

FreeSurfer: Future Directions

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Talk Outline

1. Combined Volume and Surface registration (CVS)
2. Segmentation of hippocampal subfields
3. Automated Tractography (TRACULA).
4. Inferring cytoarchitectural boundaries *in vivo*.

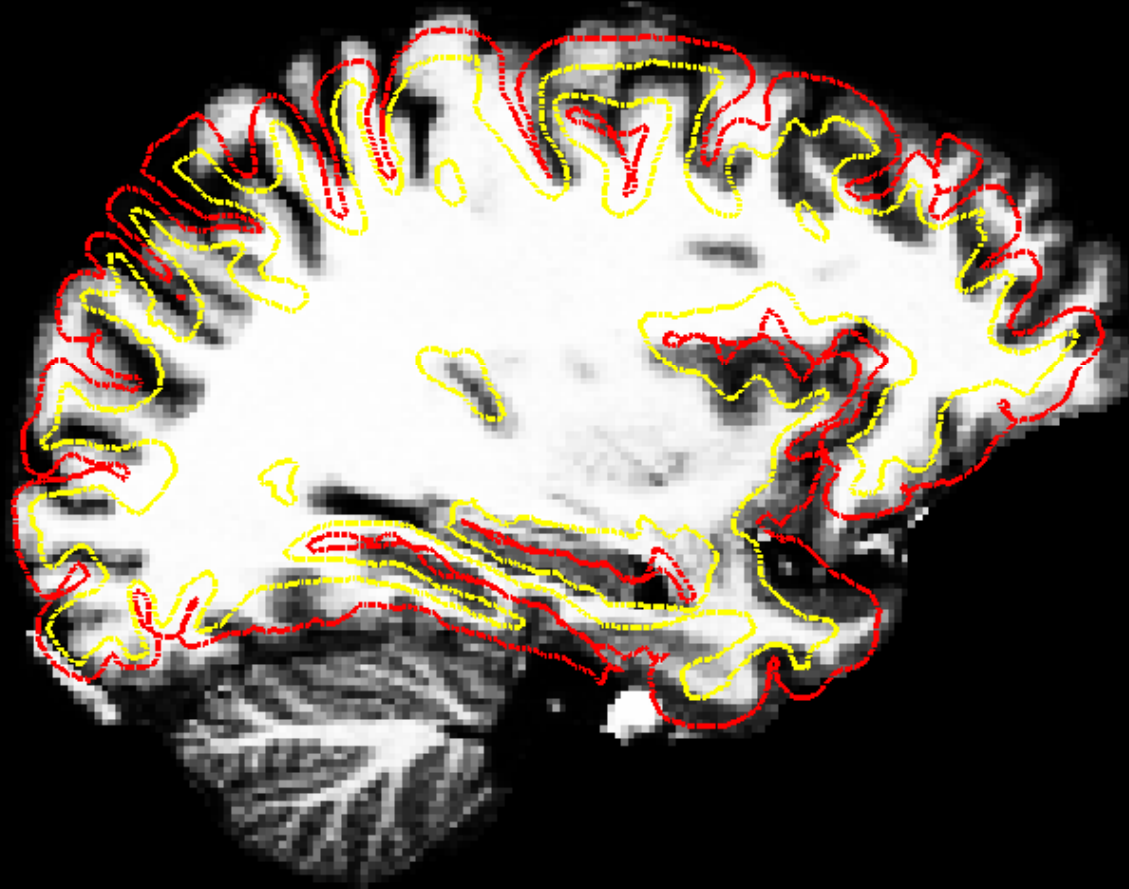
Combined Volume/Surface Registration (CVS)

Surface-based (2D) registration does an excellent job of aligning cortical folds, but doesn't apply to non-cortical structures (e.g. basal ganglia).

Volumetric (3D) registration applies to the entire brain but doesn't in general align folding patterns.

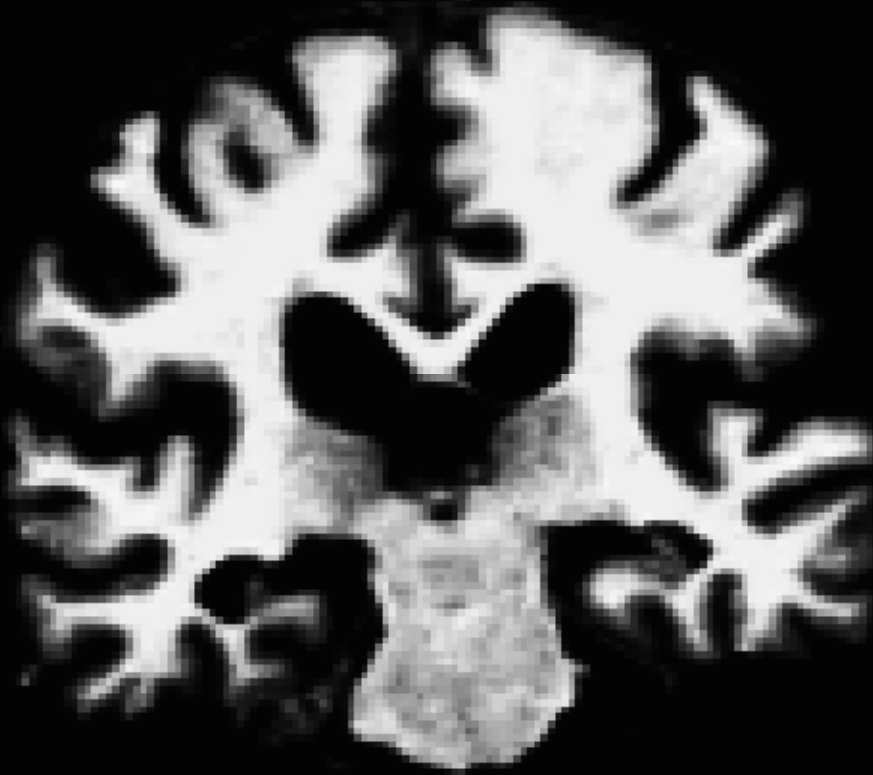
Solution: integrate them.

Why Aligning Folds in the Volume is Hard!

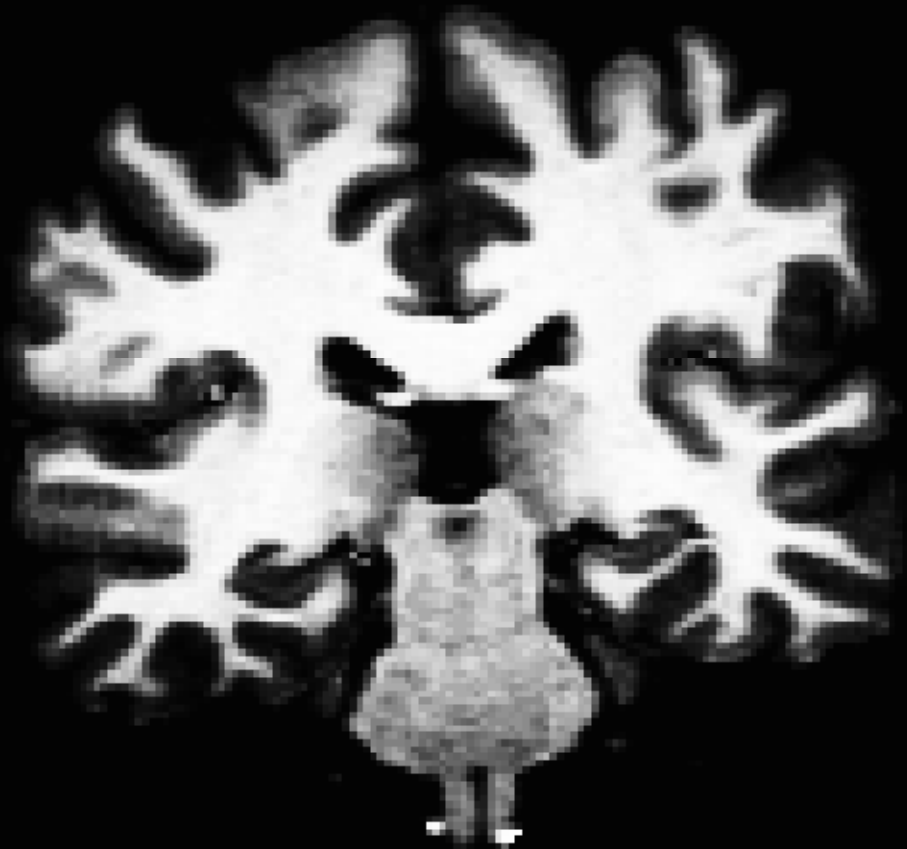


Affine transform of surfaces from one subject mapped to another.

CVS Registration: Example.



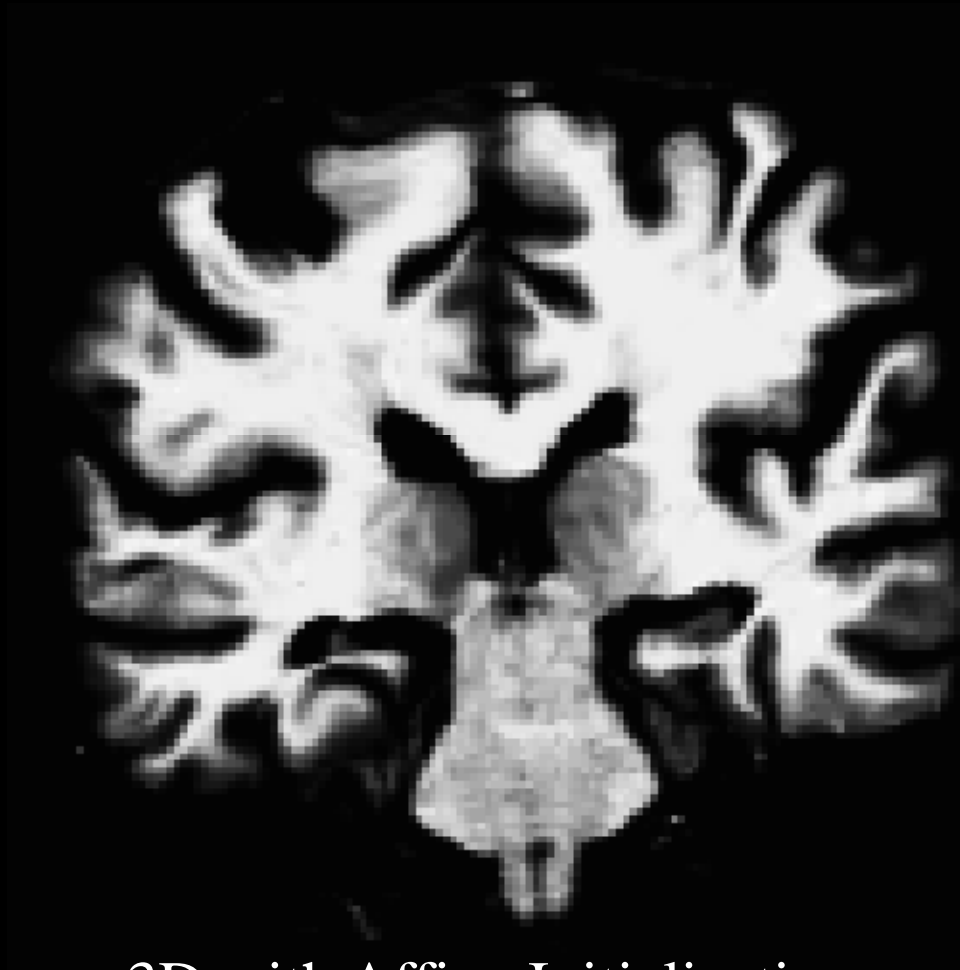
Source



Target

Joint work with Gheorghe Postelnicu and Lilla Zollei

CVS Registration: Preliminary Results.



