Age-specific MRI brain and head templates for healthy adults from 20 through 89 years of age

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Hard Data Café 3/2/12

Today's Outline

- Why create age-specific MRI templates?
- Goals
- Image characteristics
- Methods
- Results
- Conclusions

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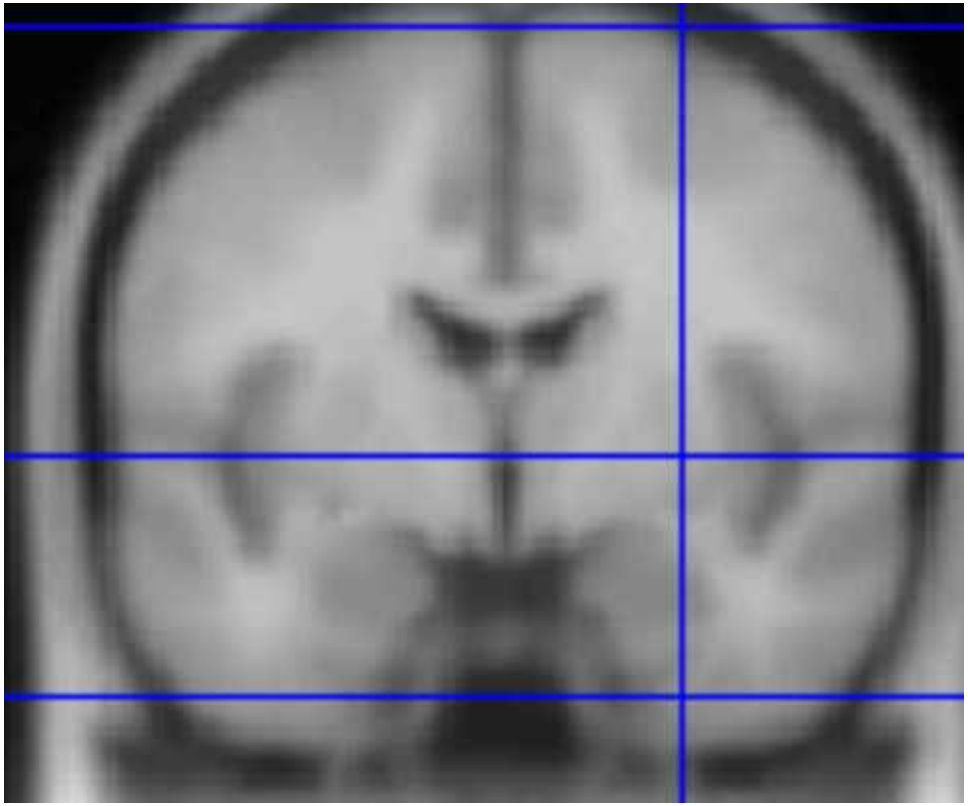
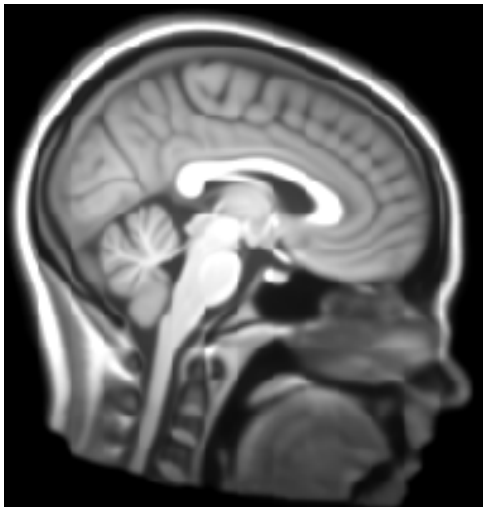
MRI Templates

- What it is?
  - Average brain representing a population
- Why is it important?
  - Individual differences in neuroanatomy
  - Compare results across studies
  - Generalize results to a larger population

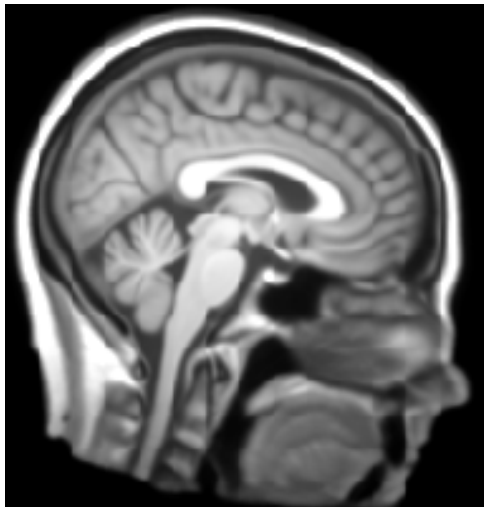
Current MRI Templates



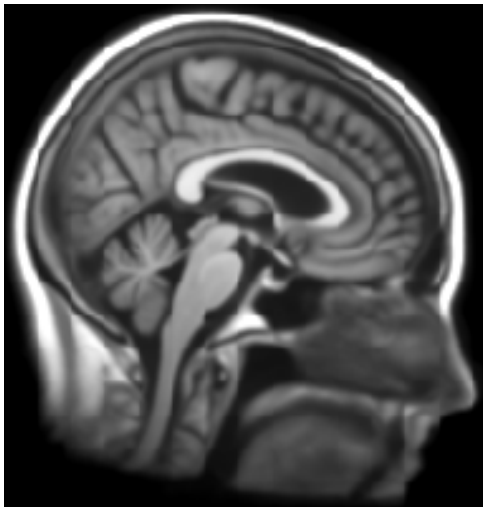
Brain Changes as We Age



20-24 Years Old



50-54 Years Old



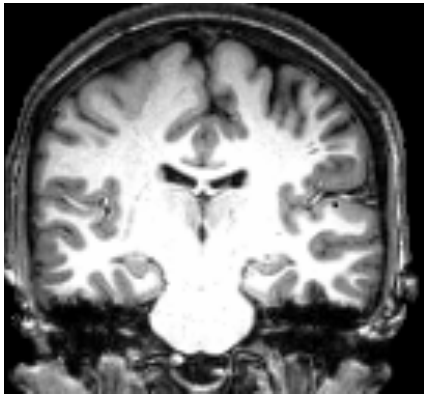
80-84 Years Old

Measuring Volumetric Changes

- Accurate tissue segmentation is especially important in the measurement of volumetric characteristics
- Segmentation procedures often use *a priori* reference data
- MNI tissue priors

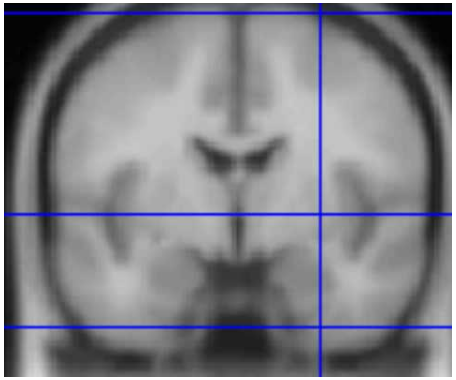
Measuring Volumetric Changes

Individual Brain

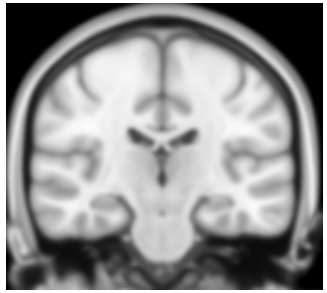


Spatial Normalization

Common template



MNI
Tissue Priors



Measuring Volumetric Changes

- Problem?
  - Using MNI reference data as a starting place for segmentation of a 65-year-old brain may bias our tissue estimates
- Solutions
  - Study-specific template
    - VBM (Ashburner & Friston, 2000; Good, et al., 2001; Thompson, et al., 2001)
  - Age-matched templates
    - Pediatric templates (Sanchez, Richards, & Almli, 2011, in press; Wilke, et al., 2003)

