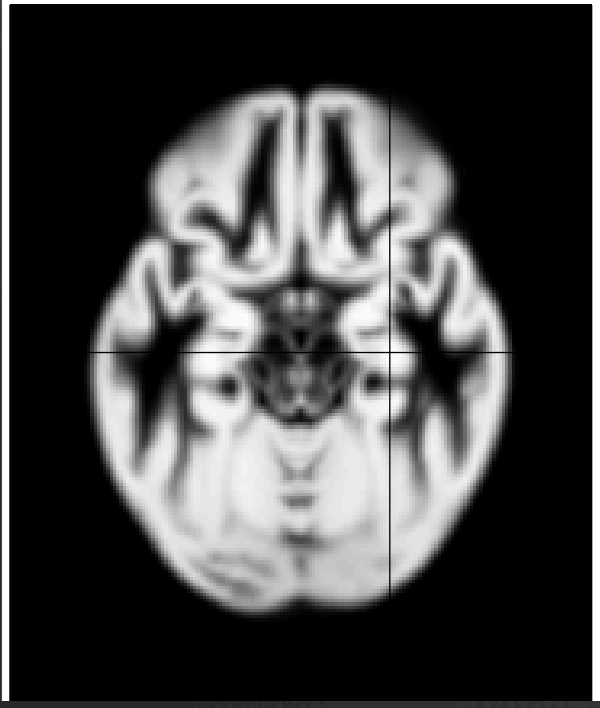




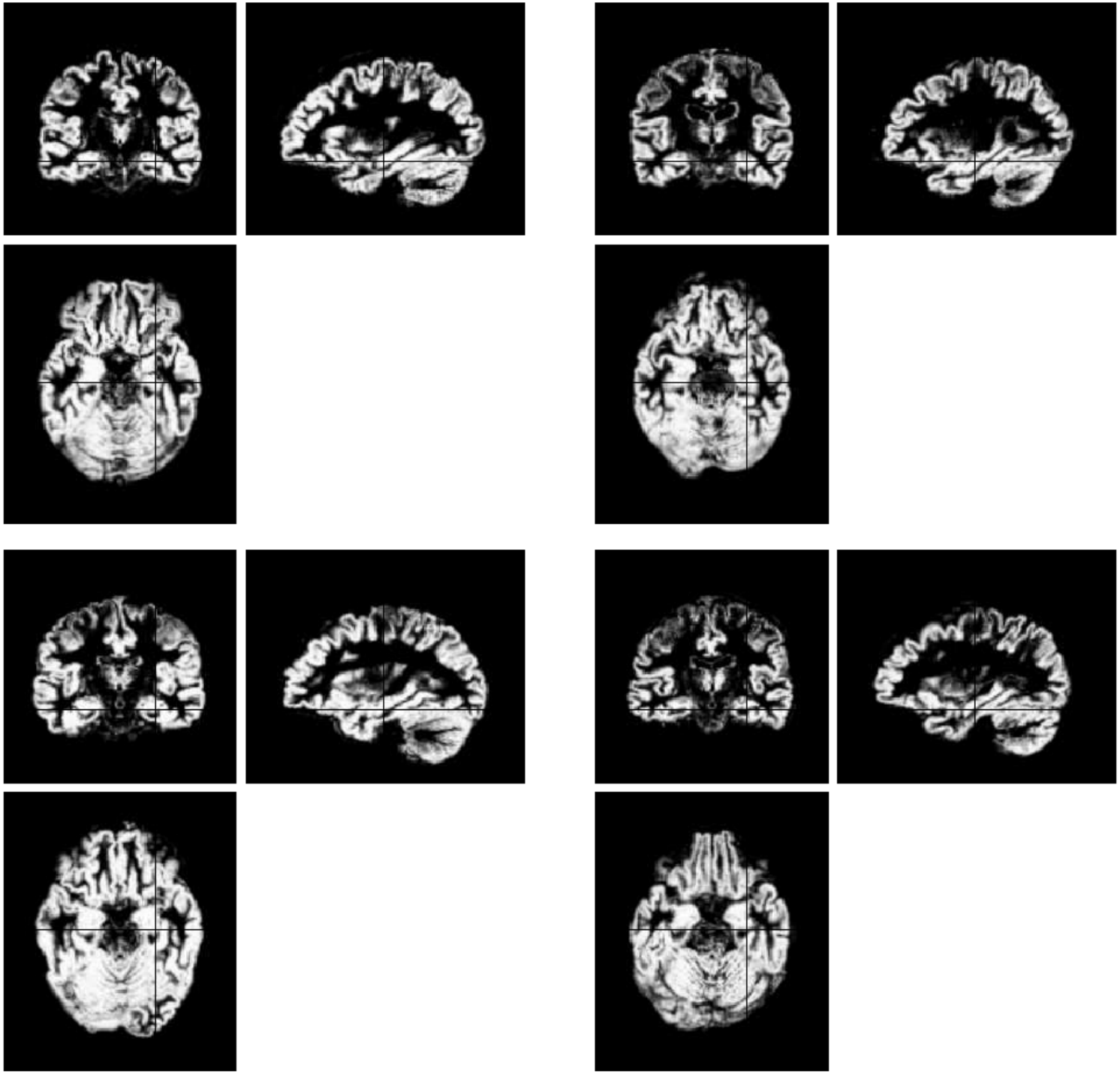