3D with Affine Initialization

Joint work with Gheorghe Postelnicu and Lilla Zollei

CVS Registration: Preliminary Results.



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CVS Registration: Preliminary Results.



CVS

Joint work with Gheorghe Postelnicu and Lilla Zollei

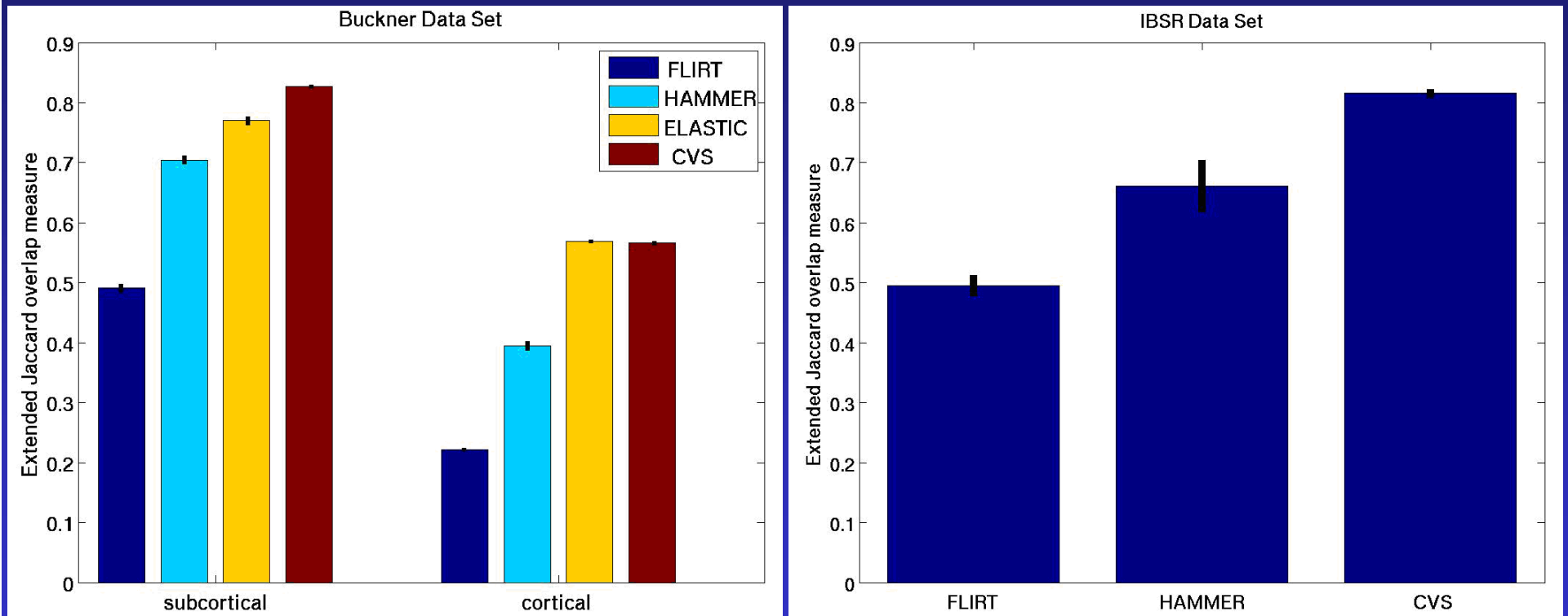
CVS Registration: Preliminary Results.



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CVS Registration: Accuracy



Jaccard Coefficients (overlap) for 40 (left) and 11 (IBSR, right) manually labeled datasets.

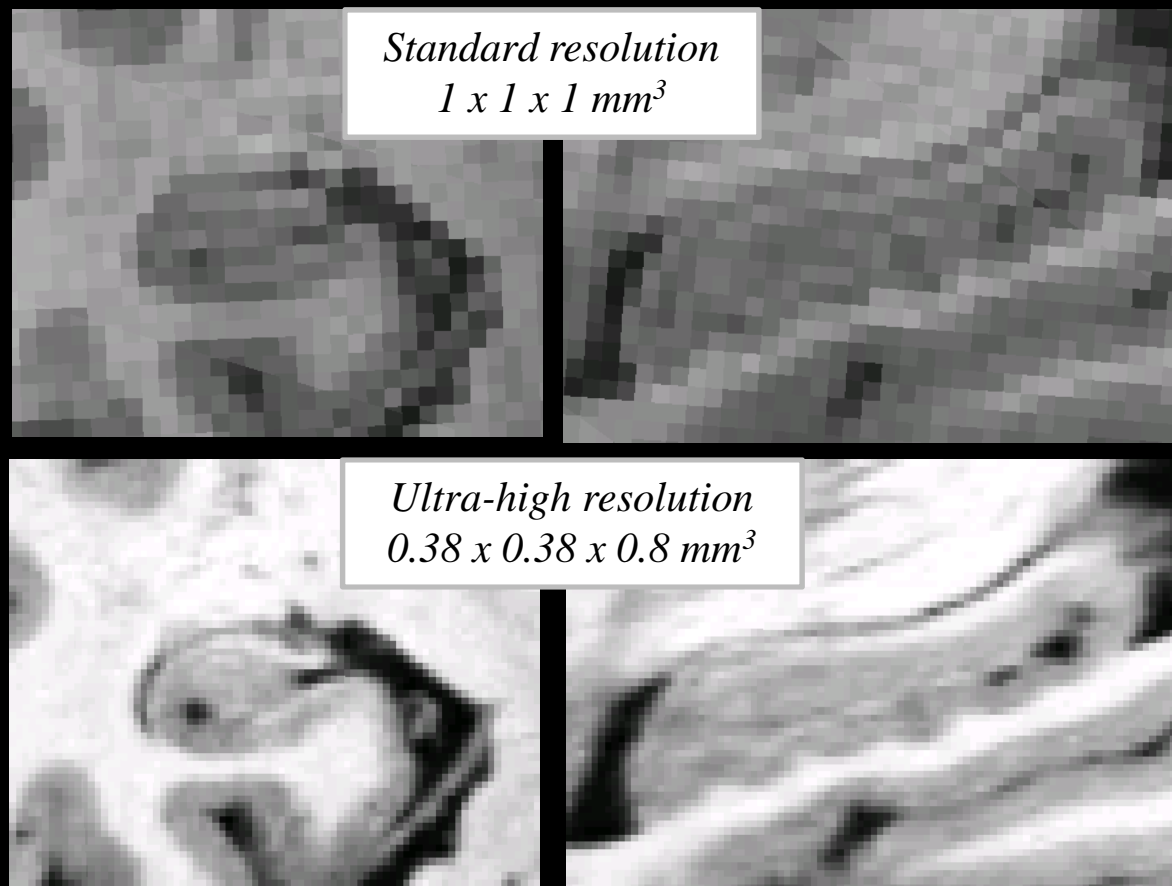
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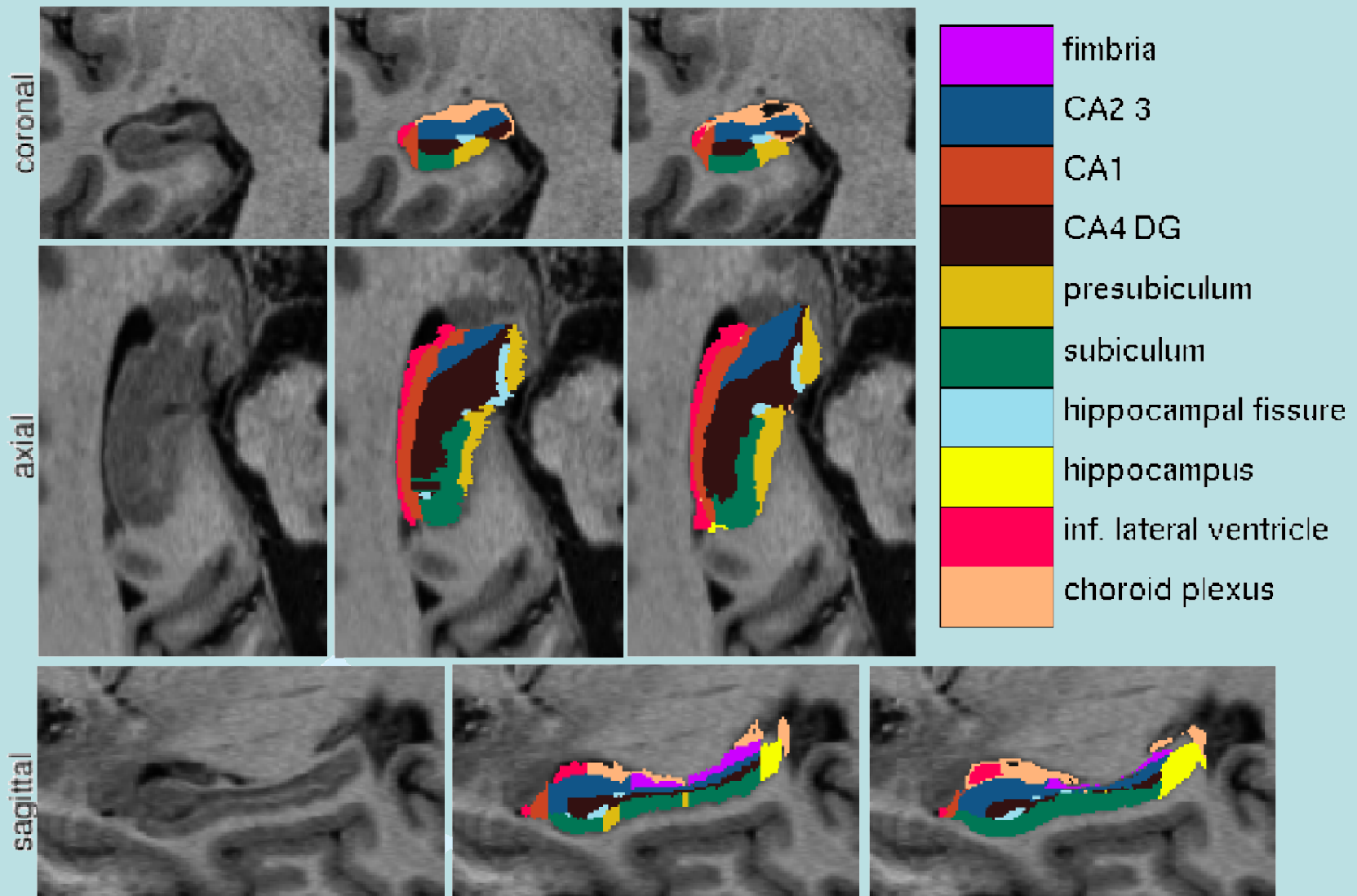
Hippocampal Subfield Segmentation