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Goals

- Construct age-specific brain templates for adults 20-89 years of age for use by the research and clinical community

- Compare the use of age-specific templates to age-inappropriate templates (like MNI) for tissue segmentation

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Image Characteristics

- Sources:
  - NIH MRI Study of Normal Brain Development (NIHPD; Almli, Rivkin, & McKinstry, 2007; Evans & BDCG, 2006; Waber, et al., 2007)
    - 26, 20-24
  - USC McCausland Center for Brain Imaging (USC-MCBI)
    - 132, 20-65
  - Information Extracted from Medical Images (IXI) database (Ericsson, Alijabar, & Rueckert, 2008; Heckemann, et al., 2003)
    - 546, 20-86
  - Cross-sectional database of the Open Access Series of Imaging Studies (OASIS; Marcus, et al., 2007)
    - 283, 20-89
  - Longitudinal database of OASIS (Marcus et al., 2010)
    - 175 scans from 72 participants, 60-89

Image Characteristics

- Overall 1162 T1 scans from 1059 participants were used for creation of the templates
  - 693 Female/469 Male

- External Test Set
  - USC-MCBI (20, 21-35 years)
  - Medical University of South Carolina (MUSC; 15, 58-83 years)

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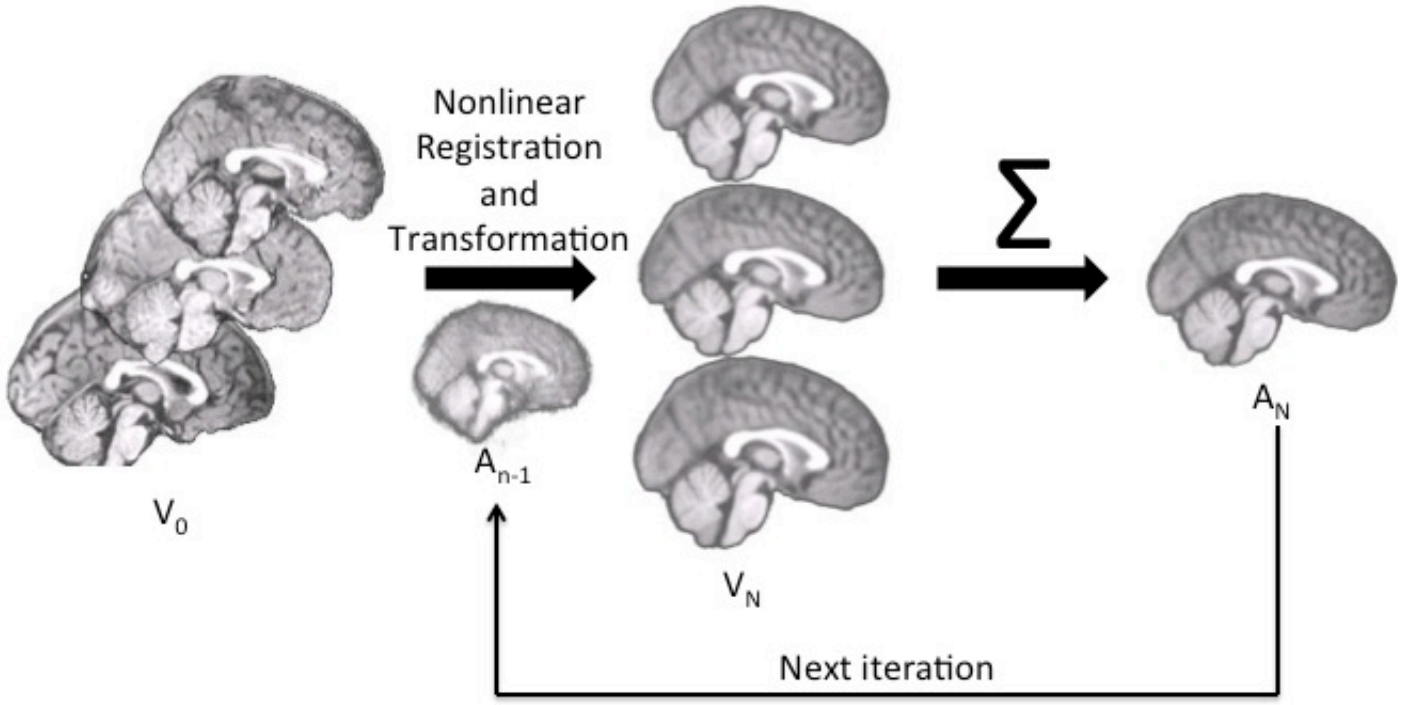
File Preparation

- Brains were extracted from whole-head MRI volume using the brain extraction tools of FSL

- Adjusted the MRI intensity variations found in the datasets that stemmed from different machines, different recording sites and slight differences in protocol

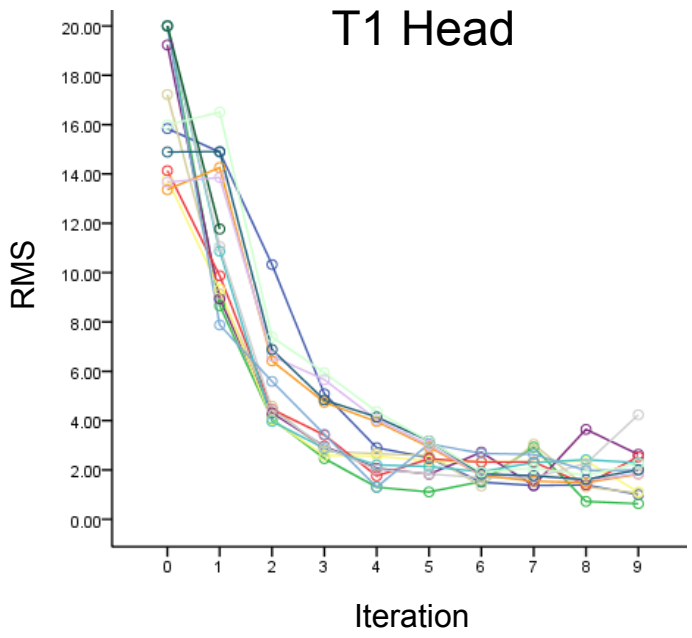
Age-Specific Template Construction

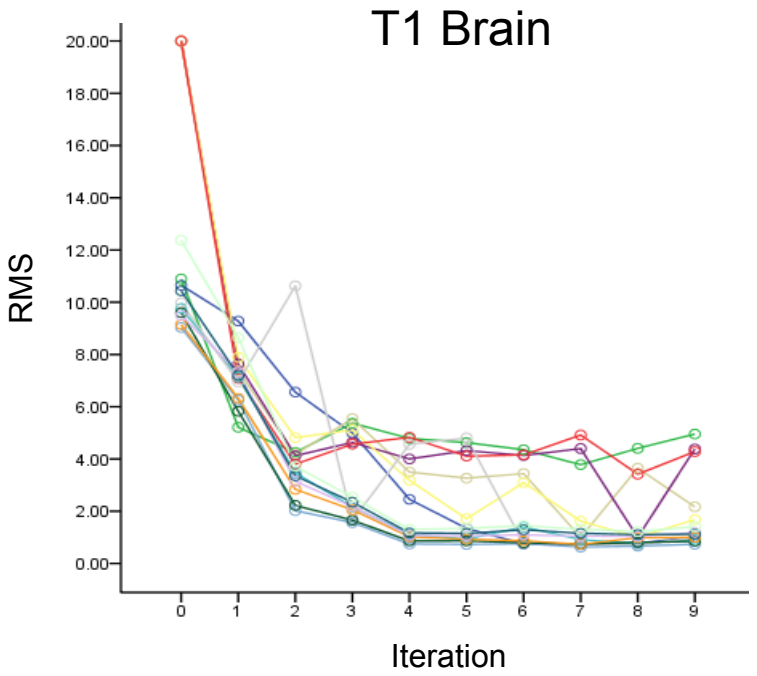
- Processing Pipeline



Age-Specific Template Construction

Each line represents an age-specific template (n=14)