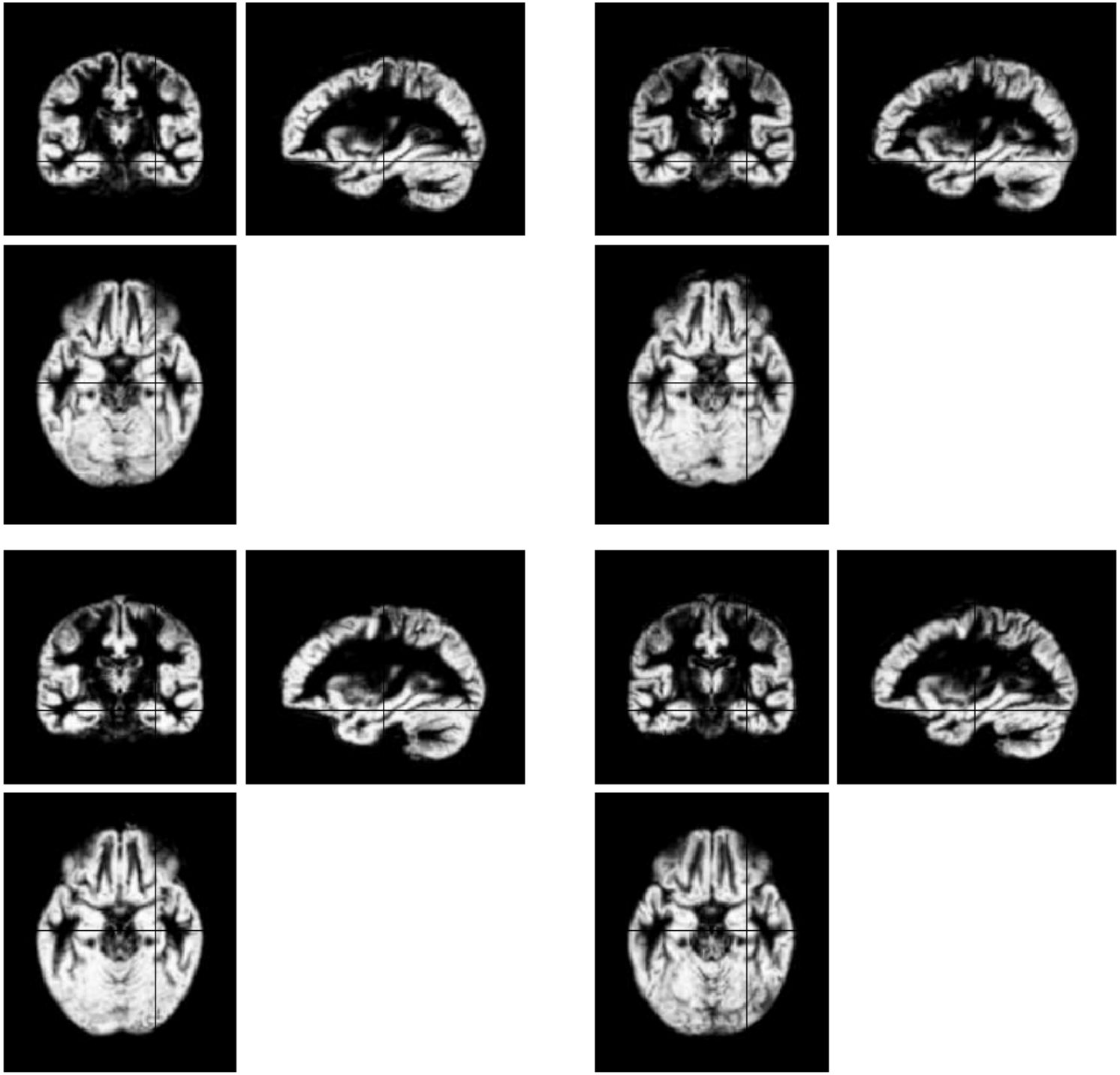


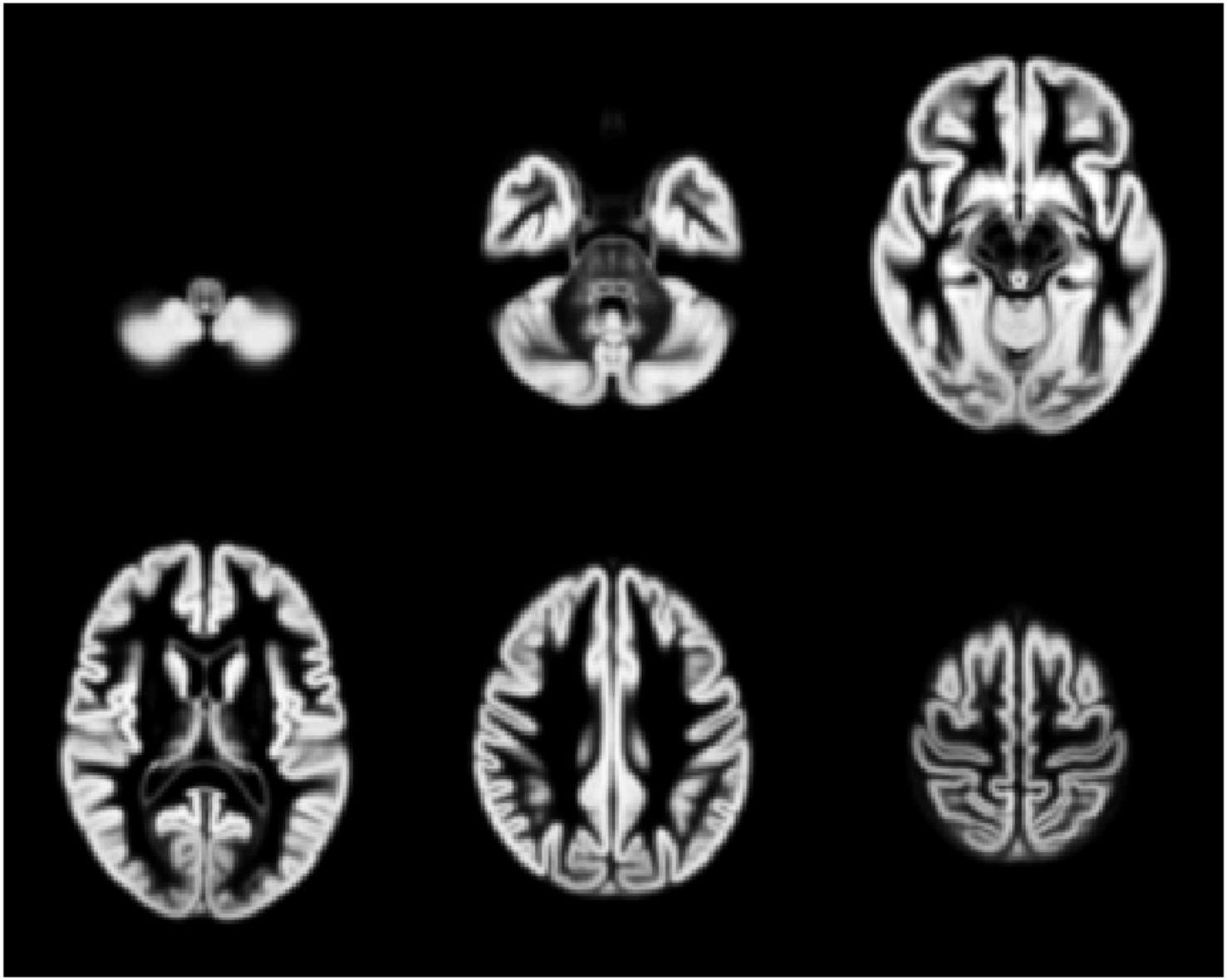


