The Haskins Pediatric Brain Atlas

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INTRODUCTION

- Spatial normalization plays a nearly essential component to multi-subject fMRI experiments by facilitating a common space in which group analyses are performed.
- Commonly, experimental data is aligned to either a group template (e.g. MNI-152) or to an individual template (e.g. N27).
- Regardless, multiple problems have been identified with using an adult template with pediatric populations due to age related-variability in grey and white matter (Fonov et al., 2011; Muzik et al., 2000).
- While some laboratories use study-specific templates (Wilke et al., 2008; Huanga et al., 2010), these limit comparison across studies, while also not providing cortical and subcortical segmentations.

ATLAS CREATION METHODS

- Structural MRI data were collected from 75 participants (7-12 years) on a 1.5T scanner.
- Two templates (affine linear and nonlinear) were created using AFNI (Cox, 1996).
- The affine template used an iterative affine alignment from a rigid equivalent (AC-PC aligned) using the MNI 152 Template.
- The nonlinear template was made with the affine template and using a nonlinear fit over progressively smaller neighborhood sizes.
- Outlier datasets were determined by computing the mean warp deformation from each dataset to all others.
- Similarly, the subject with the least deformation was selected as the "typical subject" for our alternative templates
- The final nonlinear template was affinely aligned to the affine template to correct for general size, and the template origins were repositioned to have the anterior commissure at the (0,0,0) position.
- Atlas labels were generated for each participants using FreeSurfer's automatic segmentation with hand correction
- The segmentation was transformed to the template space using the corresponding affine and nonlinear transformations.
- Across subjects probability maps were used to generate maximum probability maps (MPM).
- The MPMs were then smoothed using a local neighborhood histogram procedure to find the modal region at each voxel.

DATA COLLECTION

- Participants were selected from a subset of an ongoing longitudinal study on reading development in New Haven, Connecticut.
- N=74 children (37 Male, 37 Female)
- All participants participated in extensive behavioral assessments cataloguing IQ, Math, and Language abilities
- Data were collected on a Siemens Sonata (1.5 T) MRI Scanner at Yale University with 8-channel head coil
- Magnetization-Prepared Rapid Gradient-Echo (MPRAGE) pulse sequence (flip angle 8°; TE 3.65; TR 2000ms; FOV 256 x 256mm; voxel resolution 1 x 1 x 1mm).

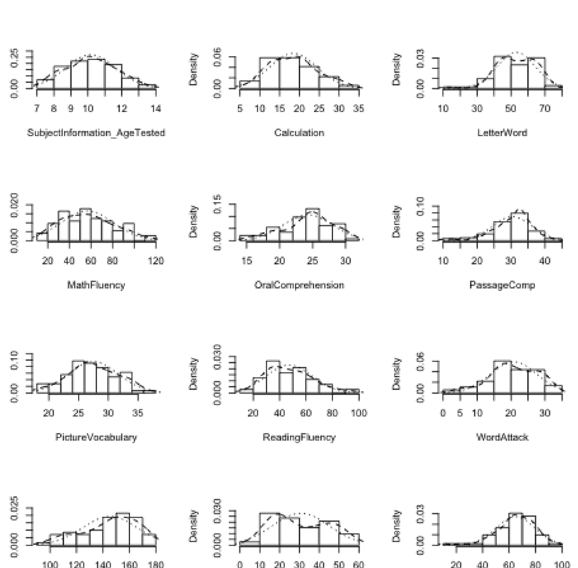


Figure 1: Demographic information for all participants: Age, Calculations, WJ-LWID, Math Fluency, Oral Comprehension, Passage Comp, Picture Vocabulary, Reading Fluency, WJ-WA, PPVT, TOWRE-PDE, TOWRE-SWE

INITIAL ATLASES

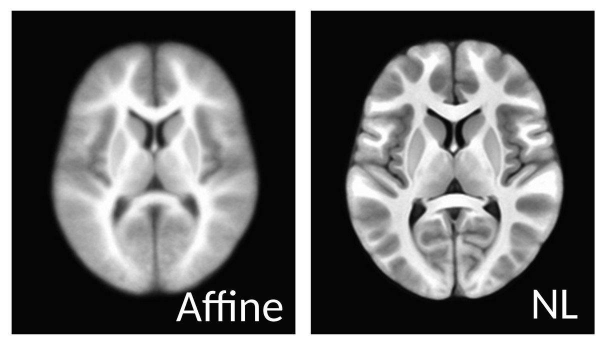


Figure 2: Affine Template (Left) and Nonlinear Template (Right)