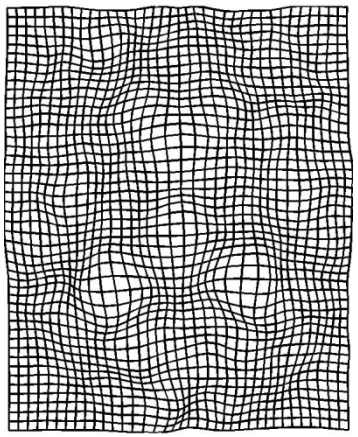




Transformation Parameters

- At the end of the final iteration, files containing values representing the parameters of the transformation from the individual participant MRI volumes to the average volumes were retained
- Used in tissue classification steps

-1.15444	0.025868	-0.05035	-3.1684
0.023488	1.06702	0.103427	-25.0112
0.059106	-0.11975	1.16483	-54.4782
0	0	0	1



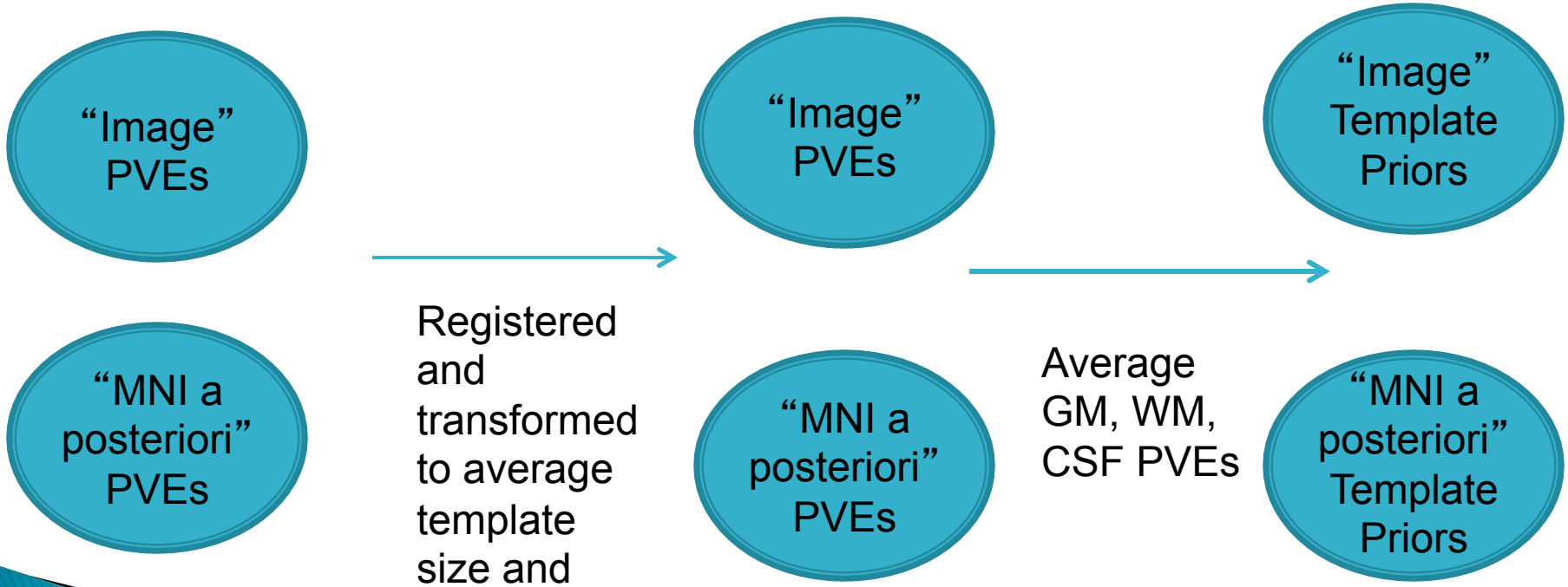
Tissue Classification

- Individual participant MRI volumes were classified into GM, WM, and CSF

- FSL FAST
  - Without using any *a priori* reference data (“Image”)
  - Used with the MNI-152 tissue priors (“MNI a priori”)
  - “MNI a posteriori” tissue priors

Tissue Classification

- All three methods resulted in a set of partial volume estimates (PVEs) for GM, WM, and CSF, for each participant's MRI volume



Tissue Classification Tests

- 56 scans from the original set
  - Template priors used to construct PVE estimates for these participants (FAST -P)
  - “MNI a posteriori” 5-year
  - “Image a posteriori”
    - 5-year
    - 10-year
    - Multi-year
    - All other 5-year (“age-inappropriate”)

Tissue Classification Tests

- The three PVE volumes were used to construct a single three-class segmented volume, by assigning each voxel a tissue type based on the maximum PVE estimate from the three tissue volumes

- Additional PVE estimates:
  - Individual's "Image"
  - Individual's MNI *a priori*

Statistical Analyses

- Dice coefficient
  - Represents the intersection of two similarly labeled regions divided by the mean volume of the regions
- Two tests:
  - Overlap between volume based on the individual's "Image" segmentation and other segmentation routines
  - Overlap between volume based on the participant's age-appropriate five-year template and that based on successively older and younger five-year templates