Recent developments in MR data acquisition technology are starting to yield images that show anatomical features of the hippocampal formation at an unprecedented level of detail (c.f. Zeineh et al, 2001)



Collaboration with Koen van Leemput, Polina Golland, Brad Dickerson and Akram Bakkour

Qualitative results



MRI data

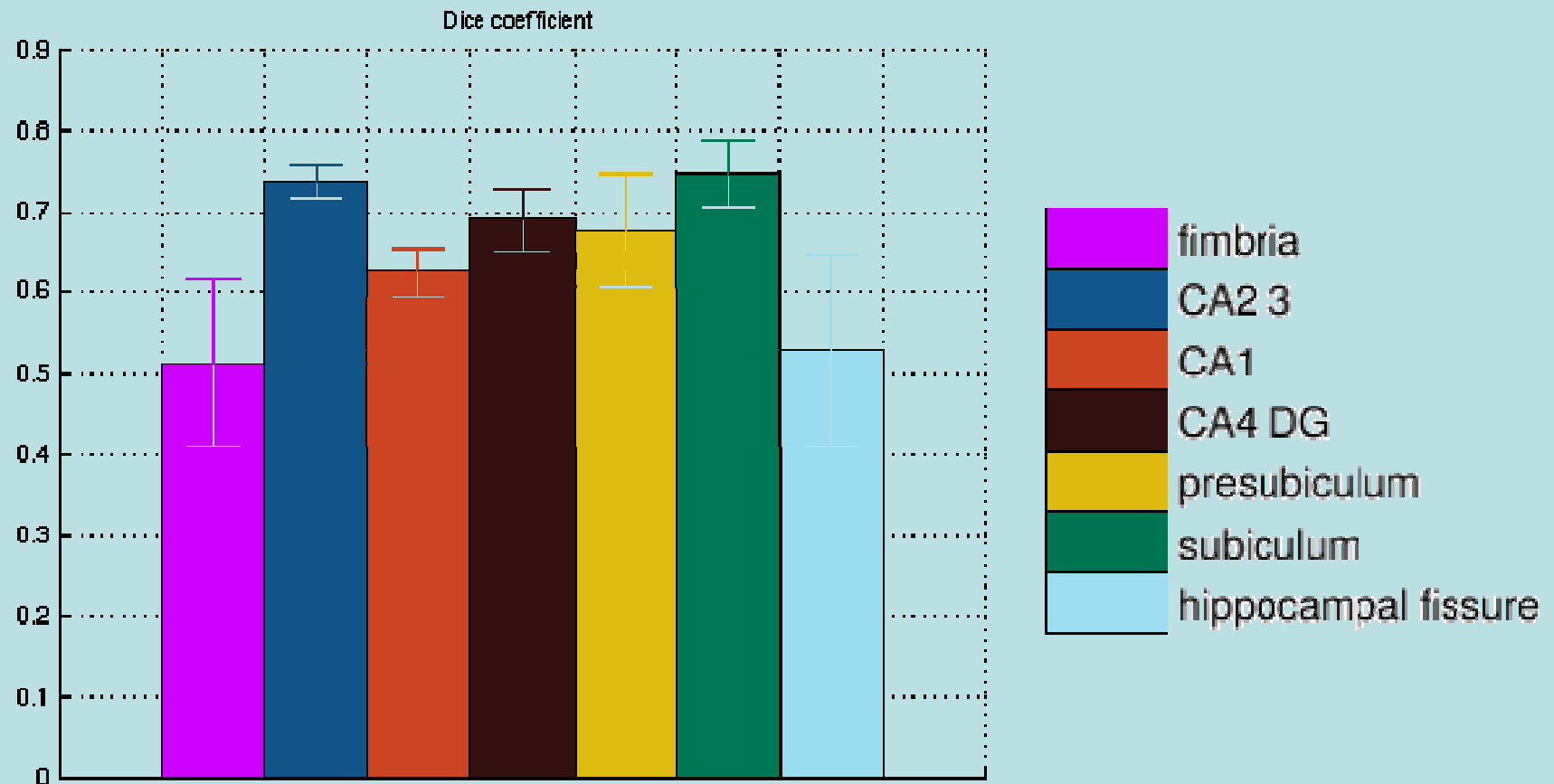
manual segmentation

automated segmentation

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Quantitative results: spatial overlap

- ✓ Dice coefficient for automated vs. manual segmentation (5 datasets)
 - $(\text{volume of overlap}) / (\text{average volume})$

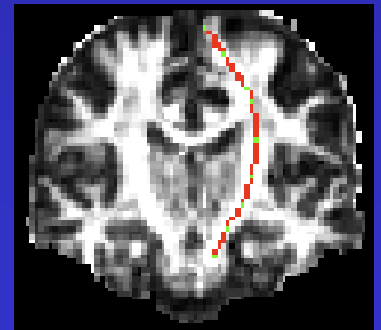
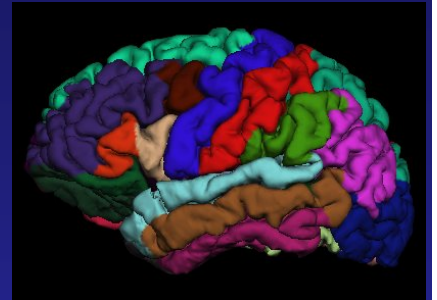


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TRACULA

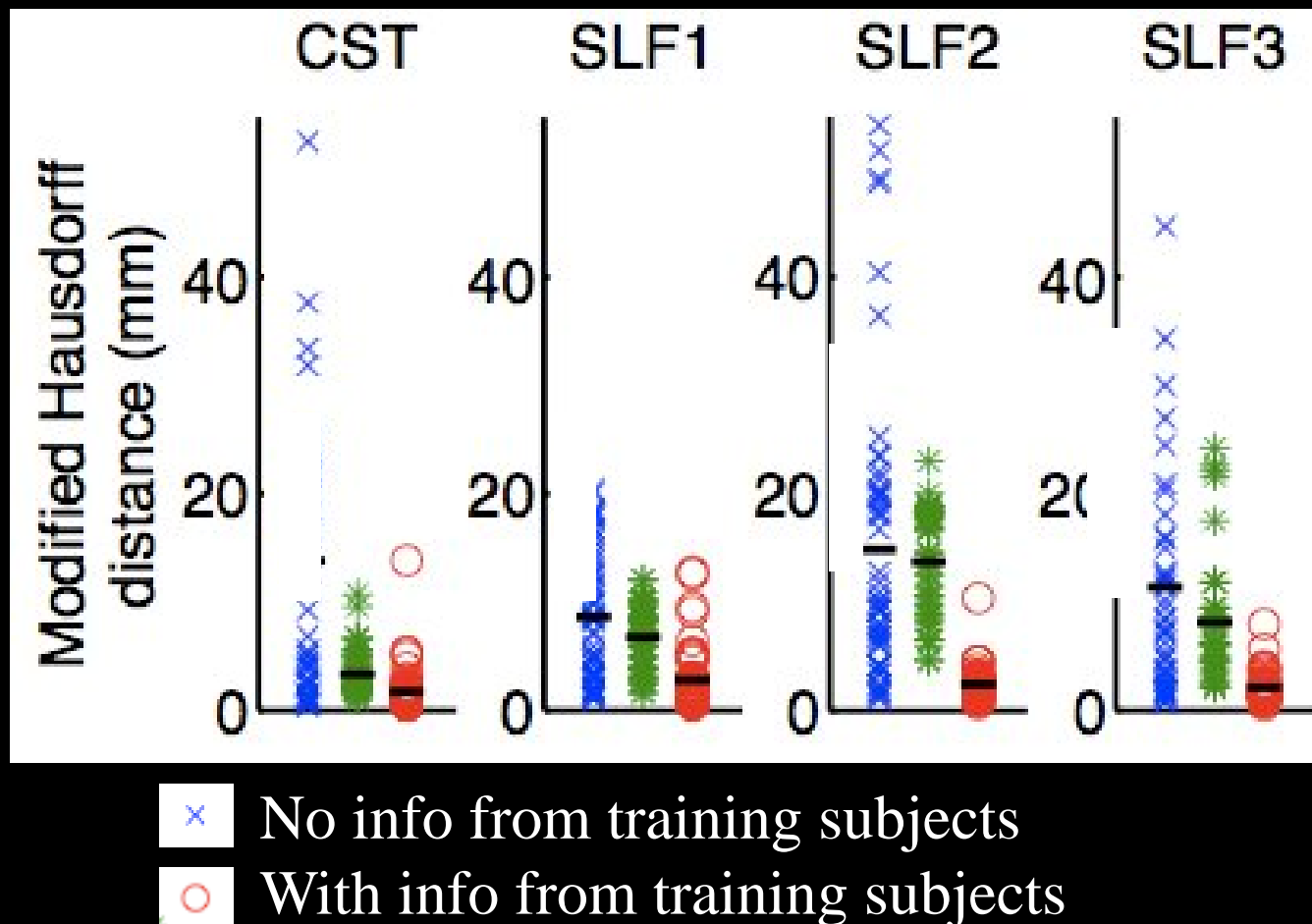
- TRActs Constrained by UnderLying Anatomy
- Global probabilistic tractography
 - Constrain start/end ROIs
- Prior info on tract anatomy from training subjects
 - No manual intervention in new subjects
 - Robustness w.r.t. ROI selection
 - Anatomically plausible solutions



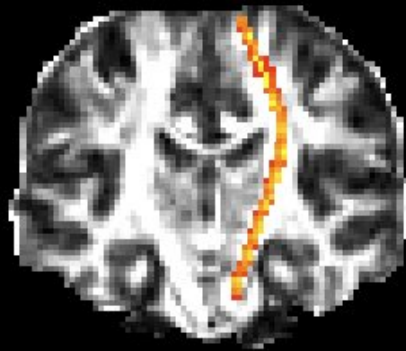
Collaboration with A. Yendiki, J. Augustinack, D. Salat, A. Stevens, R. Wang, L. Zöllei
S. Jbabdi, T. Behrens

Test-retest reliability

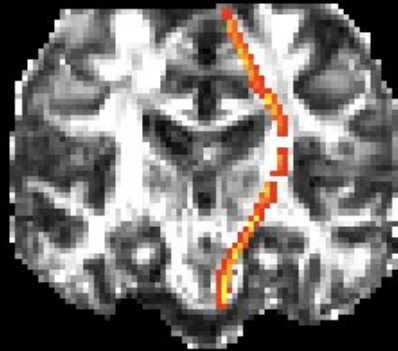
- Compare tract solutions from 2 scans of each of 10 subjects (from Randy Gollub and MIND)