Initial
GM images

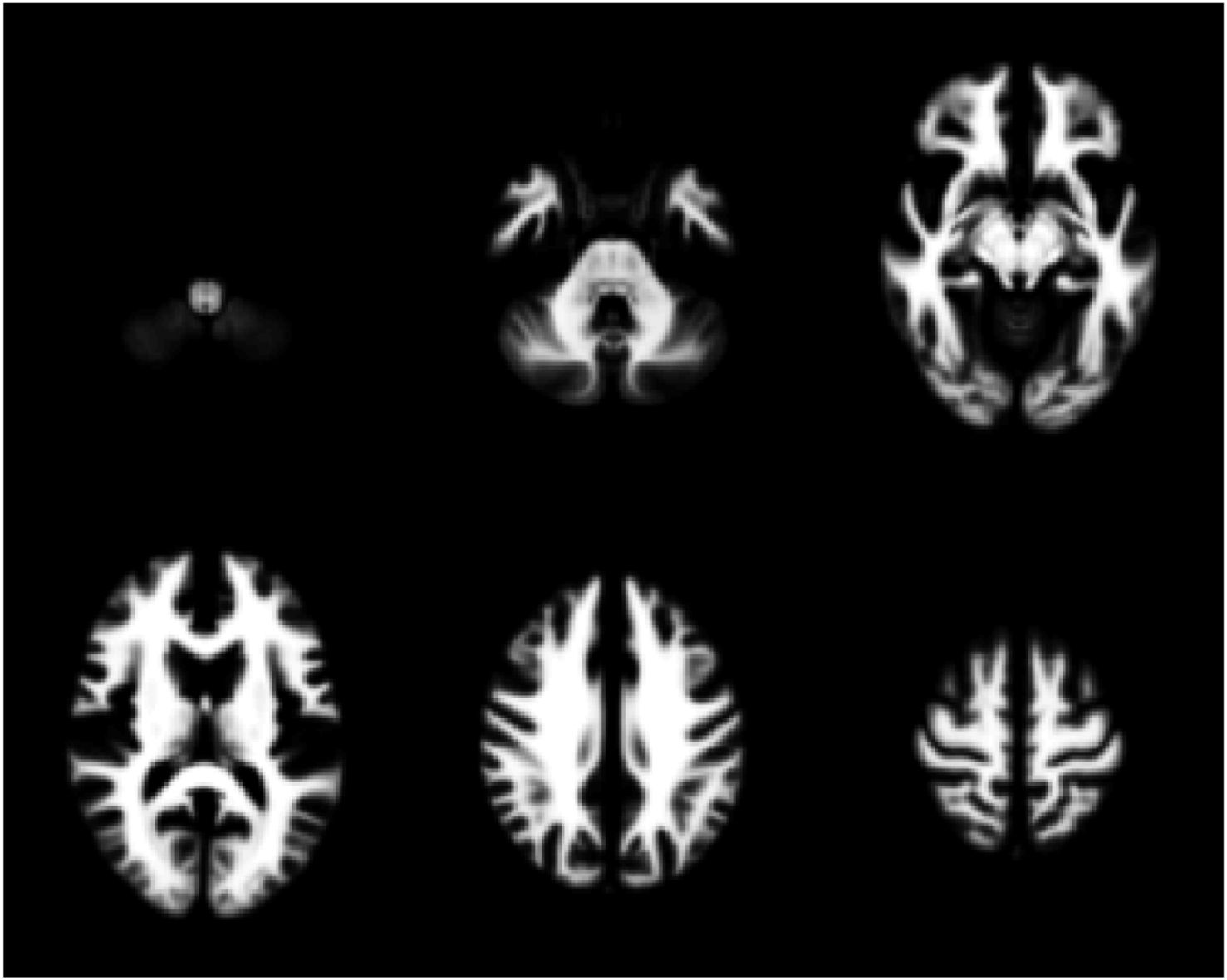


Warped