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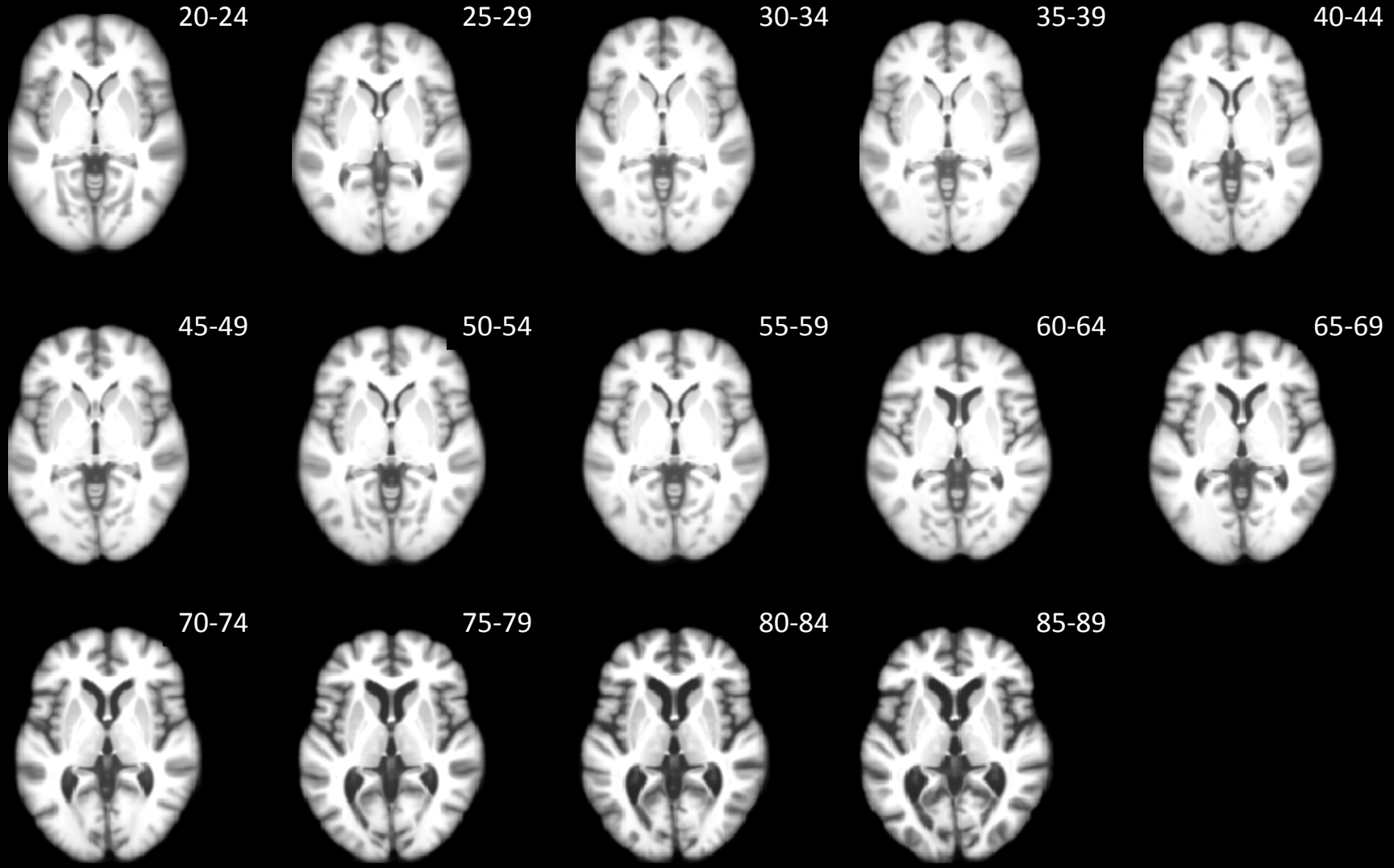
20-24
25-29
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70-74
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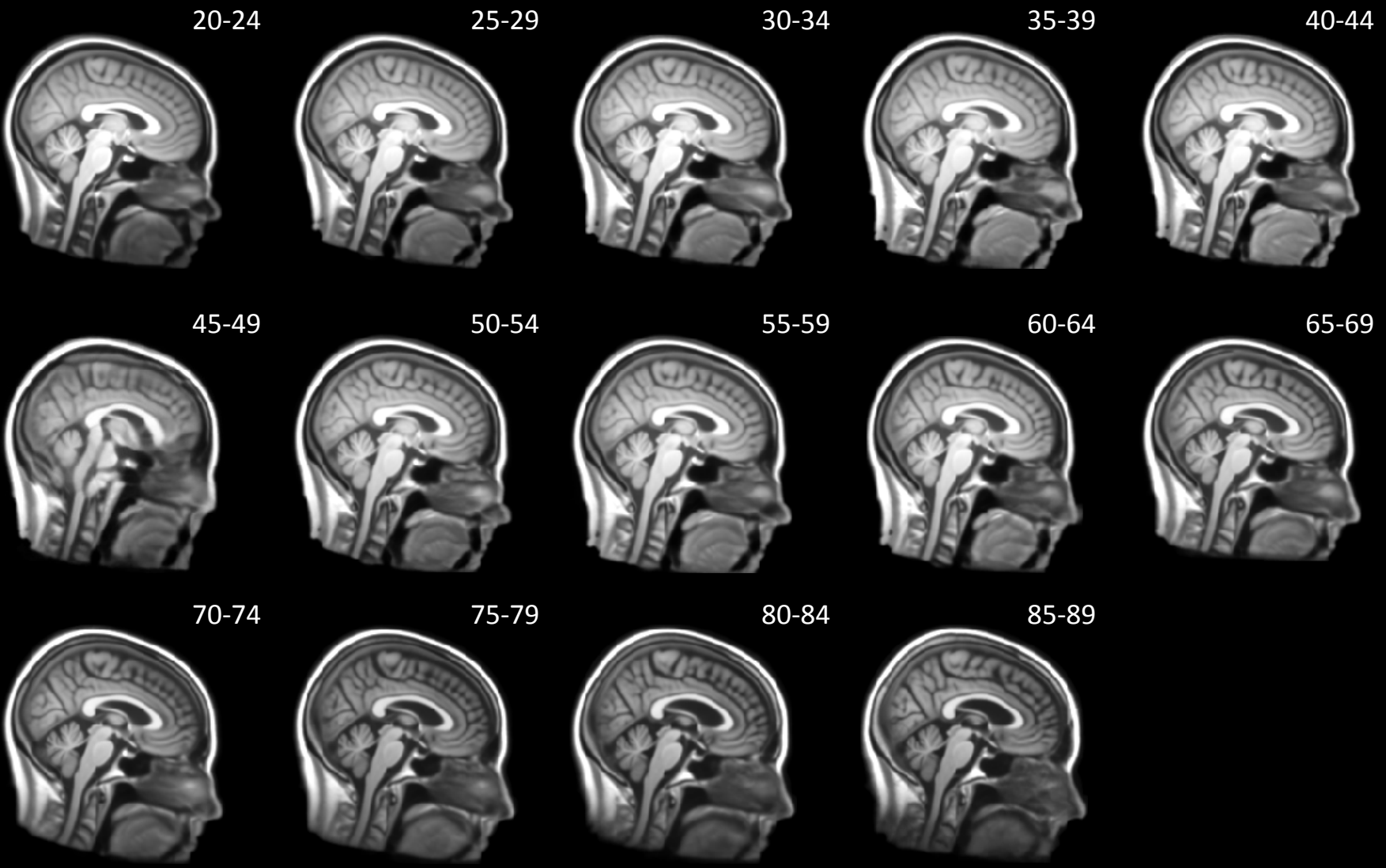
80-84
85-89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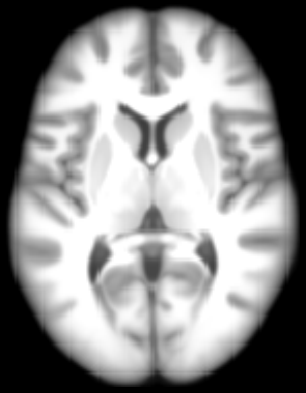
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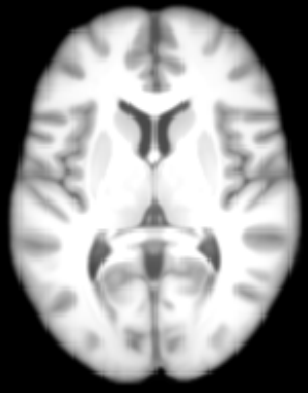
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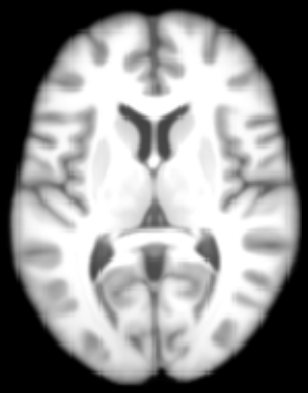
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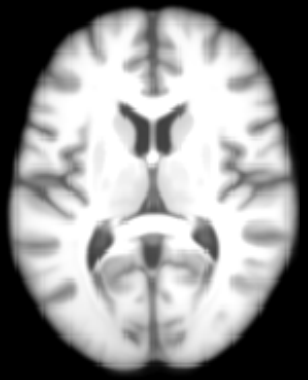
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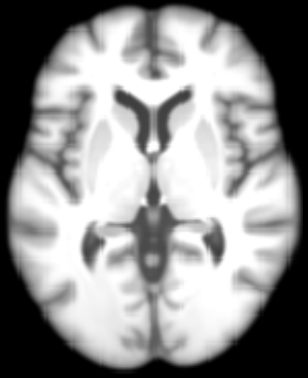
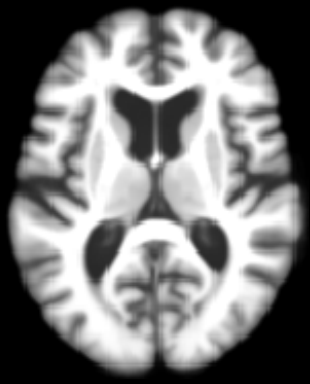
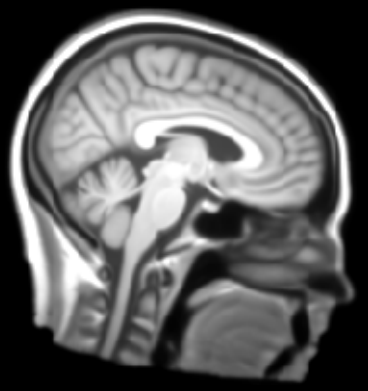

