3dQwarp
and Its *Nwarp* Friends

Or, How I Learned to Stop Worrying and Love Getting My Datasets all Warped

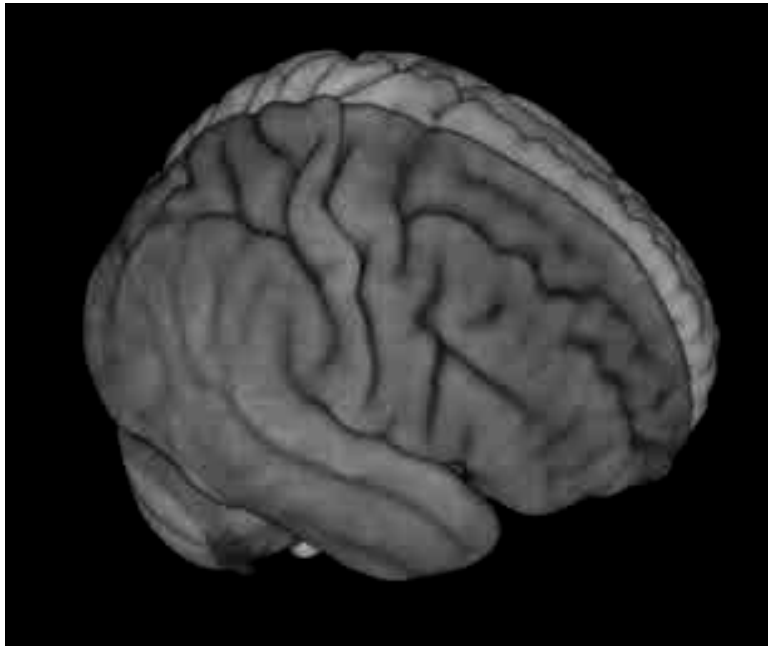
Linear and Nonlinear Warping

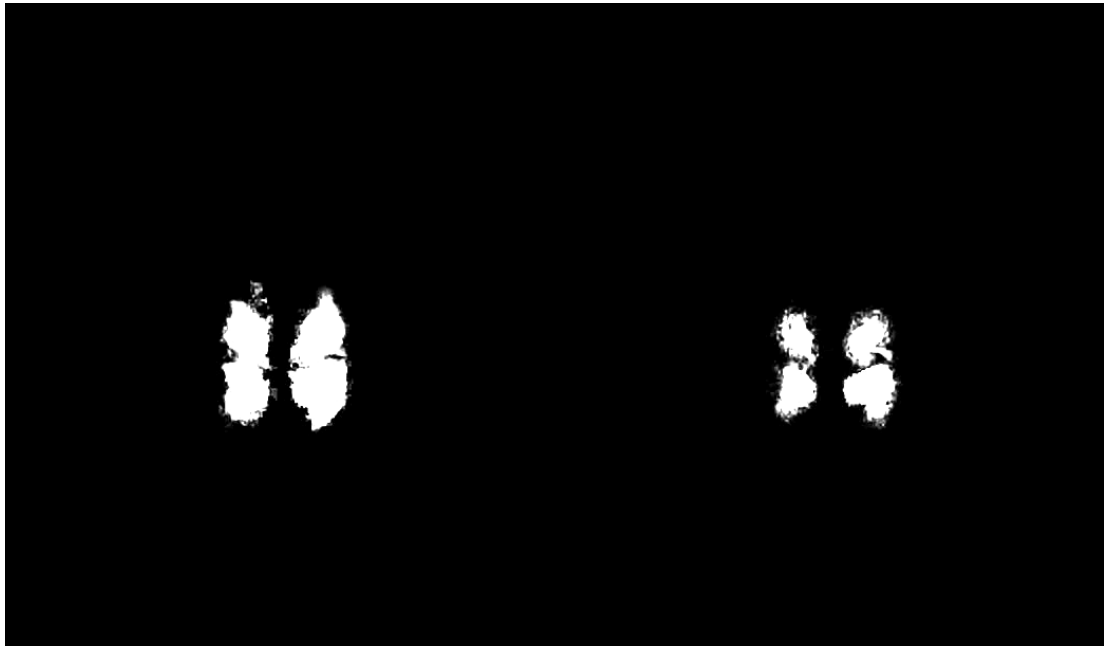
- The Central Equation:
  - S(x) = source image B(x) = base image
  - ➢ $S(W(x)) \approx B(x)$ where W(x) = desired warp function
    = shows where each point x in B maps to in S
- *3dAllineate*: W(x) = **M**x where **M** = 4x3 matrix
  - M has 12 parameters to optimize
- *3dQwarp*: $W(x) = W_1(W_2(\ldots W_{n-1}(W_n(x))) \ldots))$
  - Each $W_k(x)$ is a polynomial warp over a "patch"
  - Patches start big [$W_1(x)$] and shrink and shrink
  - Cubic patch = 24 parameters ; Quintic = 81 params
  - By the end, 1000s of parameters have been used