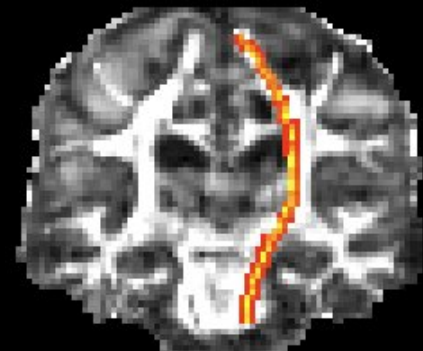
Application: Huntington's disease



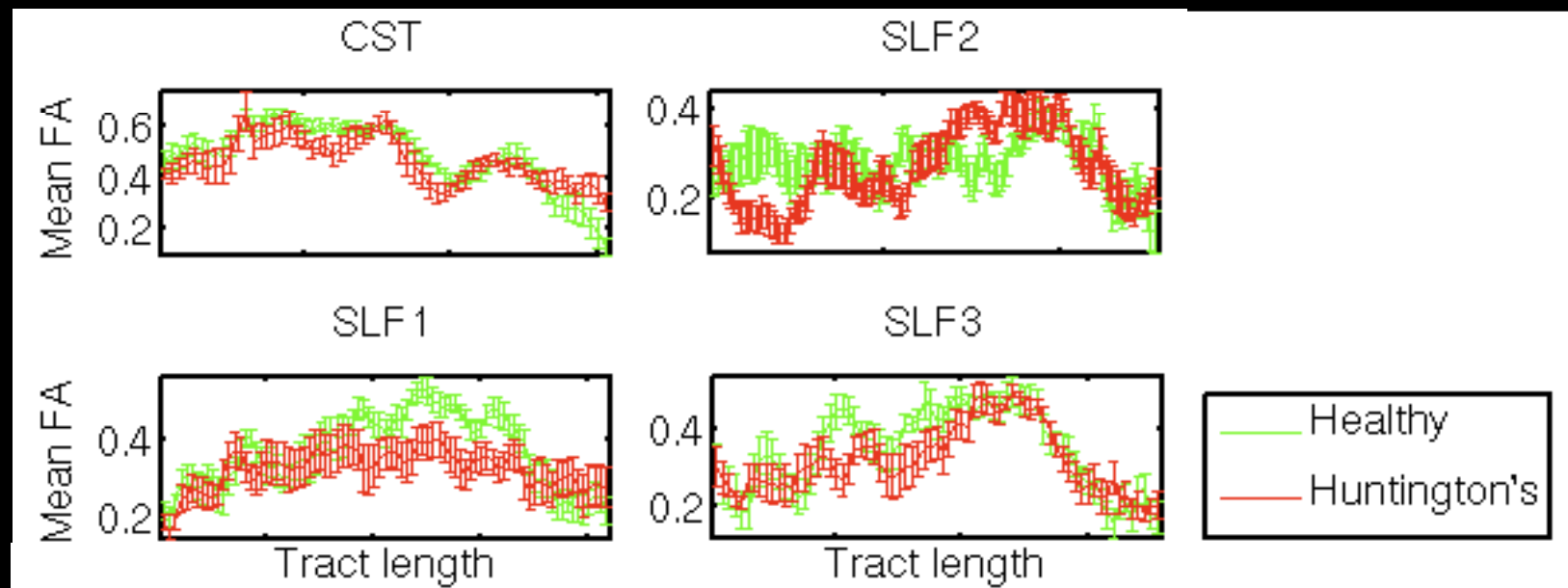
Healthy



Huntington's (premanifest)



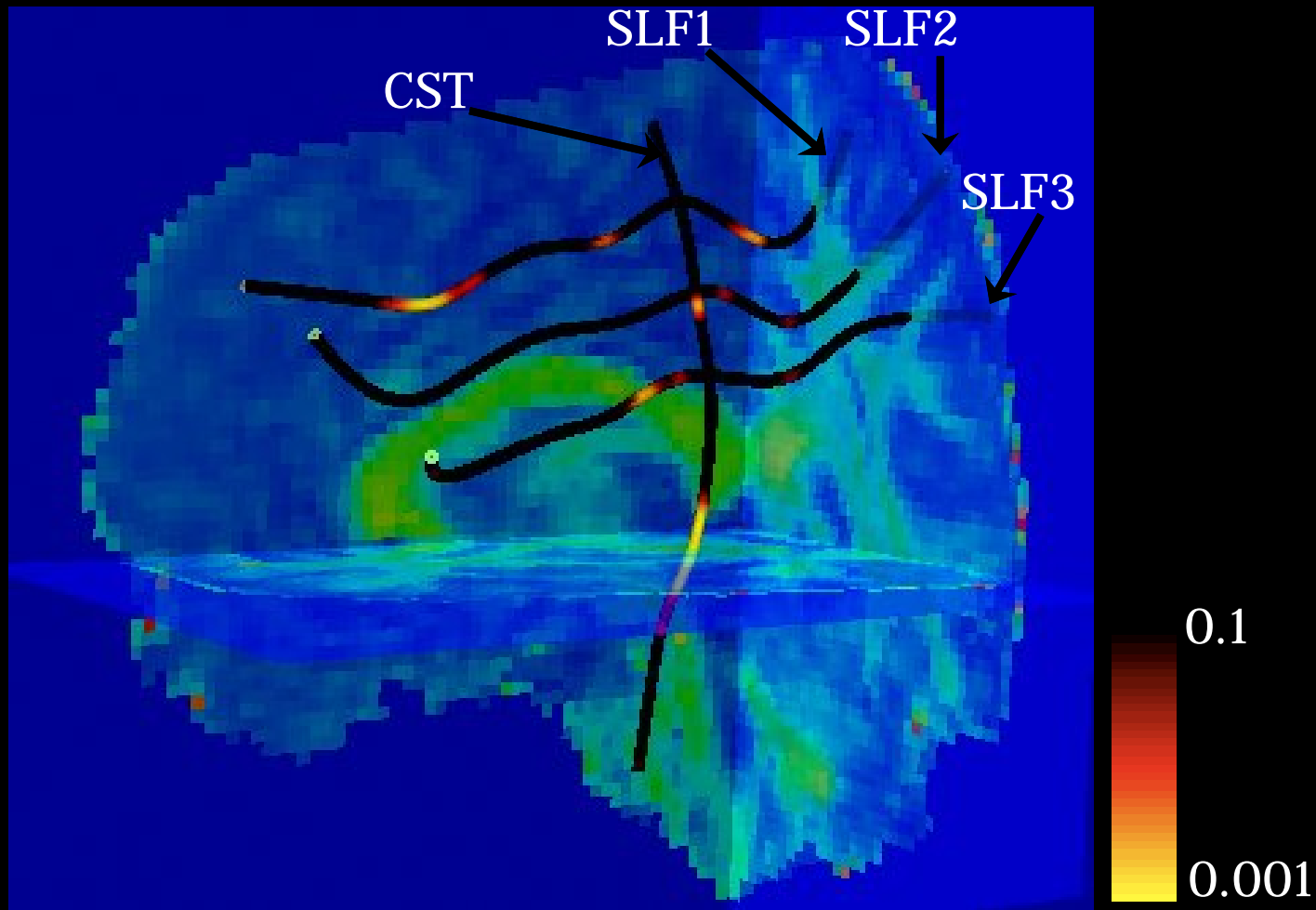
Huntington's (advanced)



33 HD patients (ages 42 ± 8) in disease stages 1-4, 22 healthy controls (ages 45 ± 8)

Data courtesy of Dr. H.D. Rosas, MGH

Application: Huntington's disease



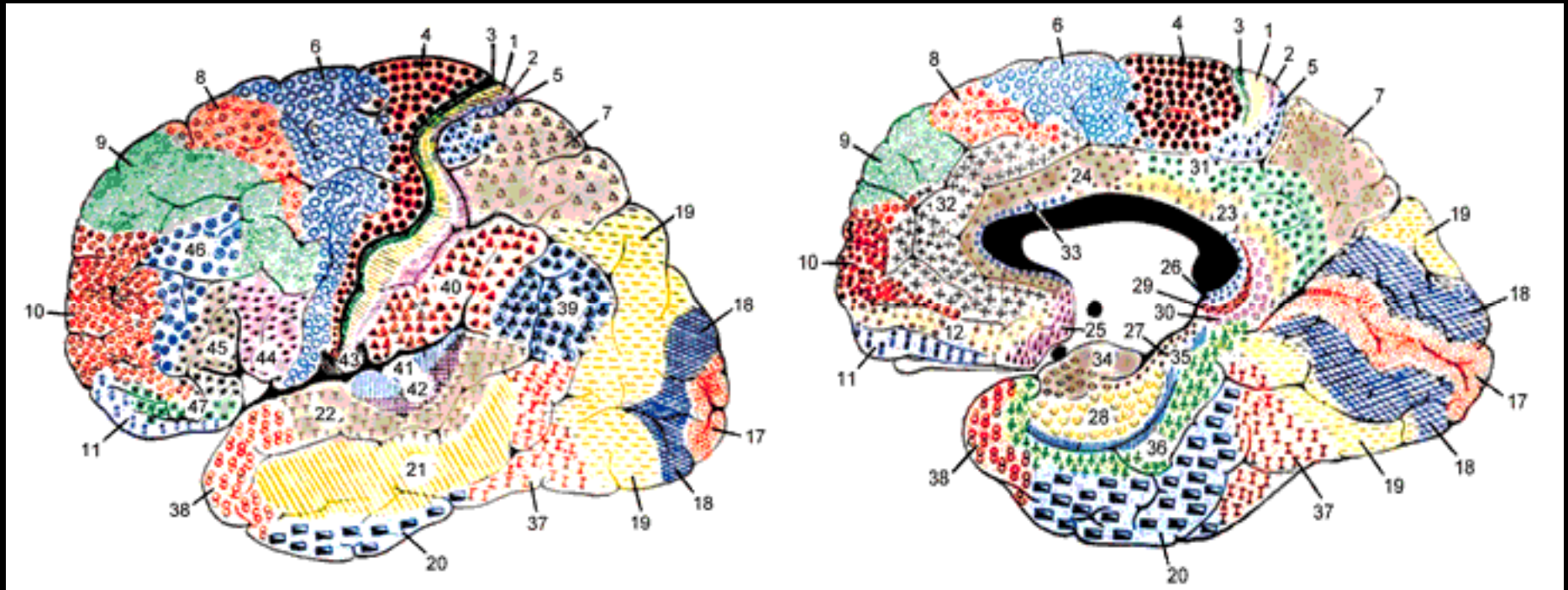
p-values for t-test on mean FA of Huntington's patients (N=33) and controls (N=22)