60-69


70-79


80-89

20-29

30-39



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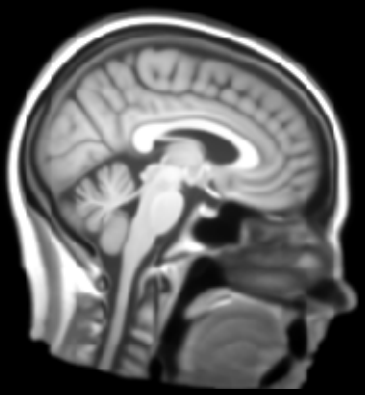

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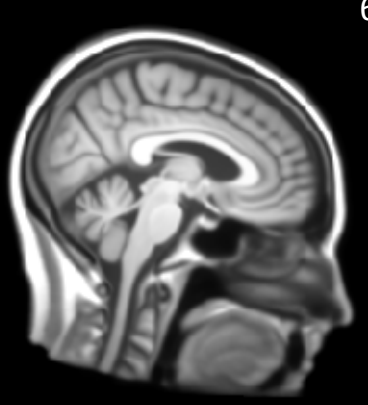

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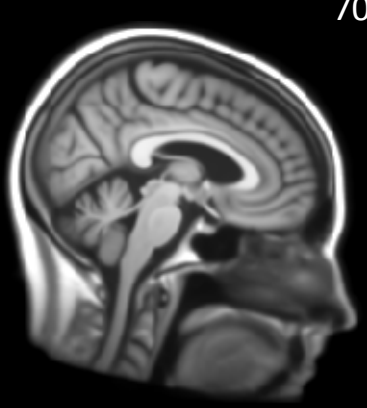

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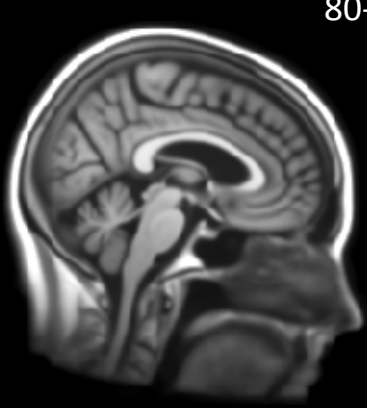
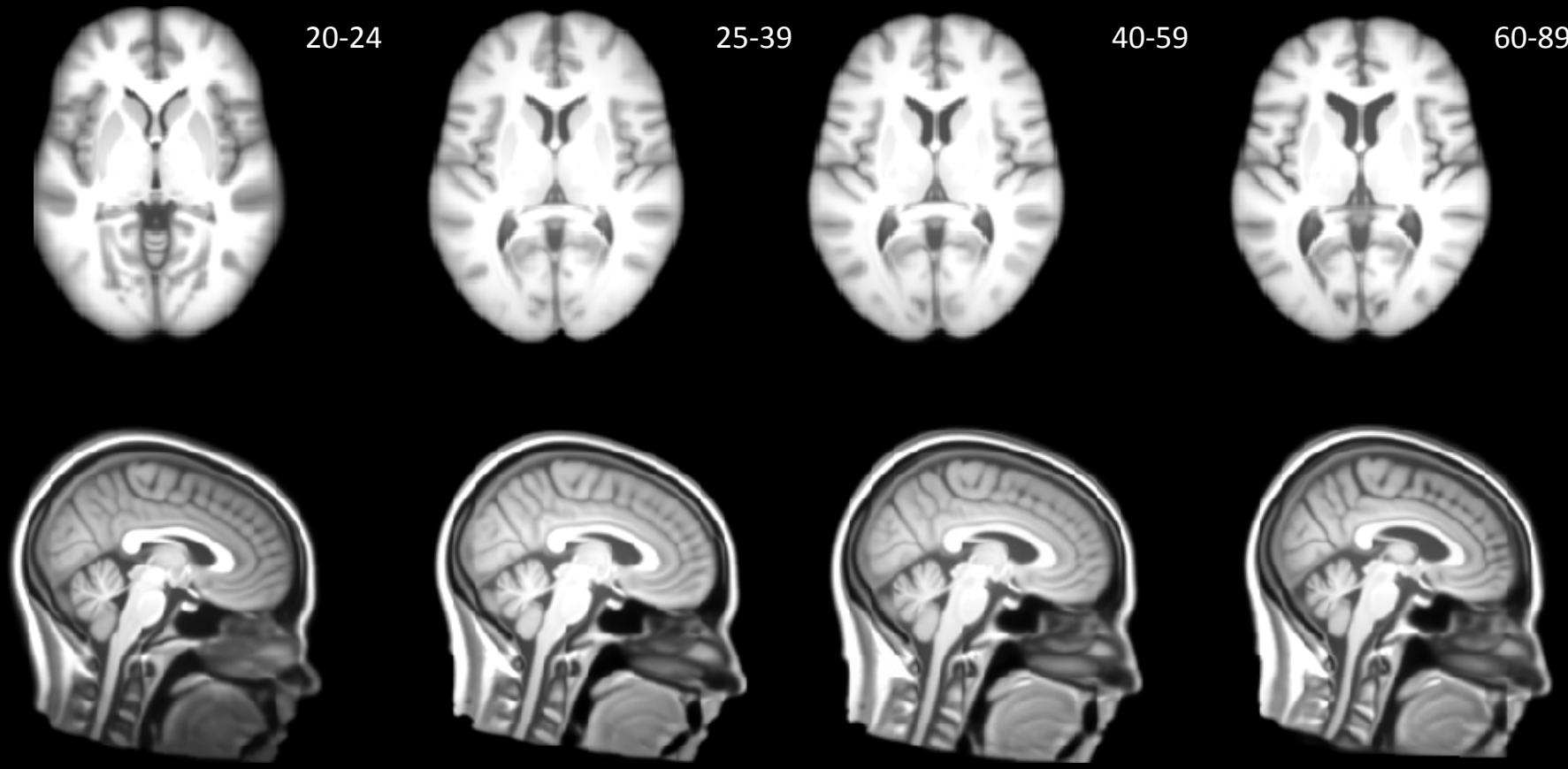


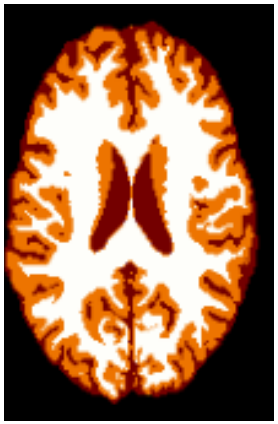
80-89


20-24
25-39
40-59
60-89

Results

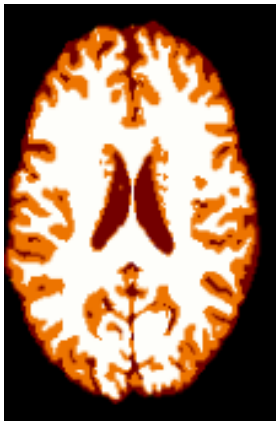
- Example three-class segmented volumes:

"Image"



"Image a posteriori"

"MNI a priori"



Results

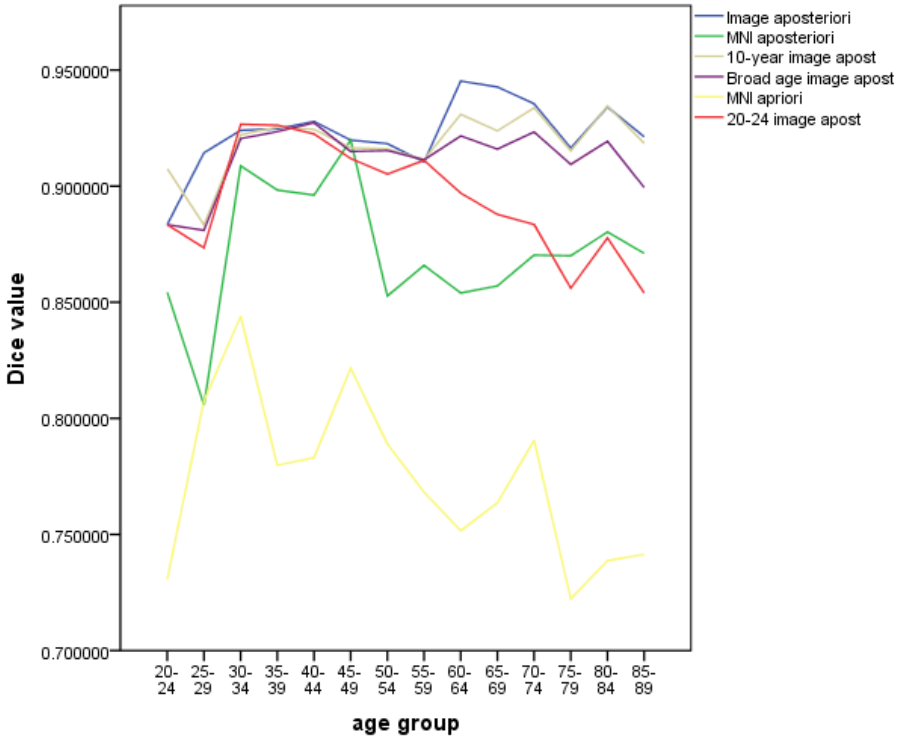


Image aposteriori
MNI aposteriori
10-year image apost
Broad age image apost
MNI apriori
20-24 image apost
Dice value
0.950000
0.900000
0.850000
0.800000
0.750000
0.700000
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
age group

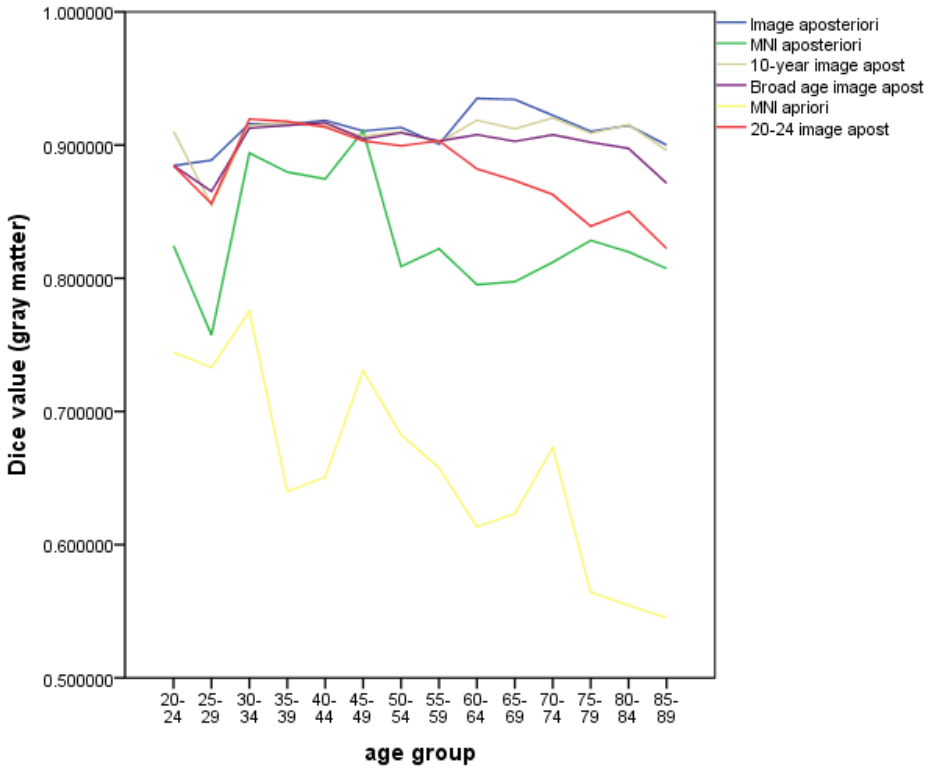


Image aposteriori
MNI aposteriori
10-year image apost
Broad age image apost
MNI apriori
20-24 image apost
Dice value (gray matter)
1.000000
0.900000
0.800000
0.700000
0.600000
0.500000
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
age group

Results

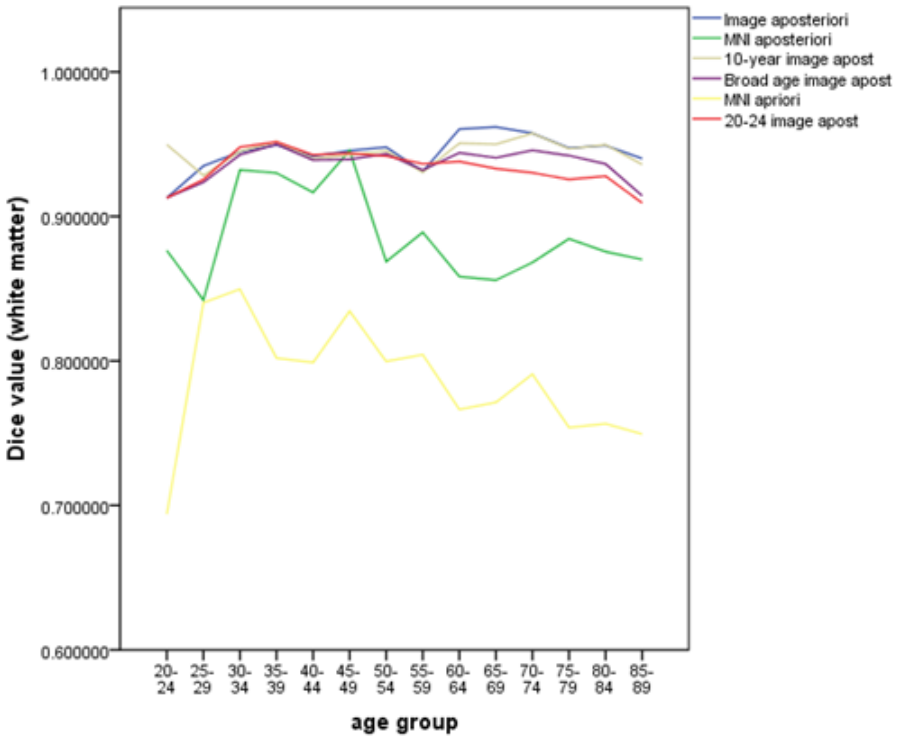


Image aposteriori
MNI aposteriori
10-year image apost
Broad age image apost
MNI apriori
20-24 image apost
Dice value (white matter)
1.000000
0.900000
0.800000
0.700000
0.600000
20-24
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45-49
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70-74
75-79
80-84
85-89
age group