The Good and The Ugly

- the Good:
  - Nonlinear warping can match anatomical structures between subjects more closely than linear transformation
  - Can also be used for intra-subject warping for high accuracy matching (e.g., pre- and post-surgery)
- the Ugly:
  - Nonlinear warping can seriously distort when it tries to match in regions that don't really "fit together" (e.g., 2 gyri in one person, 1 gyrus in another)
  - Extraneous small features can drive warping in strange ways (unlike linear transformation)
  - Partial brain coverage is a problem

Start: Looking Good



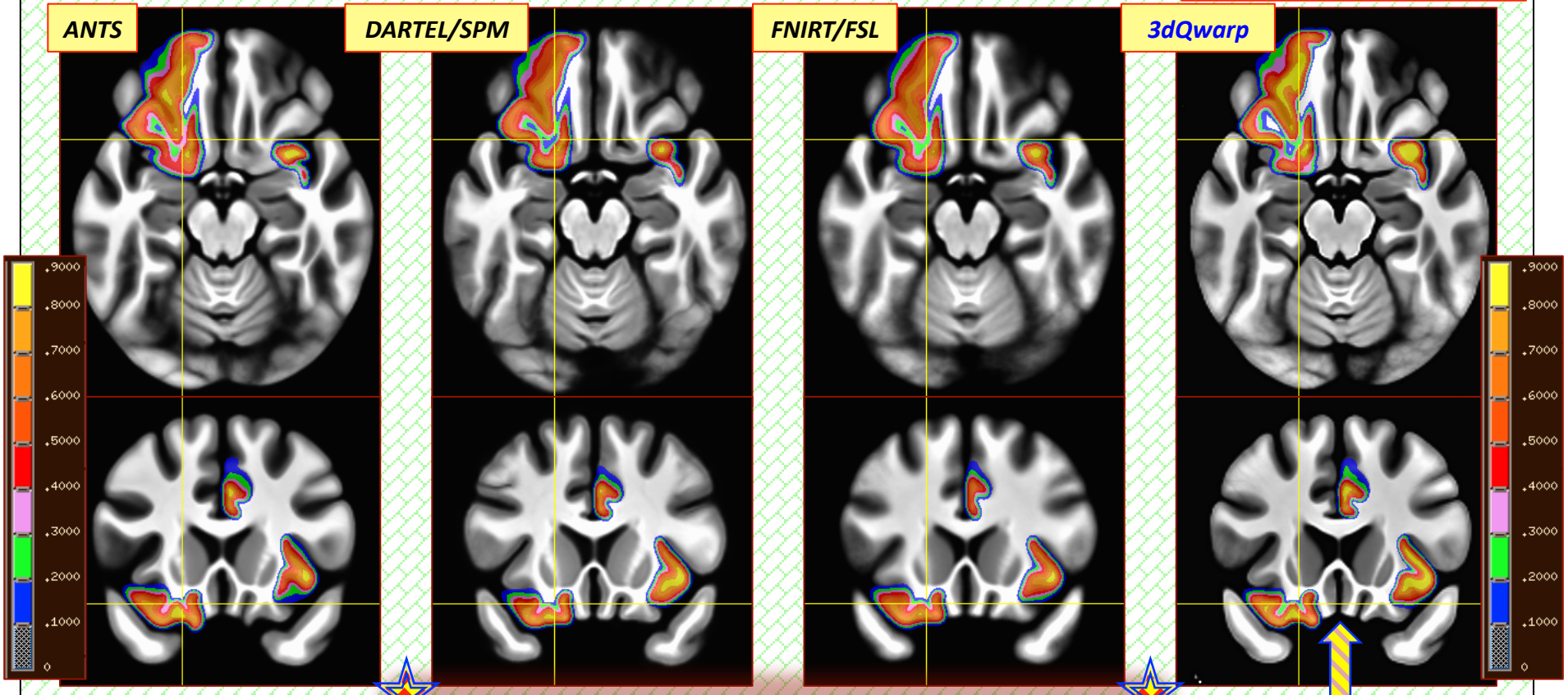


Compare FSL *FNIRT* vs AFNI *3dQwarp*
Average of 101 brain volumes warped to template

Good Matches to Anatomical Labels

Align MindBoggle 101 T_1 Datasets to Separate Template:
Overlap Probability Maps for 3 of the Labeled Regions