Data courtesy of Dr. H. D. Rosas, MGH

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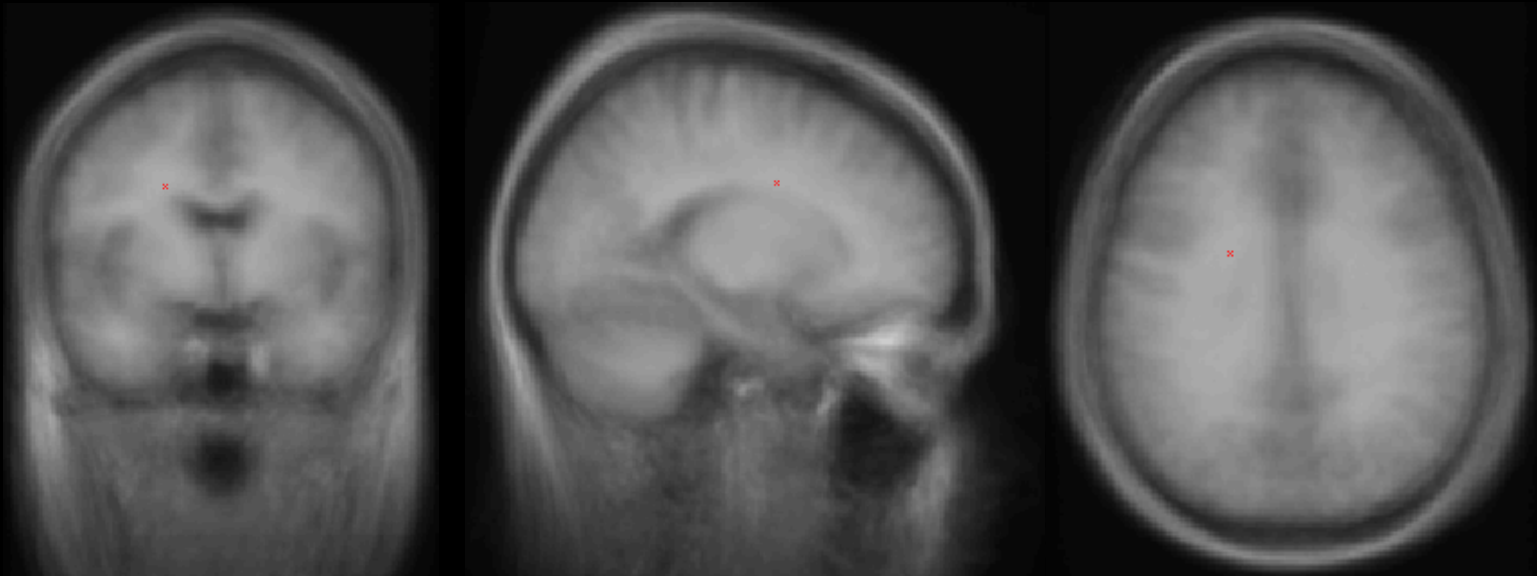
Can we do better than this?



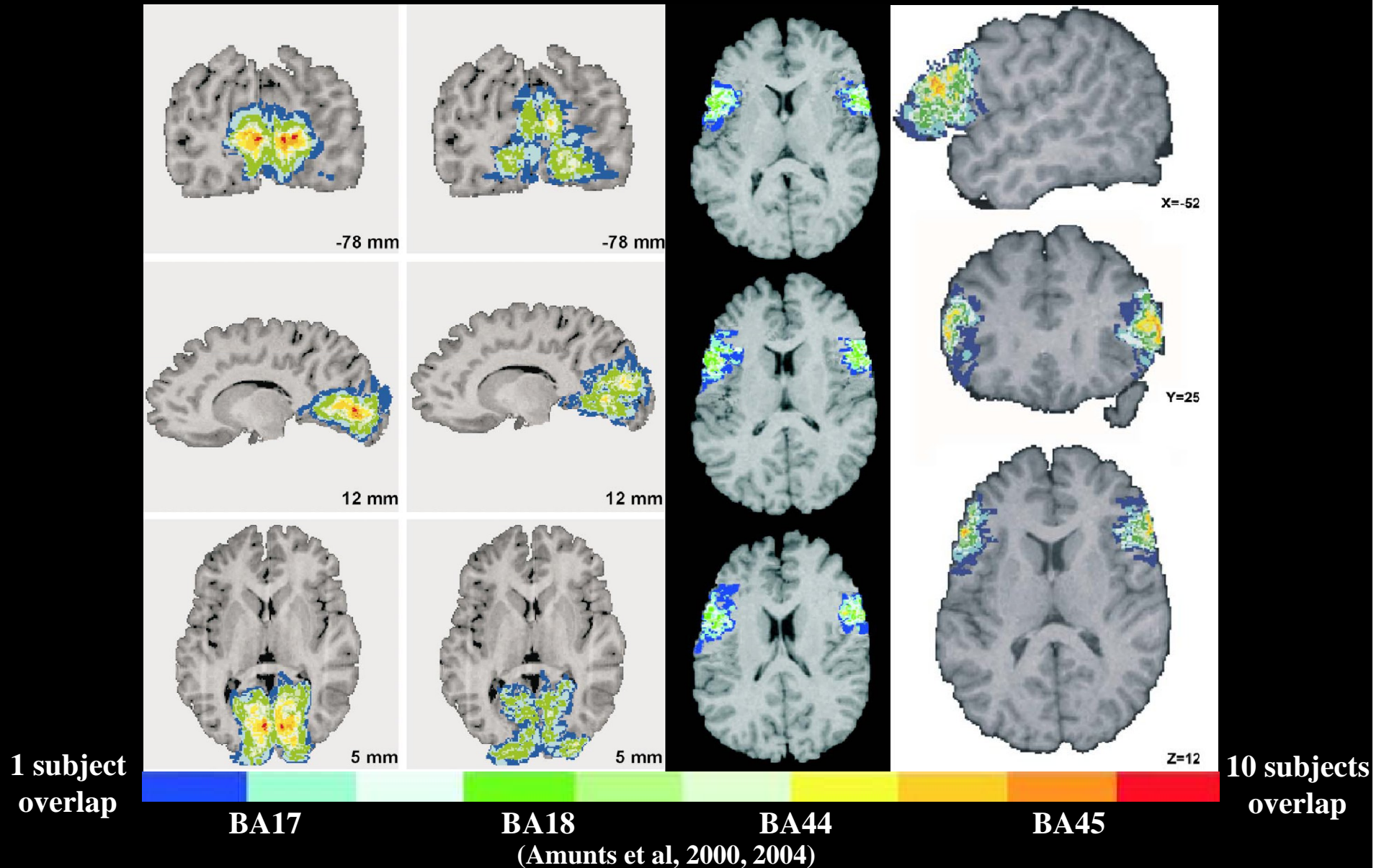
Brodman, 1909

Standard Methods for Inferring Cortical Area Identity.

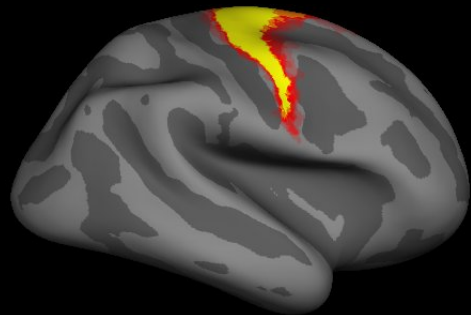
1. Talairach coordinate system (usually a 12 parameter affine registration).
2. Guessing.



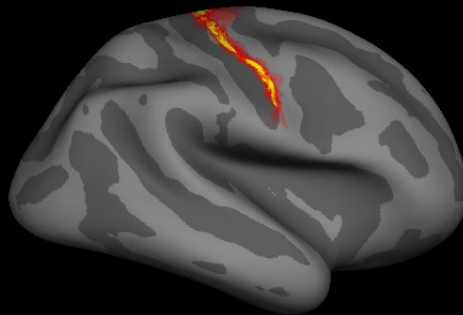
Predicting Brodmann Areas: Talairach Coordinates



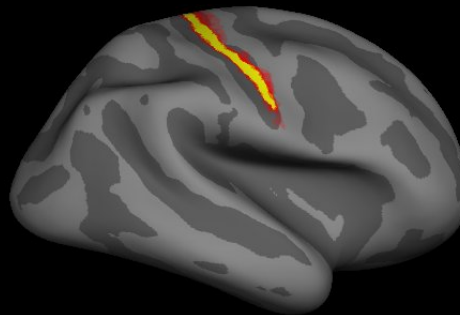
Predicting Brodmann Areas from Cortical Geometry