GM images





471 Subject Average



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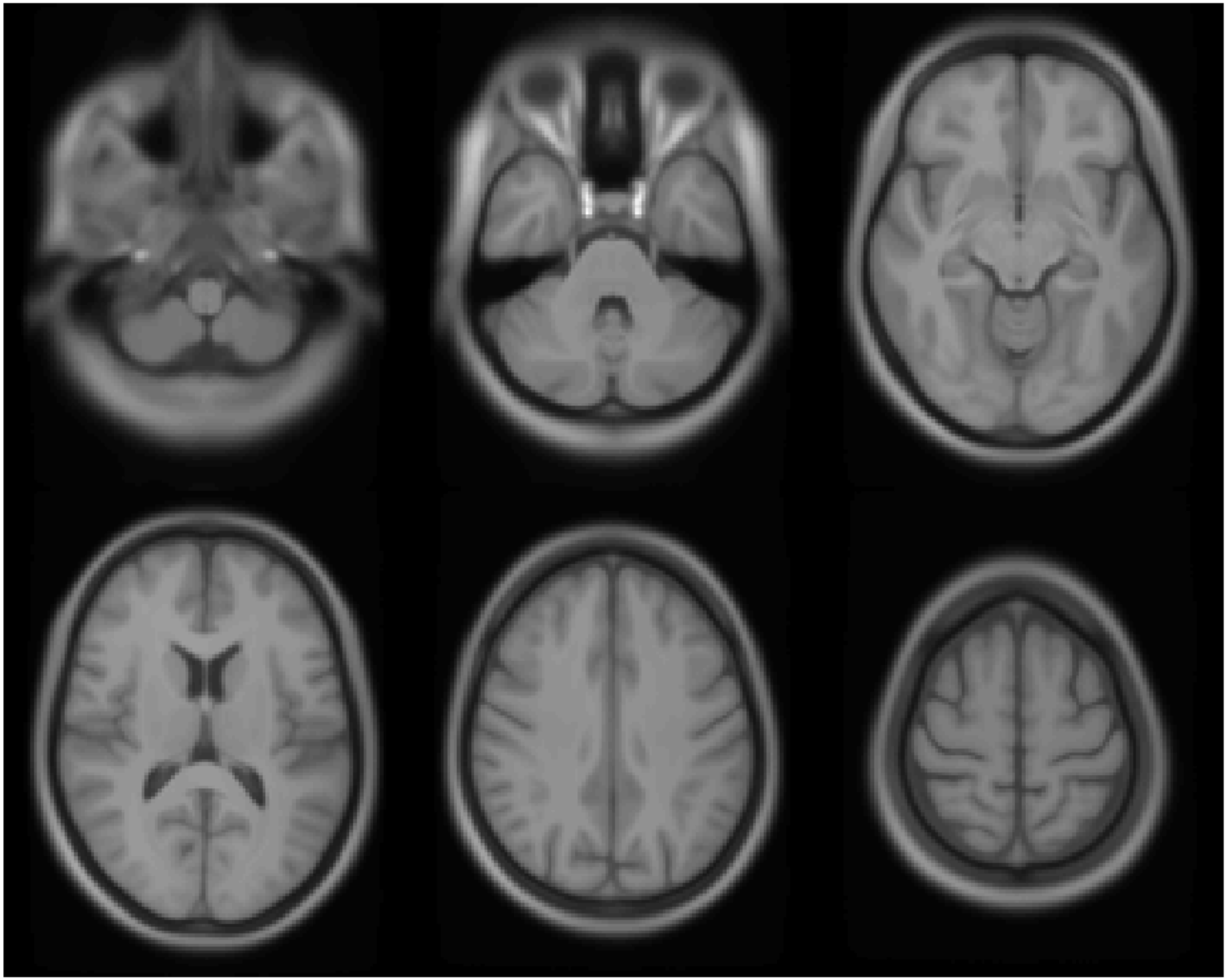
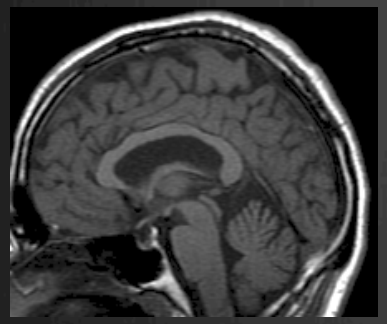