LH: lateral orbital frontal
RH: caudal anterior cingulate
RH: insula

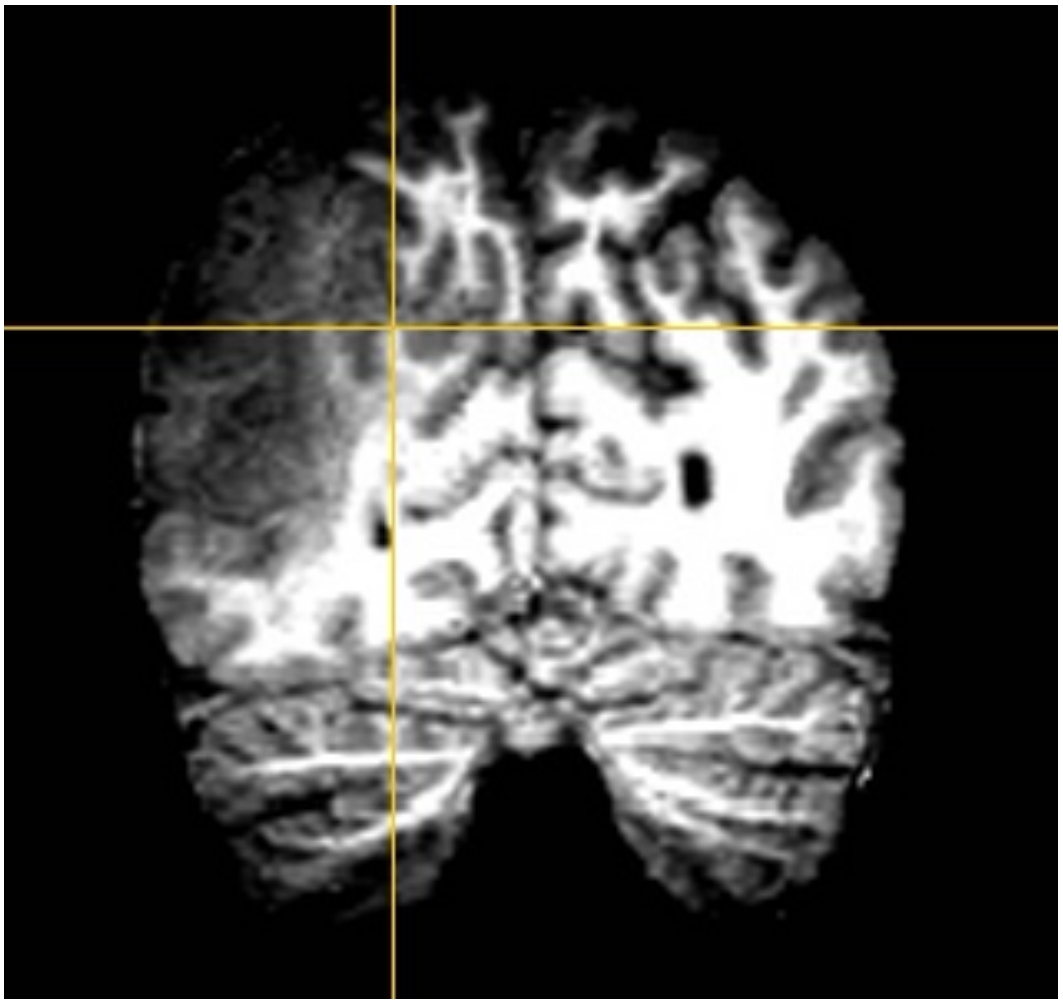


ANTS & *DARTEL* & *FNIRT* run with default settings

3dQwarp distribution of overlap probabilities is 2nd order stochastically dominant in a majority of 62 labeled regions