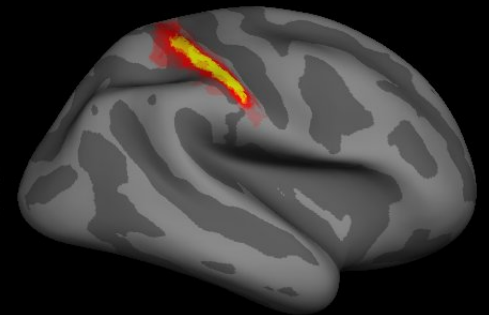
Area 6



Area 4a

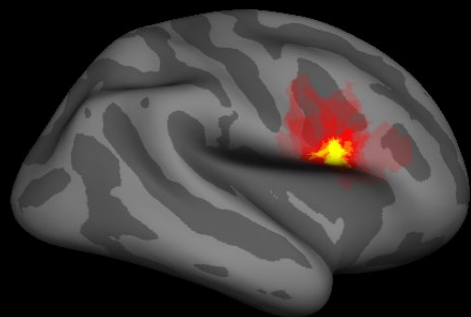


Area 4p

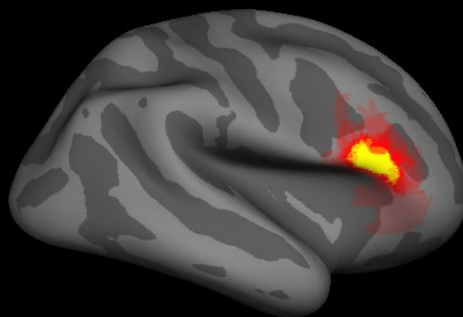


Area 2

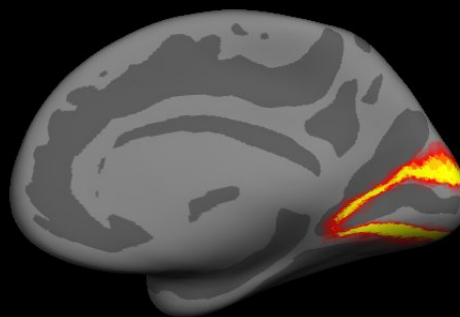
0%  100%



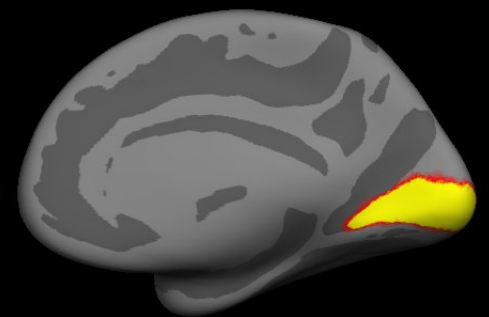
Area 44



Area 45



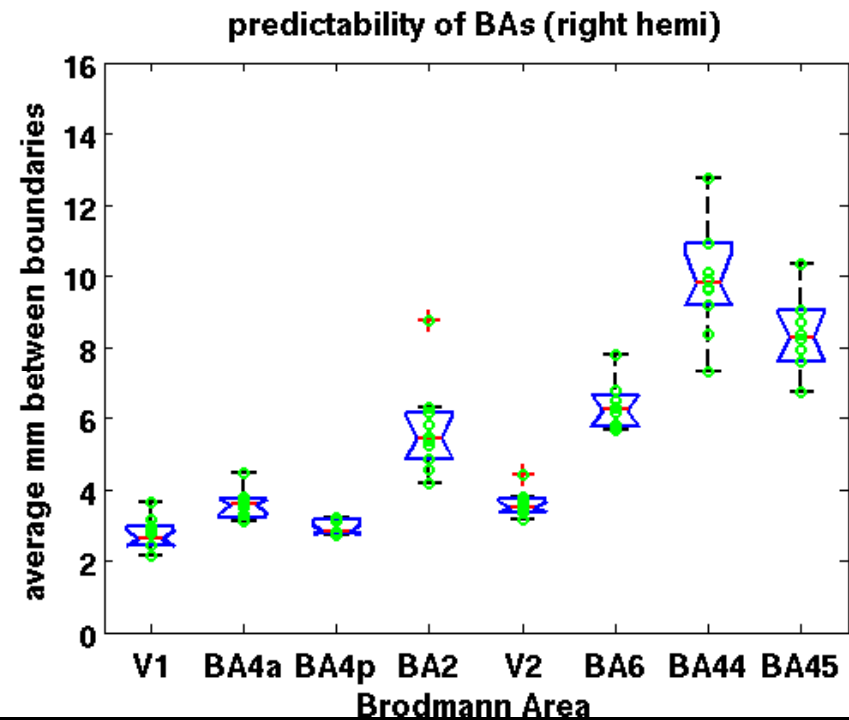
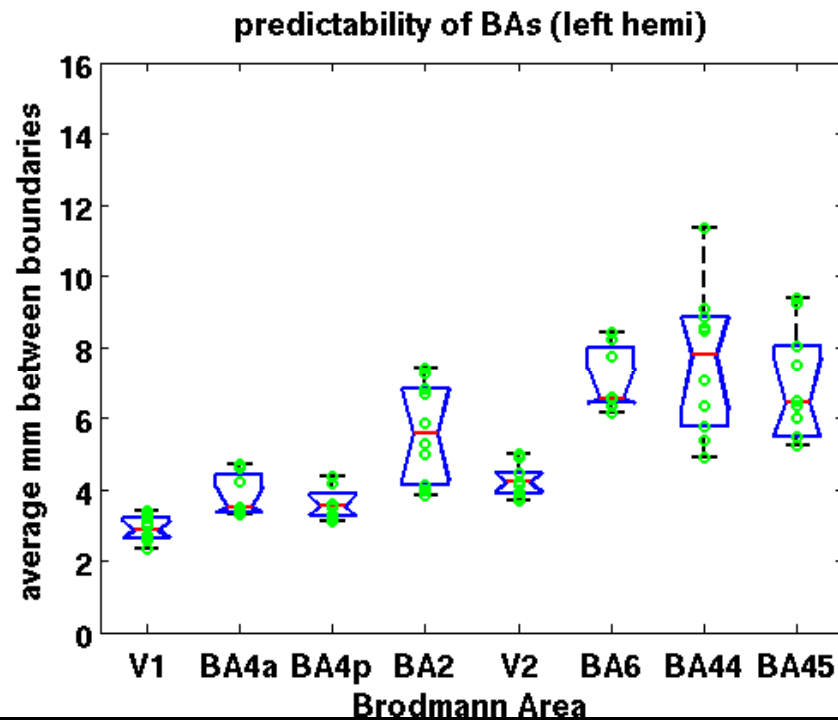
Area 18



Area 17

Thanks to Katrin Amunts, Karl Zilles and Hartmut Mohlberg for the data, and to Niranjini Rajendran and Evelina Busa for the analysis

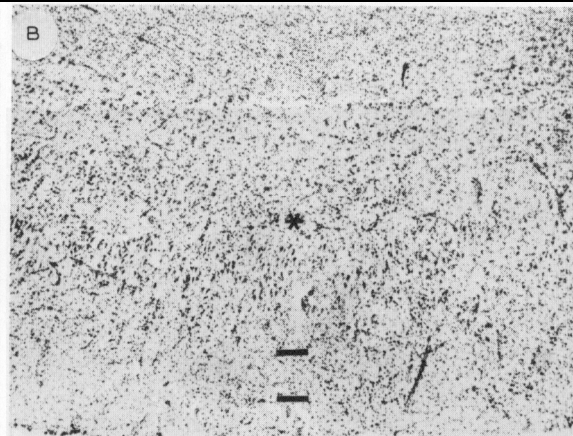
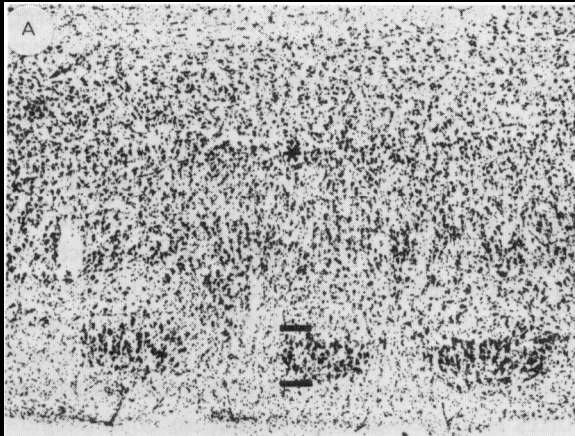
Brodmann Area Predictability



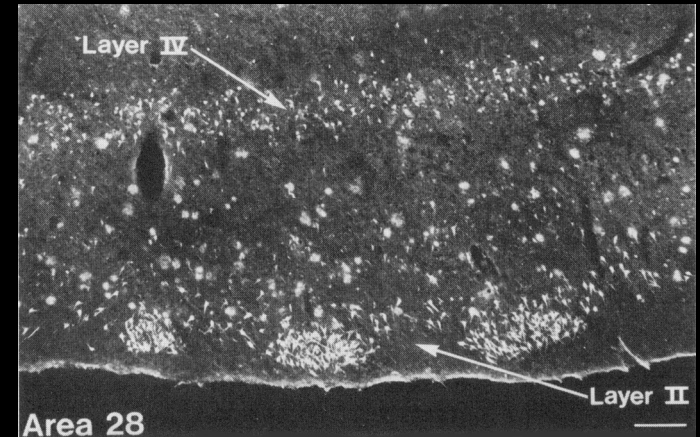
Histology in Alzheimer's Disease (entorhinal cortex=BA28)