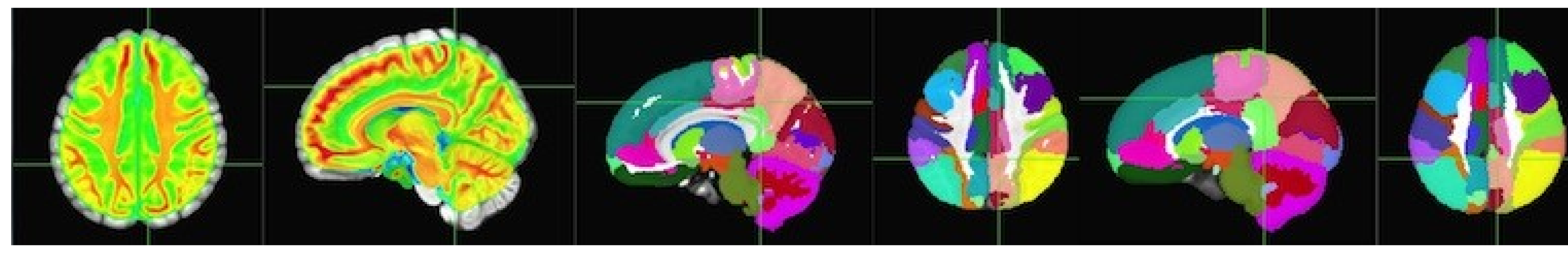


Figure 3: A) The size of the pediatric template (yellow/green/red) relative to the MNI152_2009a_nonlinear template; B) The nonlinear atlas; C) The affine atlas.