More yellow in the overlay means more 90+% overlap in labels

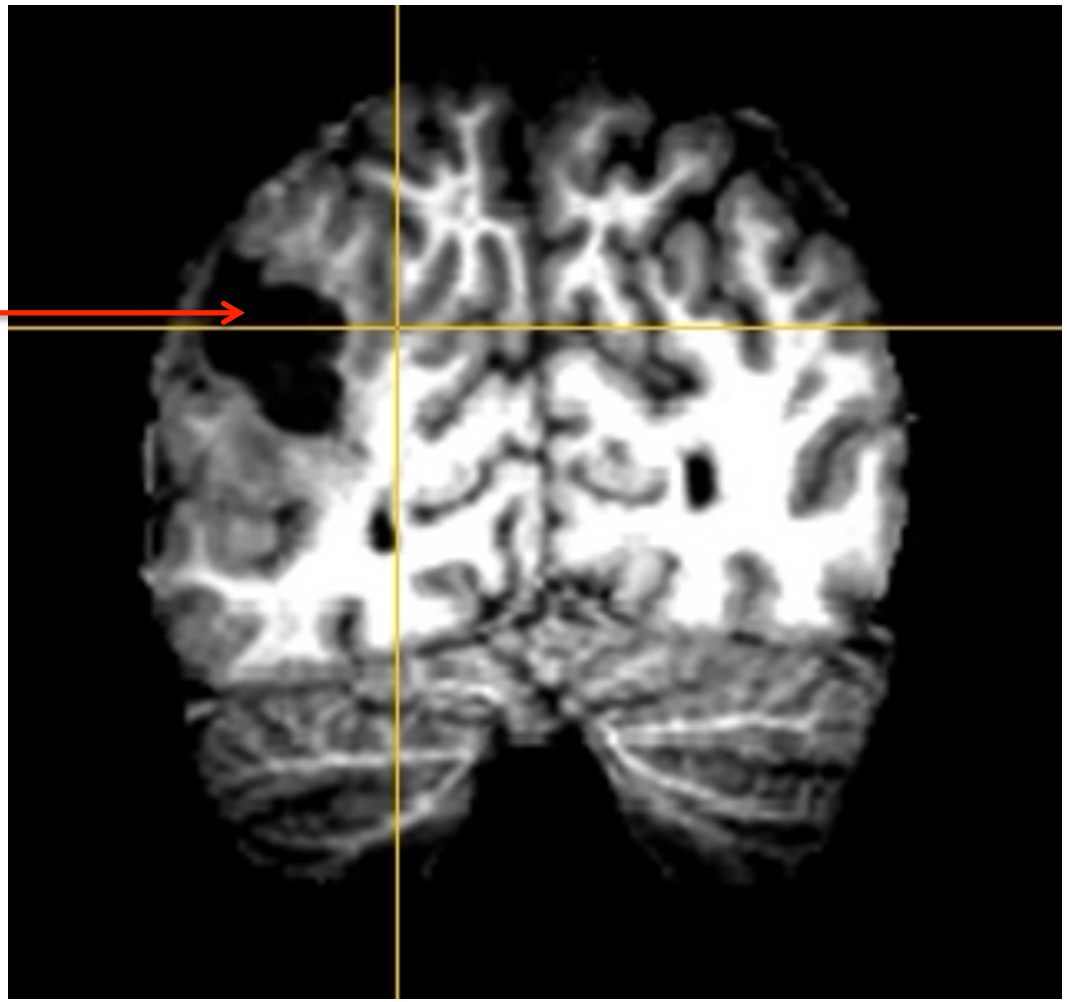
Maybe Even Useful: Neurosurgery