471 Subject Average

SPM for Anatomical MRI



Some References

- Wright, McGuire, Poline, Travere, Murray, Frith, Frackowiak & Friston. *A voxel-based method for the statistical analysis of gray and white matter density applied to schizophrenia*. Neuroimage 2(4):244-252 (1995).
- Ashburner & Friston. "*Voxel-based morphometry-the methods*". Neuroimage 11(6):805-821, (2000).
- Mechelli et al. *Voxel-based morphometry of the human brain…* Current Medical Imaging Reviews 1(2) (2005).
- Ashburner & Friston. "*Unified Segmentation*". NeuroImage **26**:839-851, 2005.
- Ashburner. "*A Fast Diffeomorphic Image Registration Algorithm*". NeuroImage 38:95-113 (2007).
- Ashburner & Friston. "*Computing Average Shaped Tissue Probability Templates*". NeuroImage **45**:333-341 (2009).
- Klein et al. *Evaluation of 14 nonlinear deformation algorithms applied to human brain MRI registration*. NeuroImage 46(3):786-802 (2009).
- Ashburner. "*Computational Anatomy with the SPM software*". Magnetic Resonance Imaging **27**(8):1163-1174 (2009).
- Ashburner & Klöppel. "*Multivariate models of inter-subject anatomical variability*". NeuroImage 56(2):422-439 (2011).

Interpreting findings

VBM is sometimes described as
"unbiased whole brain volumetry"

Regional variation in registration accuracy

Segmentation problems, issues with analysis mask

Intensity, folding, etc.

But significant blobs probably still indicate meaningful systematic effects!

Summary

- VBM performs voxel-wise statistical analysis on smoothed (modulated) normalised tissue segments
- SPM performs segmentation and spatial normalisation in a unified generative model
  - Based on Gaussian mixture modelling, with warped spatial prior probability maps, and multiplicative bias field

End of the second lecture!

Next time (29 Nov. 2013):
Basics of Diffusion tensor imaging

http://www.fil.ion.ucl.ac.uk/spm/