ALTERNATIVE ATLAS CREATION TECHNIQUES: ITERATIVE AND TYPICAL METHODS

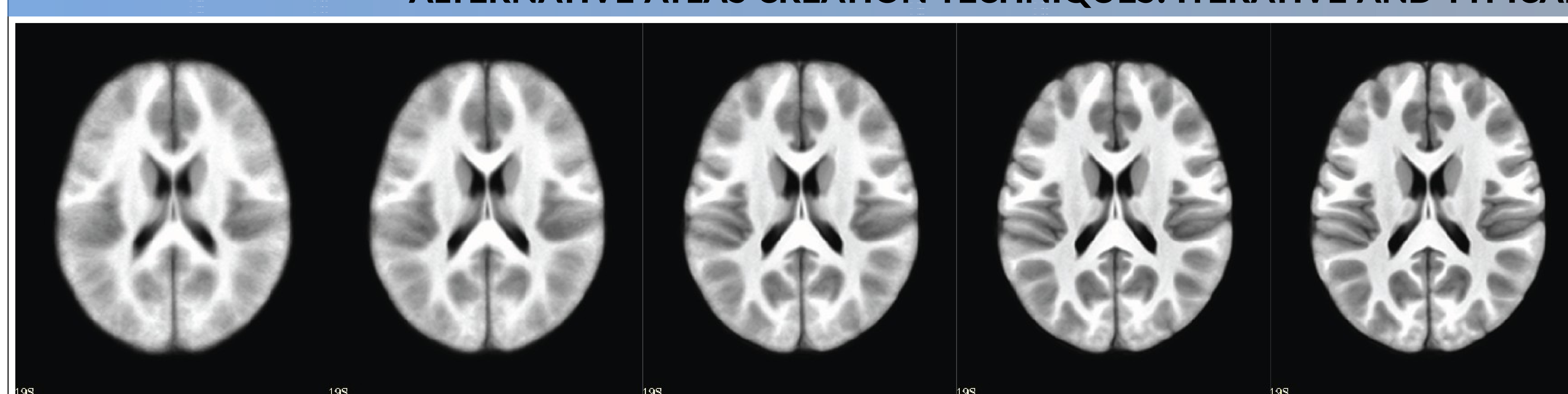
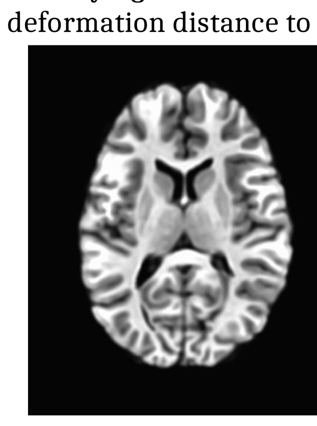
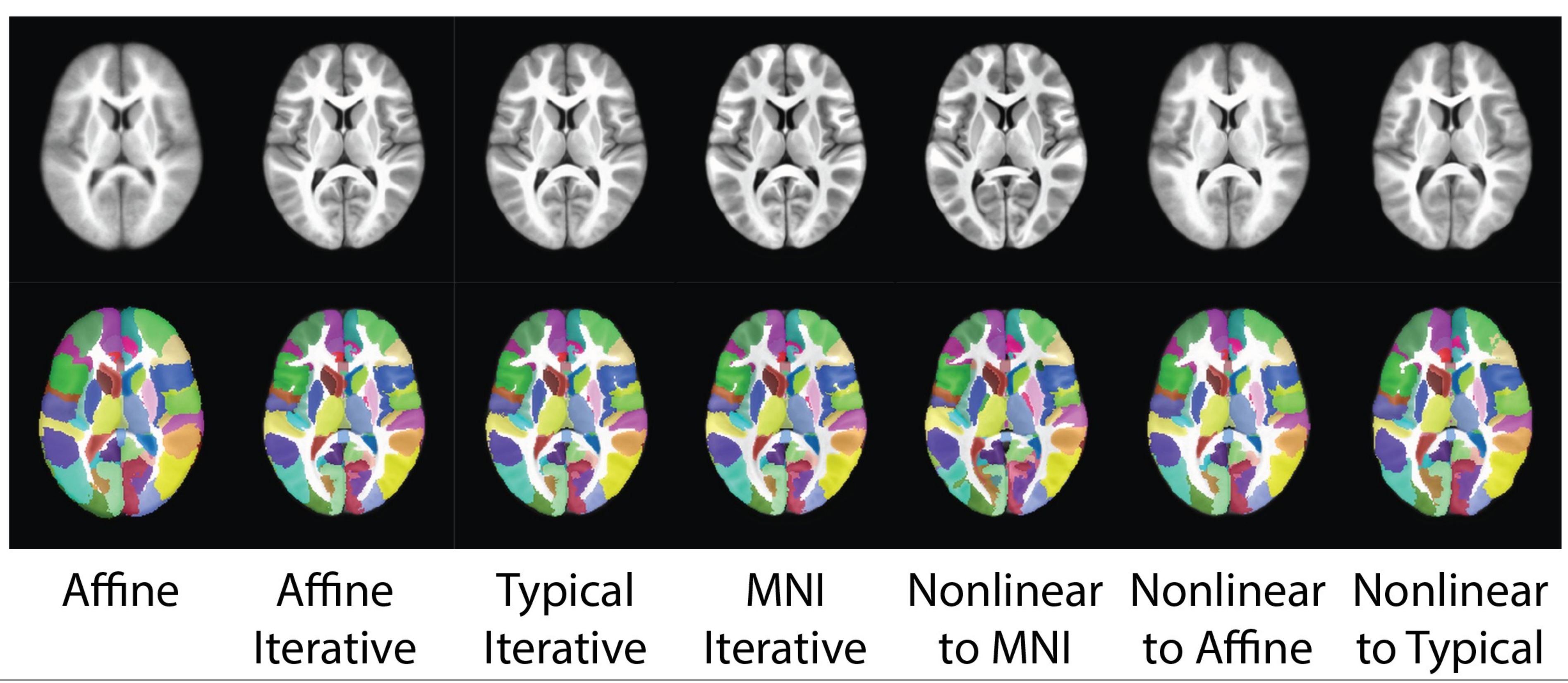


Figure 4: Iterative nonlinear alignment to affine template with progressively smaller patch sizes (left to right): Original, 101, 49, 23, 13. The application of this technique is shown below.

Figure 5: The "Typical" brain was identified by calculating mean deformation distances pairwise and identifying the brain with the least deformation distance to every other brain.