CONTROL

AD



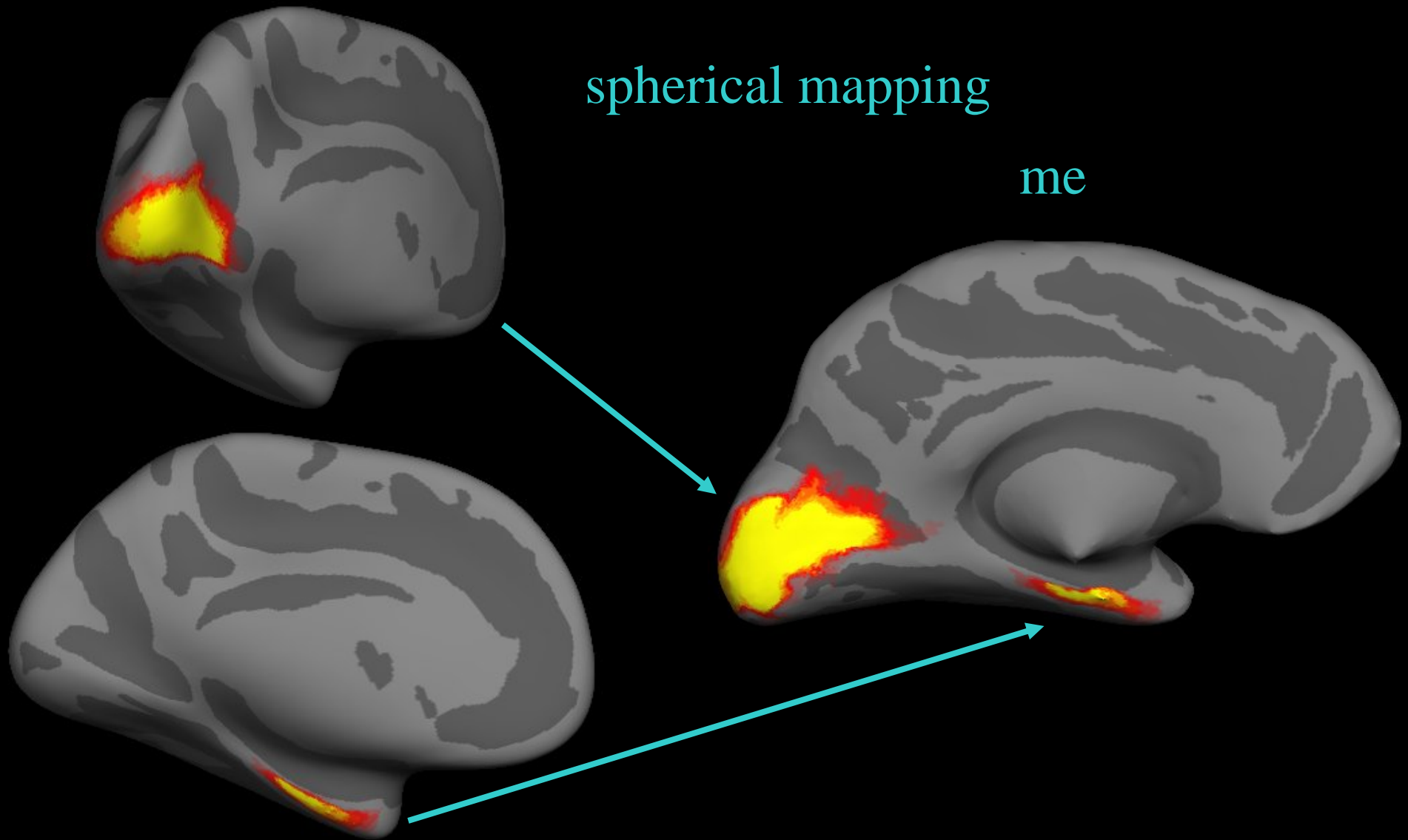
Nissl Stain



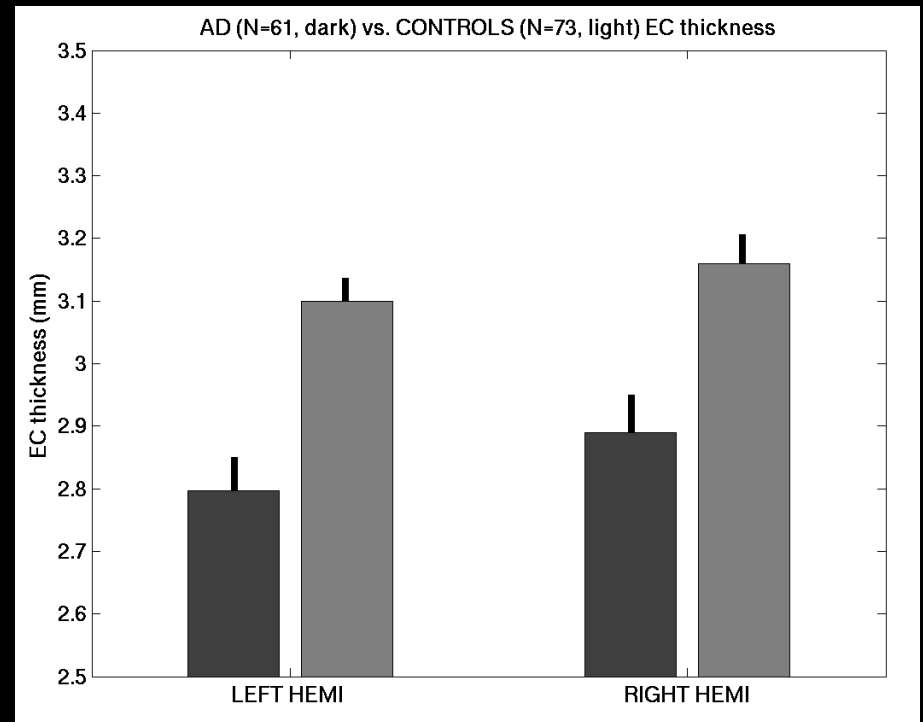
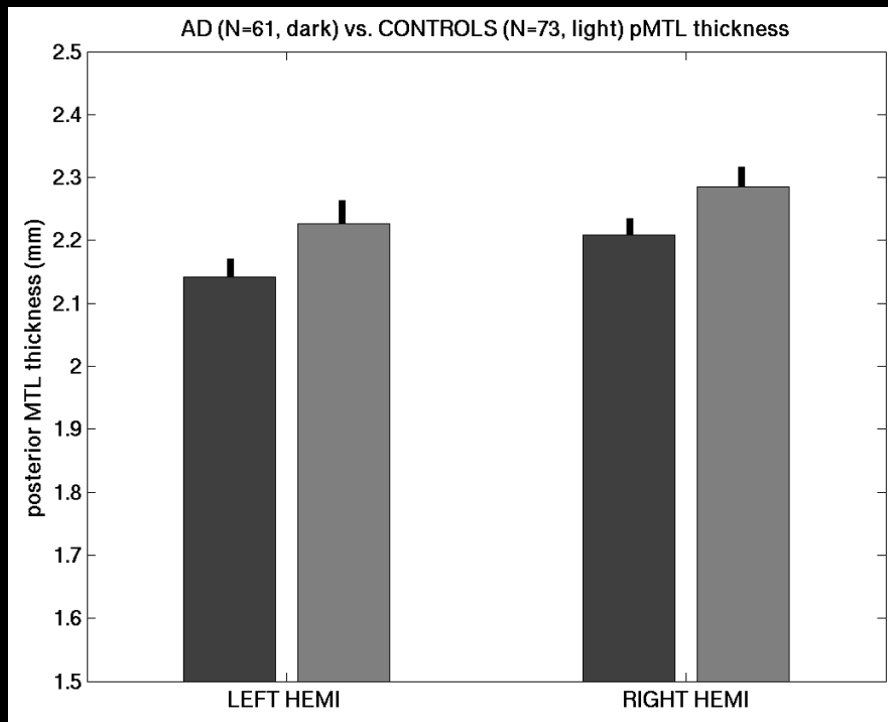
thioflavin S
(neurofibrillary tangles
and neuritic plaques)

Thanks to Brad Hyman and Jean Augustinack for this slide.

Making *in vivo* Predictions



Assessing Degeneration in AD



Thickness difference in predicted entorhinal cortex (right) and posterior MTL (left) between 61 patients (CDR 0.5) and 73 controls ($p < 10^{-5}$).
(Data courtesy of Dr. Randy Buckner)

What weighting is optimal?

Can we find a set of weights $\{w_v\}$ and means $\{\bar{C}_v\}$ that optimize the alignment of the underlying architectonics, *and*, do these weights generalize to novel subjects?

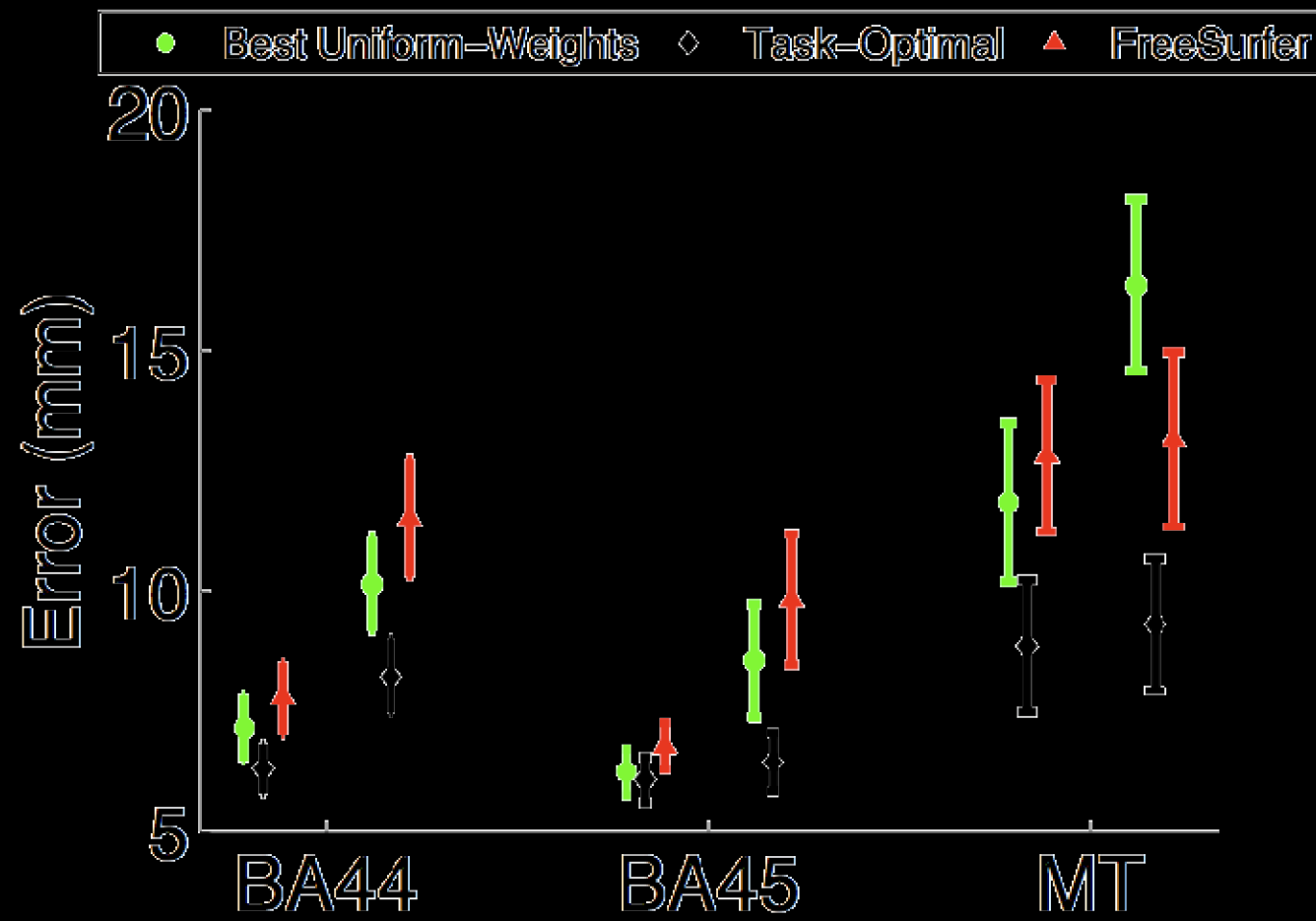
$$\text{training} : [\hat{w}, \hat{T}] = g(\arg \min_T f(w, T))$$

$$f(w, T) = \frac{1}{2V} \sum_{v=1}^V w_v (C_v - \bar{C}_v(T(v)))^2$$

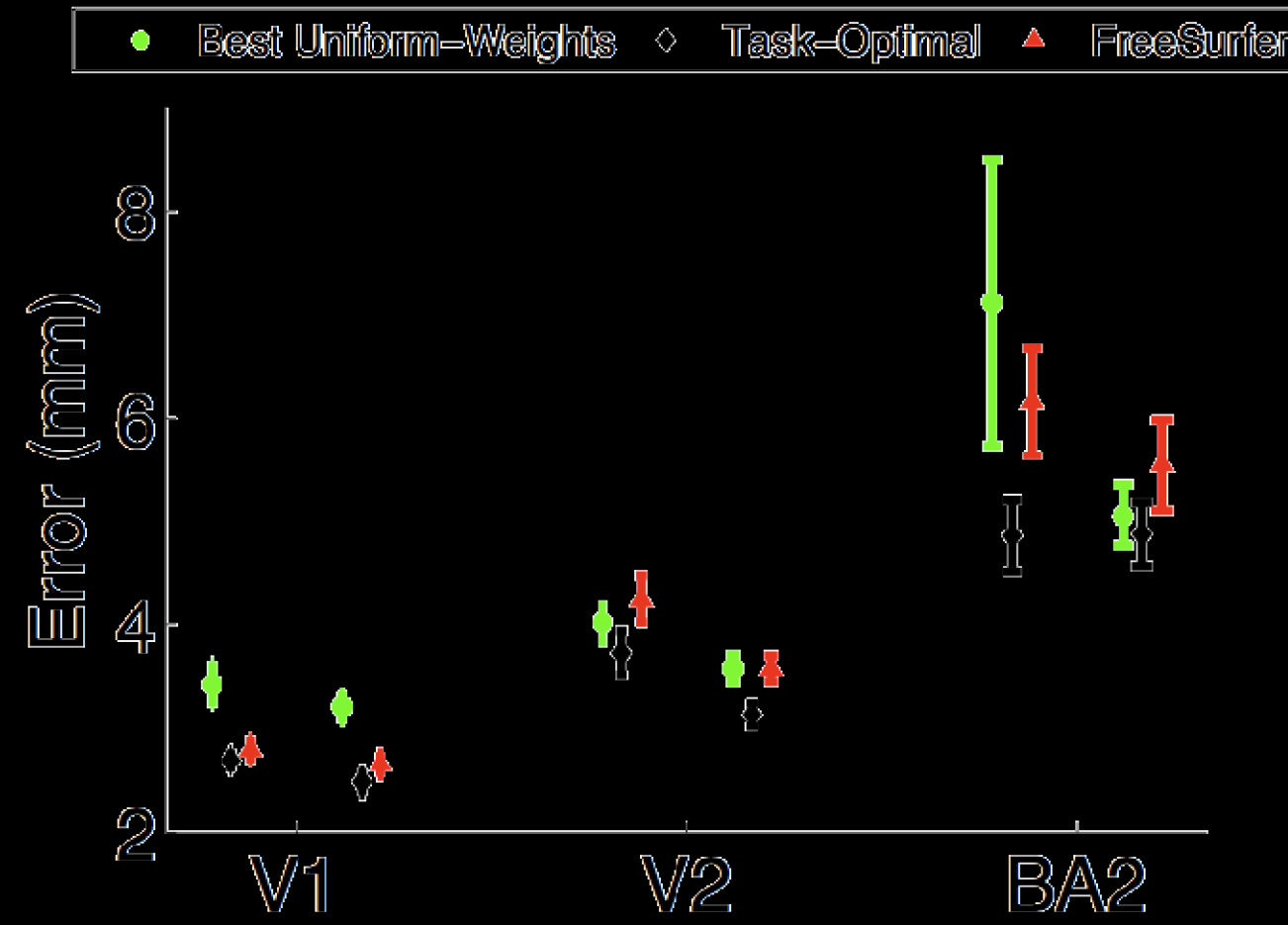
$$\text{testing} : \hat{T} = \arg \min_T f(\hat{w}, T), \text{ with optimal } \hat{w}$$