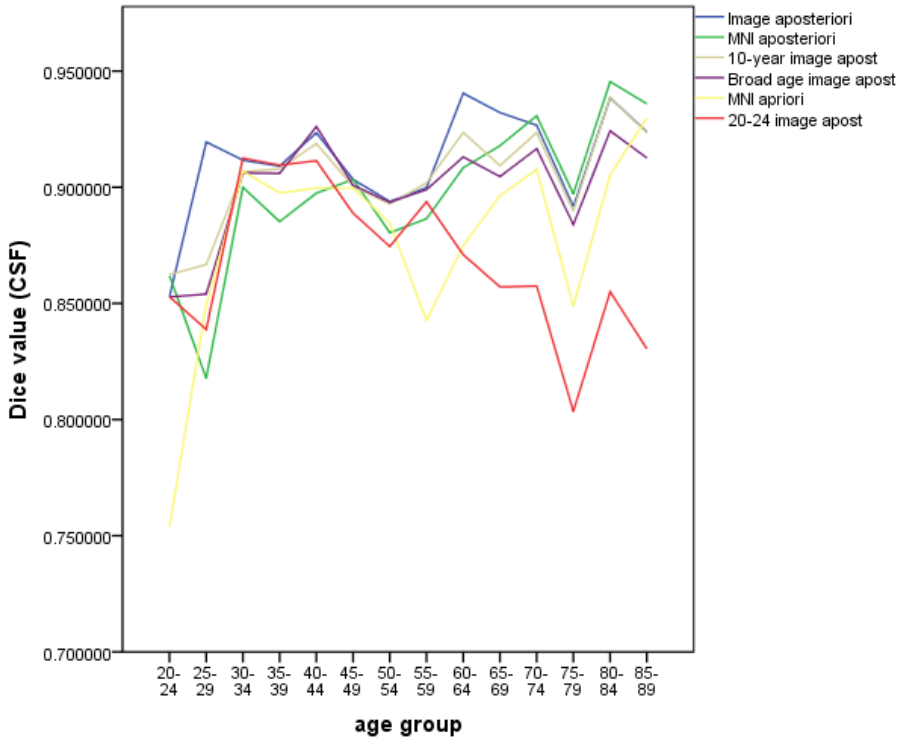
Image aposteriori
MNI aposteriori
10-year image apost
Broad age image apost
MNI apriori
20-24 image apost
Dice value (CSF)
0.950000
0.900000
0.850000
0.800000
0.750000
0.700000
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35-39
40-44
45-49
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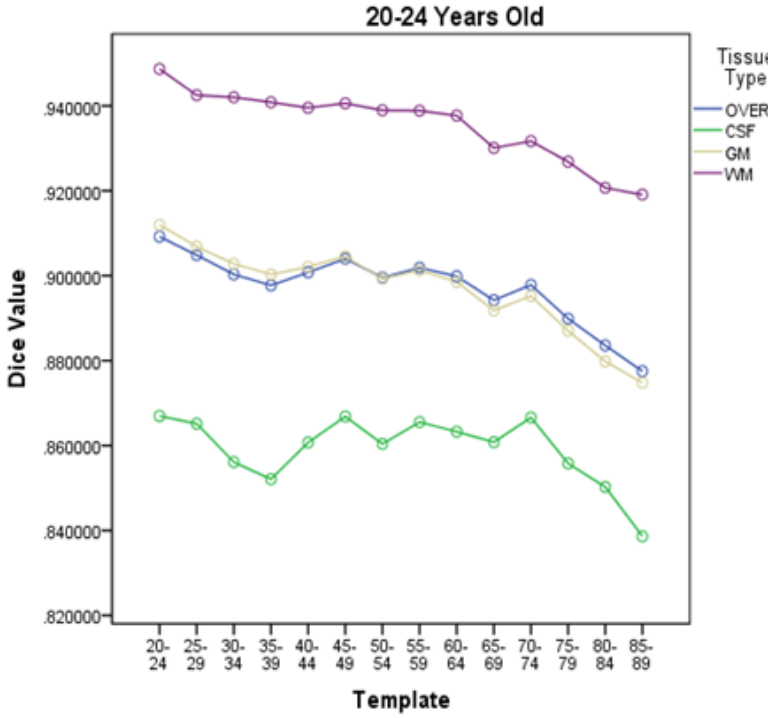
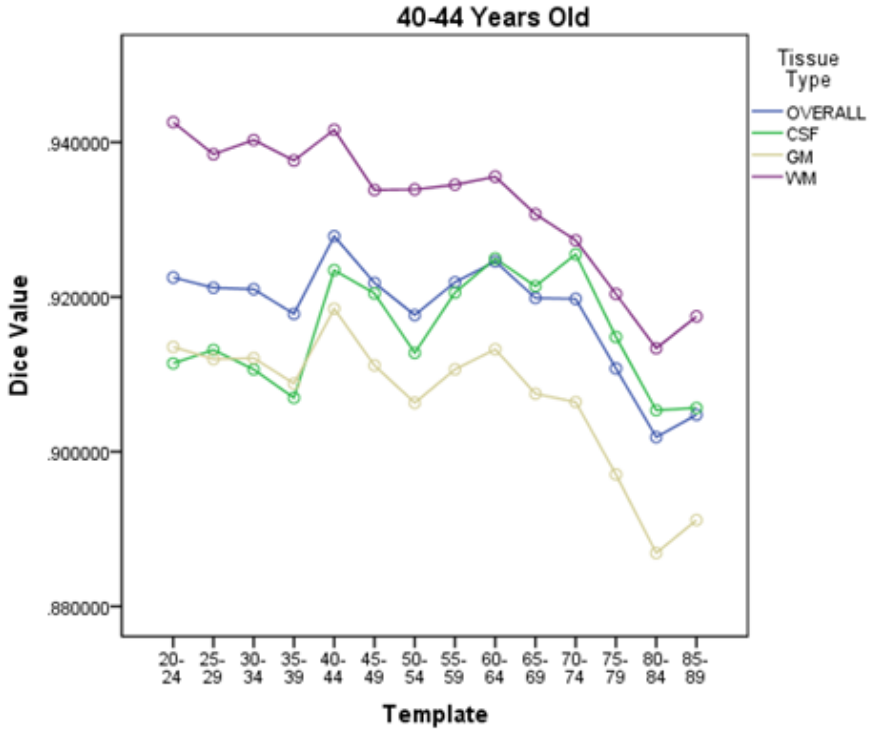
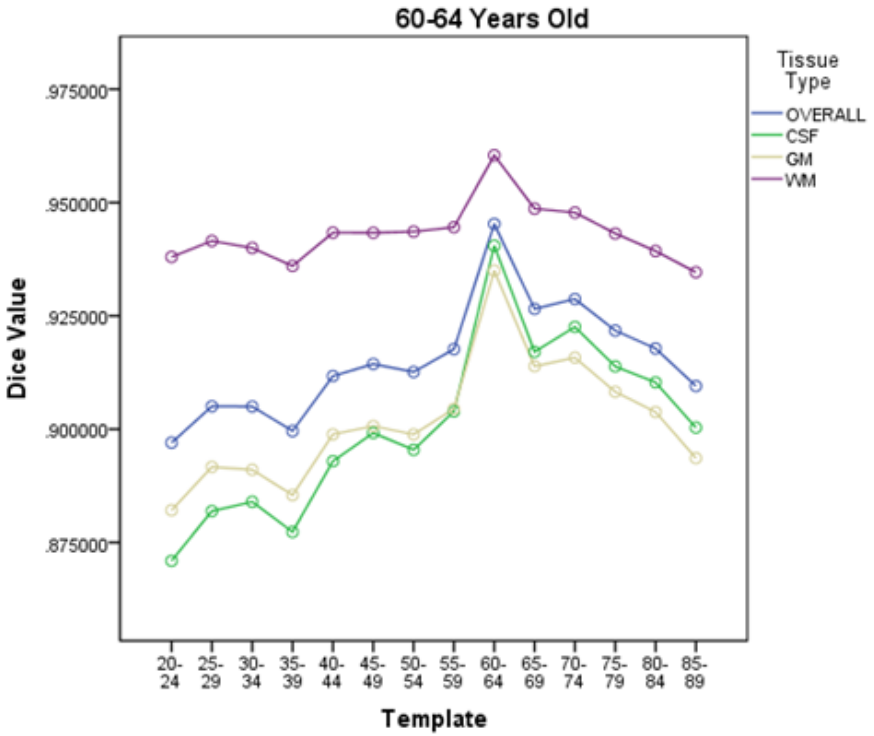
70-74
75-79
80-84
85-89
age group