ATLAS EVALUATION

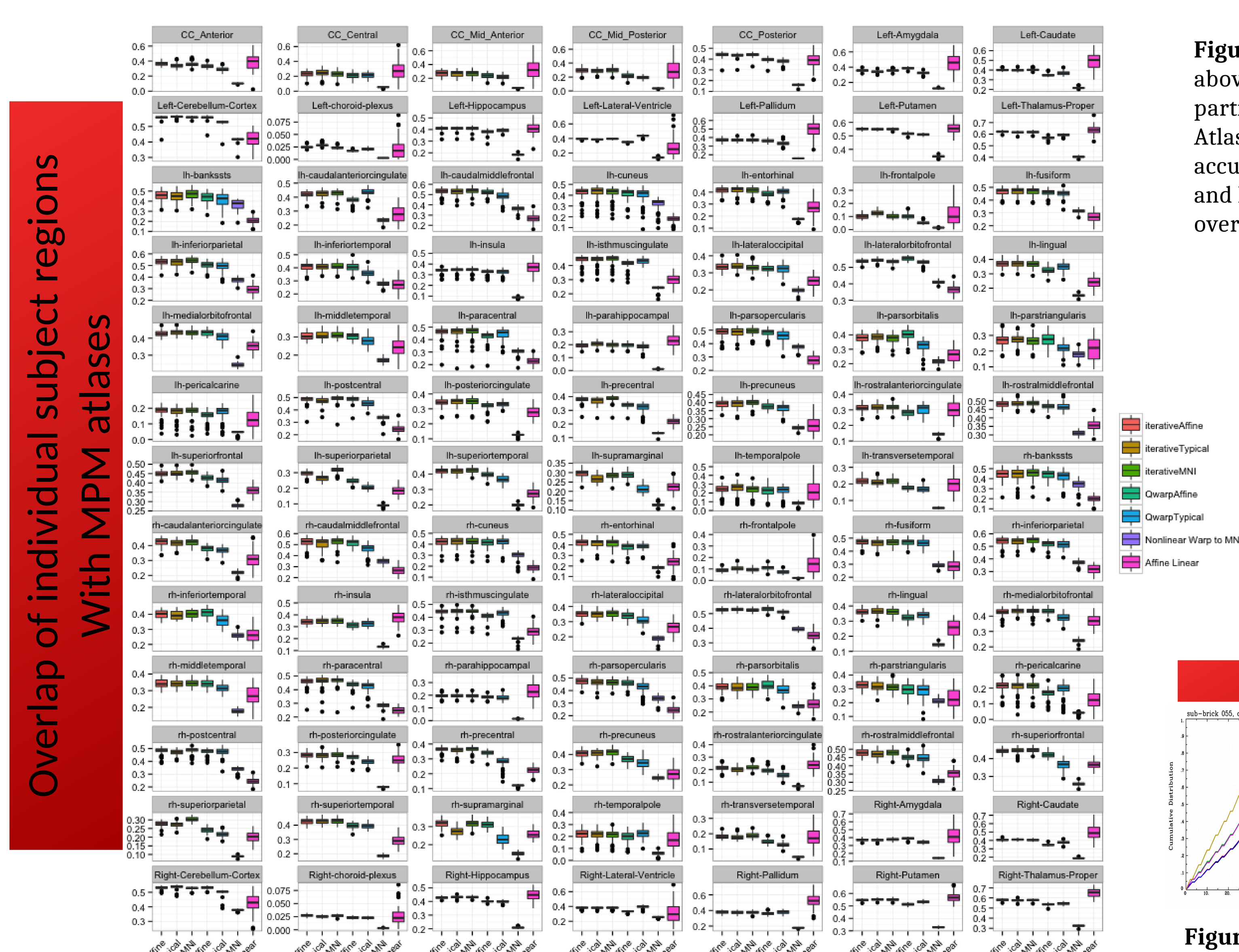


Figure 6 (Left): Overlap metric. Using each atlas above, we measured the overlap of individual participant data to the Maximum Probability Map Atlas. Iterative Atlases tend to show greater accuracy in region overlap, while traditional Affine and Nonlinear fit show more variability or less overlap, respectively.