Pre-surgical volume

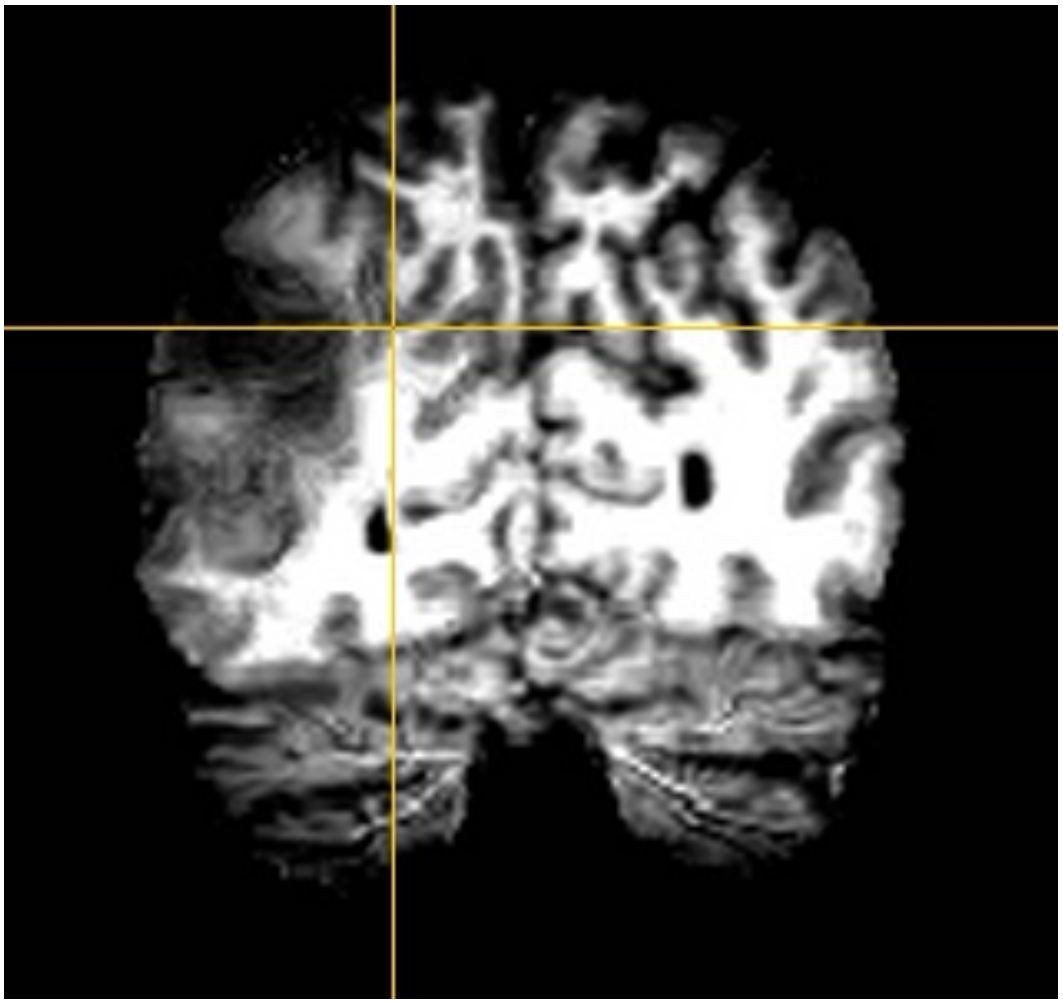
Neurosurgery

Manually drawn “exclusion Mask"