Where $g(T)$ measures how well the set of transformations T align the N training subjects (for which we have labeled Brodmann areas)

“Difficult” BAs: T



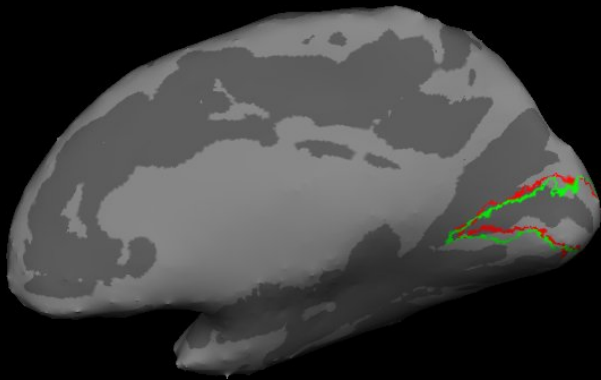
“Easy” BAs: T



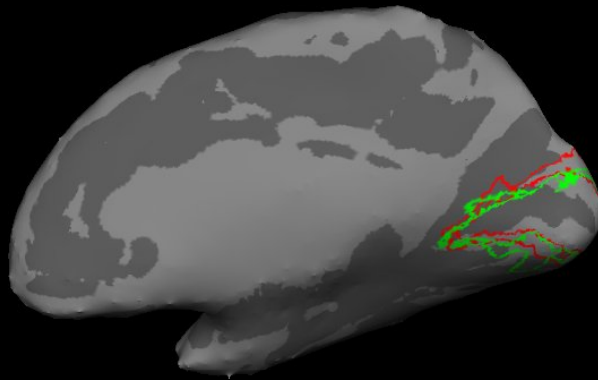
Joint work with B.T. Thomas Yeo, Polina Golland and Mert Sabuncu

Representative Results: Geometric Weighting

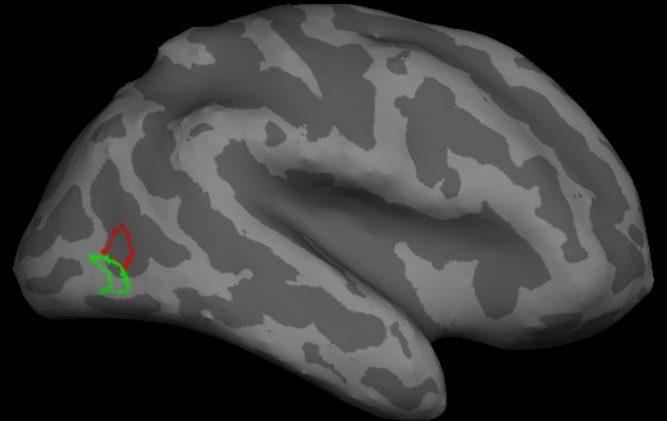
V1



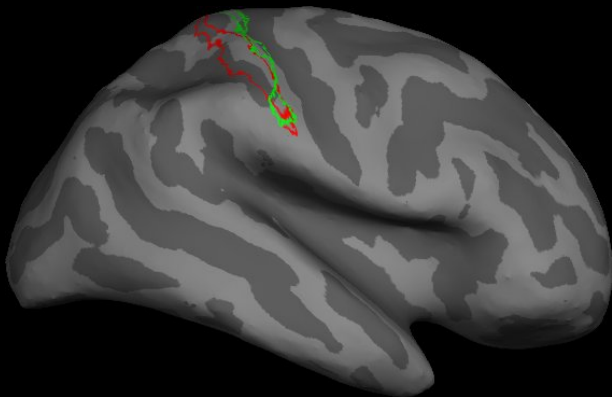
V2



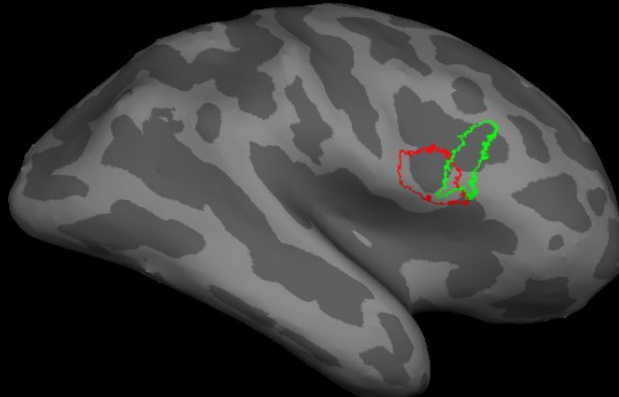
MT



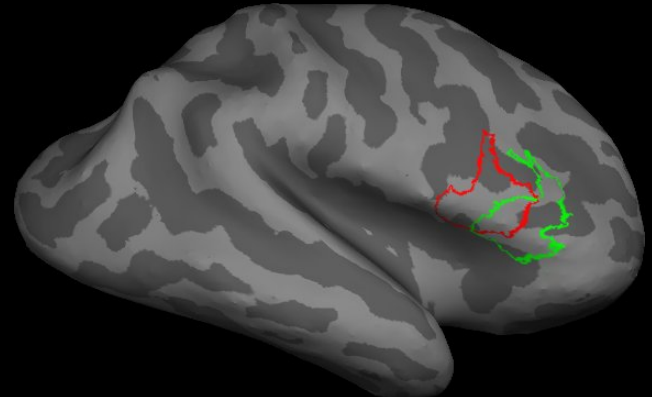
BA2



BA44



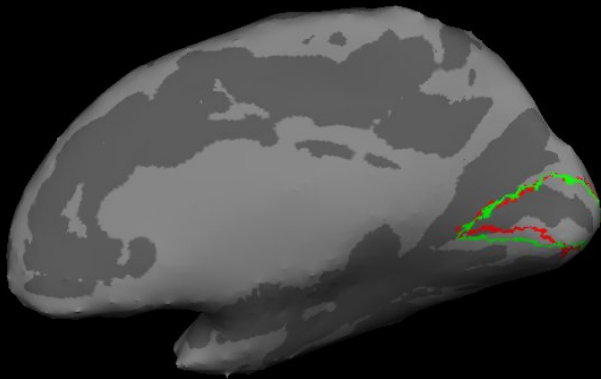
BA45



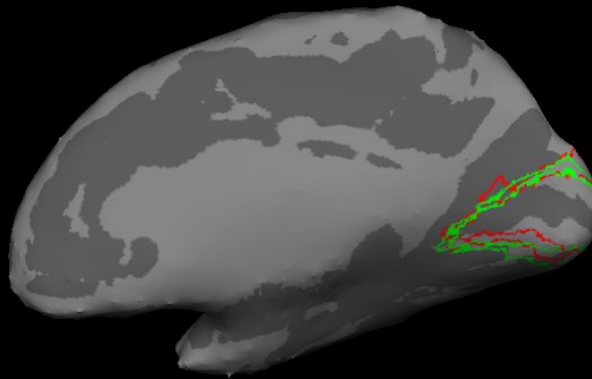
Joint work with B.T. Thomas Yeo, Polina Golland and Mert Sabuncu

Representative Results: Optimal Weighting

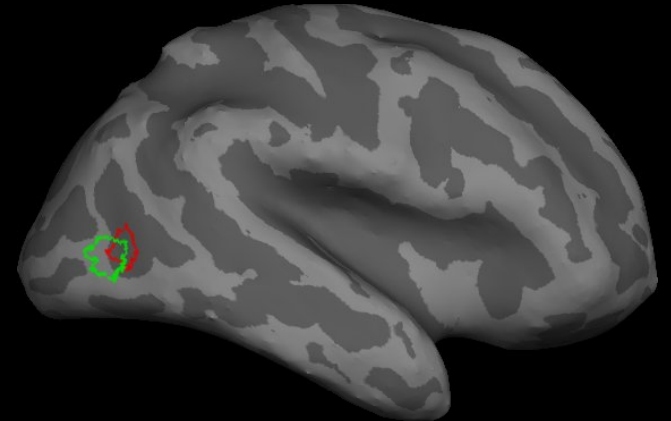
V1



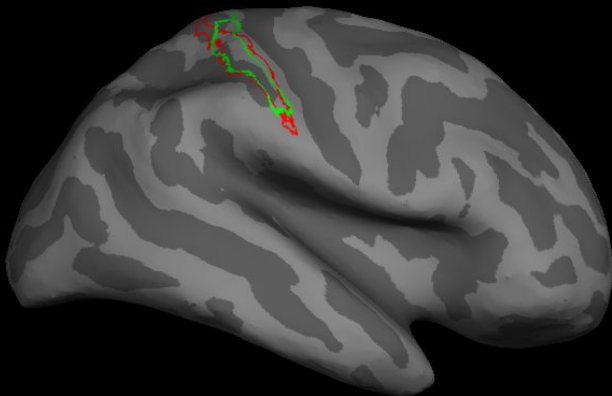
V2



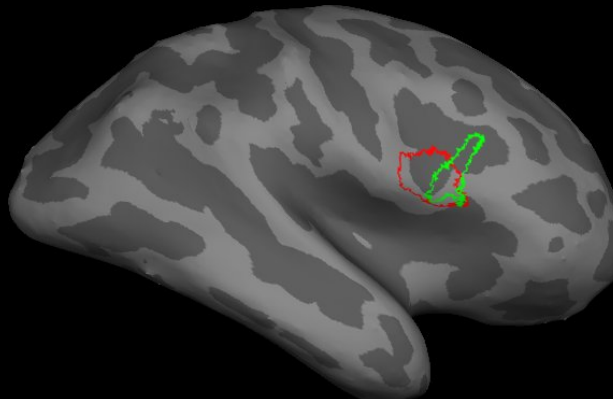
MT



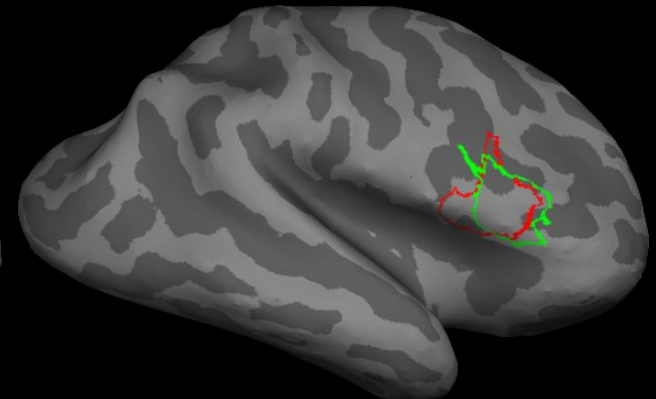
BA2



BA44



BA45



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Acknowledgements

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