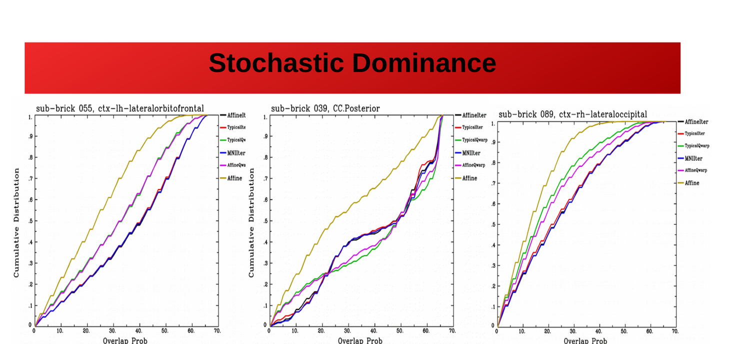


Figure 7 (Above): Stochastic Dominance ranking metric. Cumulative distributions of region overlap probabilities – rank methods by stochastic dominance (lower curves win)

Weighted p-value metric. overlap for each region and over all regions

$$p_{wt} = \sqrt{\left(\sum_{i=1}^{nvoxels} (p_i^2) / nvoxels\right)}$$

****** Overall Rankings ******

	Affine	AffineIter	TypicalIter	MNIIter	Nonlinear to Affine	Nonlinear to Typical
Stochastic Dominance Rank	6	**1**	3	2	5	4
Weighted p-value (rank)	0.4376 (6)	**0.5735 (1)**	0.5662 (3)	0.5733 (2)	0.5473 (4)	0.5097 (5)
Overlap average (rank)	0.300 (6)	0.385 (2)	0.383 (3)	**0.387 (1)**	0.366 (4)	0.353 (5)

Table 1. Comparison of template/atlas method using three different metrics

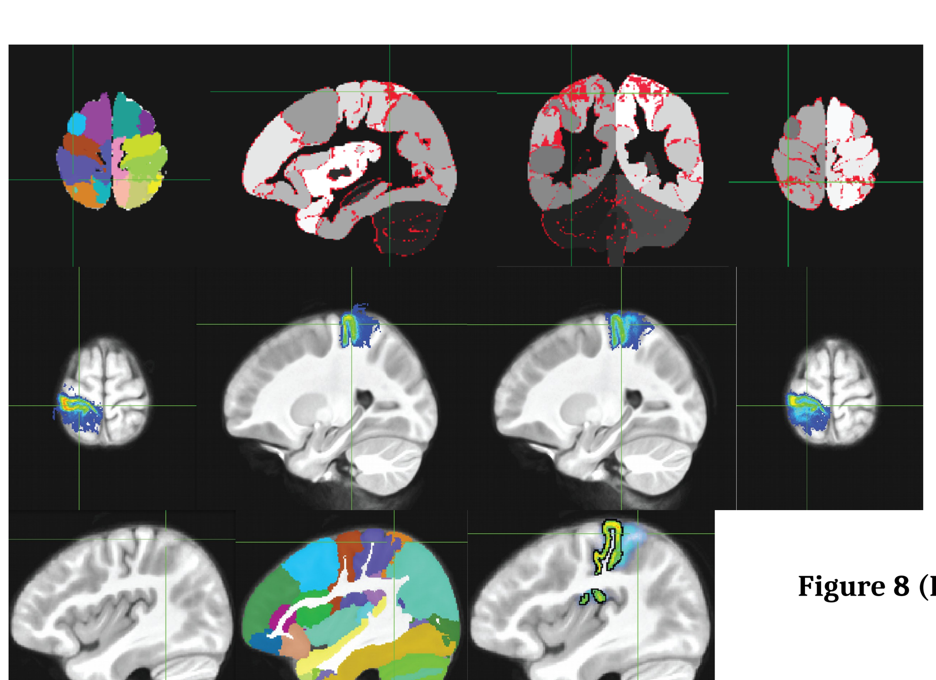


Figure 8 (Left): Region variability and methods lead to atlas differences

CONCLUSIONS

We have introduced a new pediatric template together with atlas segmentation. Our evaluation over several template-making schemes shows that iterative methods produce more consistent results across the population in this study. In particular, the affine iterative method ranks as the best template using a variety of metrics. Individual references like a particular subject or even a group average are less consistent.

Affine methods result in blurrier templates and in less defined regions. Nonlinear warp methods give results that are somewhat blurrier versions of the input templates. Nonlinear warps to an ideal or most typical subject are less useful than an iteratively generated template. Iterative methods enhance the templates further to give better defined regions with more overlap of regions across subjects.

These templates can be suitable references for group studies. Still it is important to note that no atlas will provide an exact segmentation for any particular subject over all regions because of variability across subjects. Atlases can provide a list of possible regions within neighborhoods around any particular coordinate. These templates and atlases are available at the AFNI website.

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