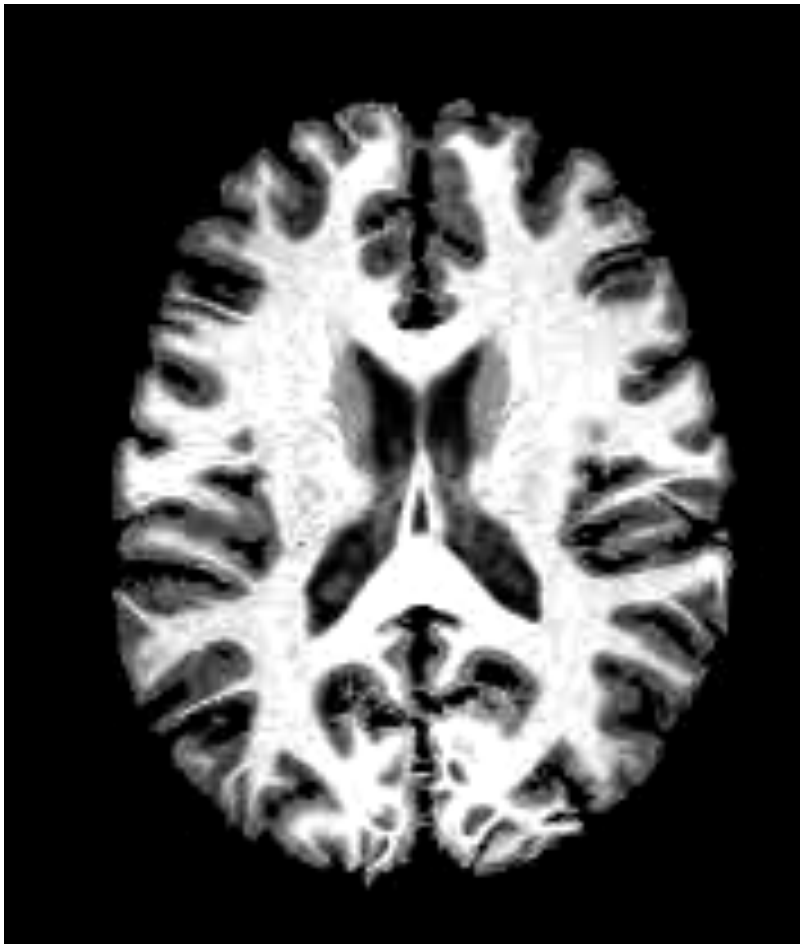
Post-surgical volume

Neurosurgery

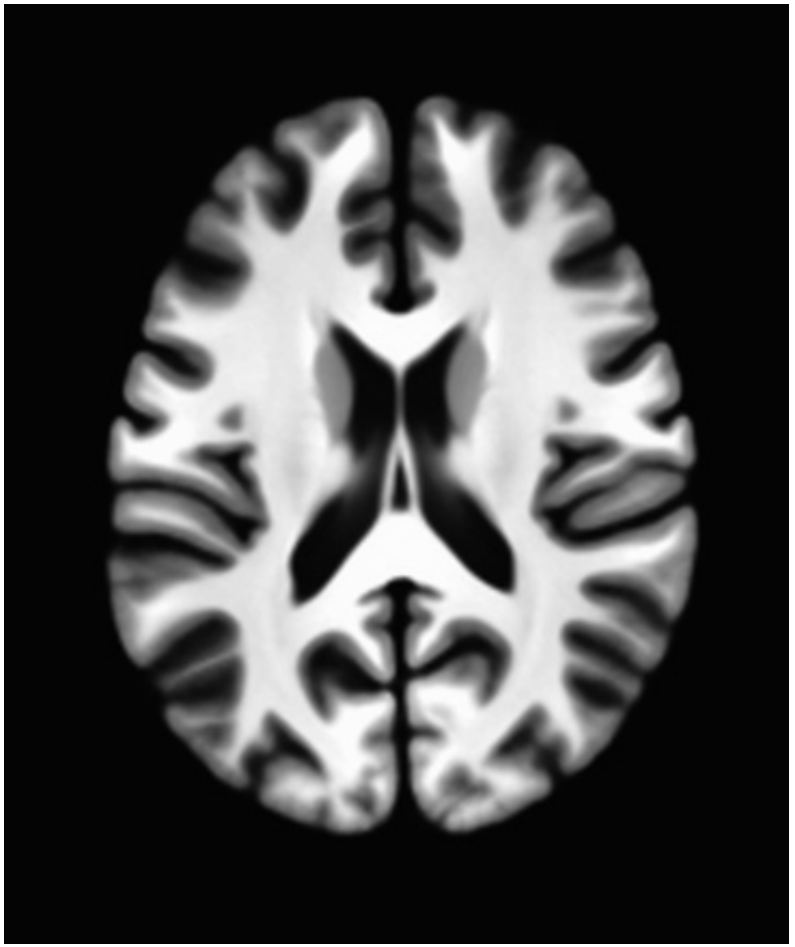


Pre-surgical volume
3dQwarp-aligned to Post-surgical volume

But … Some Ugly



All 101 Volumes
After Warping



Mean of 101 Volumes
After Warping

How to Make a Template

- Given a collection of skull-stripped structural (T_1-weighted) datasets
- Script *@toMNI_Awarp* pre-processes each dataset (*3dUnifize* and *@auto_tlrc*)
- Script *@toMNI_Qwarpar* runs *3dQwarp* to collectively warp them together over finer and finer patch levels
- Has been used to create Haskins pediatric brain atlas (coming to an AFNI near you “real soon”)

What Else to Do with a Warp?

- Warp another dataset the same way
  - *3dNwarpApply* (e.g., carry EPI to template)
- Warp some discrete points the same way
  - *3dNwarpXYZ* (e.g., eCog electrode locations)
- Compute voxel-wise functions of a warp
  - *3dNwarpFuncs* (e.g., volume distortion)
- Compose multiple warps together
  - *3dNwarpCat* and *3dNwarpCalc*
- Can compute inverse warp $W^{-1}(x)$, to map locations in S(x) to matching locations in B
  - $S(W(x)) \approx B(x)$ → $S(x) \approx B(W^{-1}(x))$

How to Use *3dQwarp*

- Run it yourself (the "old school" or "real man" way)
- *auto_warp.py* (easier, less flexible)
- Use '*-tlrc_NL_warp*' option in *afni_proc.py* to have transformation to template space be done via *auto_warp.py*
- Use *@toMNI_Awarp* and *@toMNI_Qwarpar* to create a study specific template
- Use '*-plusminus'* option in *3dQwarp* to warp blip-up and blip-down EPI datasets to "meet in the middle" (need to write script for this someday)

Yet to Be Done

- Incorporate more fully into *afni_proc.py* and *uber_subject.py*
  - Warping to template; un-warping EPI distortions
- Explore how much nonlinear warping to a template can improve group analysis in functional and anatomical MRI
  - And improvements to *3dSeg* (segmentation)
- Extend matching algorithm to allow label-based matches, vs. existing intensity-based
- Speed the damn thing up*!*
- Write a paper about it*!*