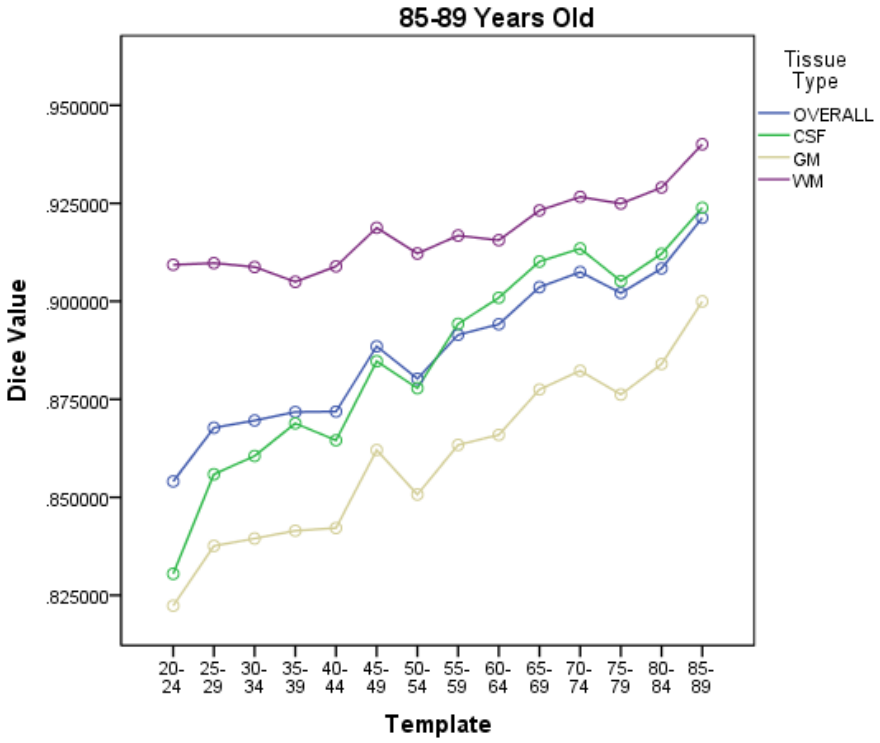
Results


20-24 Years Old
Tissue Type
OVER
CSF
GM
WM
Dice Value
.940000
.920000
.900000
.880000
.860000
.840000
.820000
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
Template


40-44 Years Old
Tissue Type
OVERALL
CSF
GM
WM
Dice Value
.940000
.920000
.900000
.880000
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
Template

Results


60-64 Years Old
Dice Value
.975000
.950000
.925000
.900000
.875000
Tissue Type
OVERALL
CSF
GM
WM
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
Template


85-89 Years Old
Dice Value
.950000
.925000
.900000
.875000
.850000
.825000
Tissue Type
OVERALL
CSF
GM
WM
20-24
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30-34
35-39
40-44
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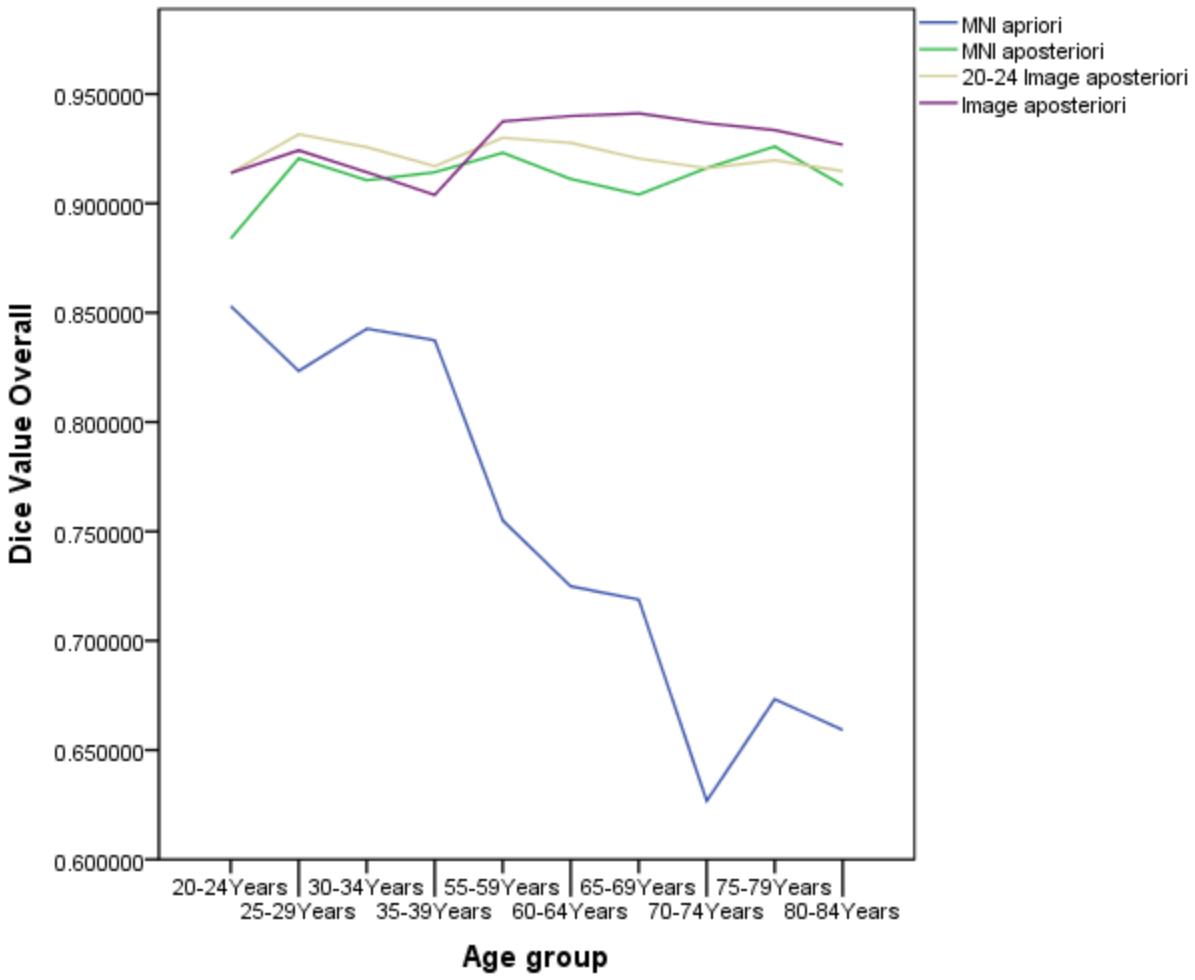
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
Template

Results – External Test Set



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Conclusions

- Reference data from age-appropriate templates leads to more accurate segmentation as compared to age-inappropriate templates
  - Internal
  - External
- Use of age-specific reference data should facilitate the generation of reliable conclusions about morphological and volumetric brain changes that occur with aging

Future Directions

- Age-specific brain atlases
- Functional imaging data
  - Huang, et al. (2010)