Transforming Datasets to Talairach-Tournoux Coordinates

- The original purpose of AFNI was to perform the transformation of datasets to Talairach-Tournoux (stereotaxic) coordinates
- The transformation is user-controlled, not automatic
- You must mark various anatomical locations, defined in

  Jean Talairach and Pierre Tournoux
  "Co-Planar Stereotaxic Atlas of the Human Brain"
  Thieme Medical Publishers, New York, 1988

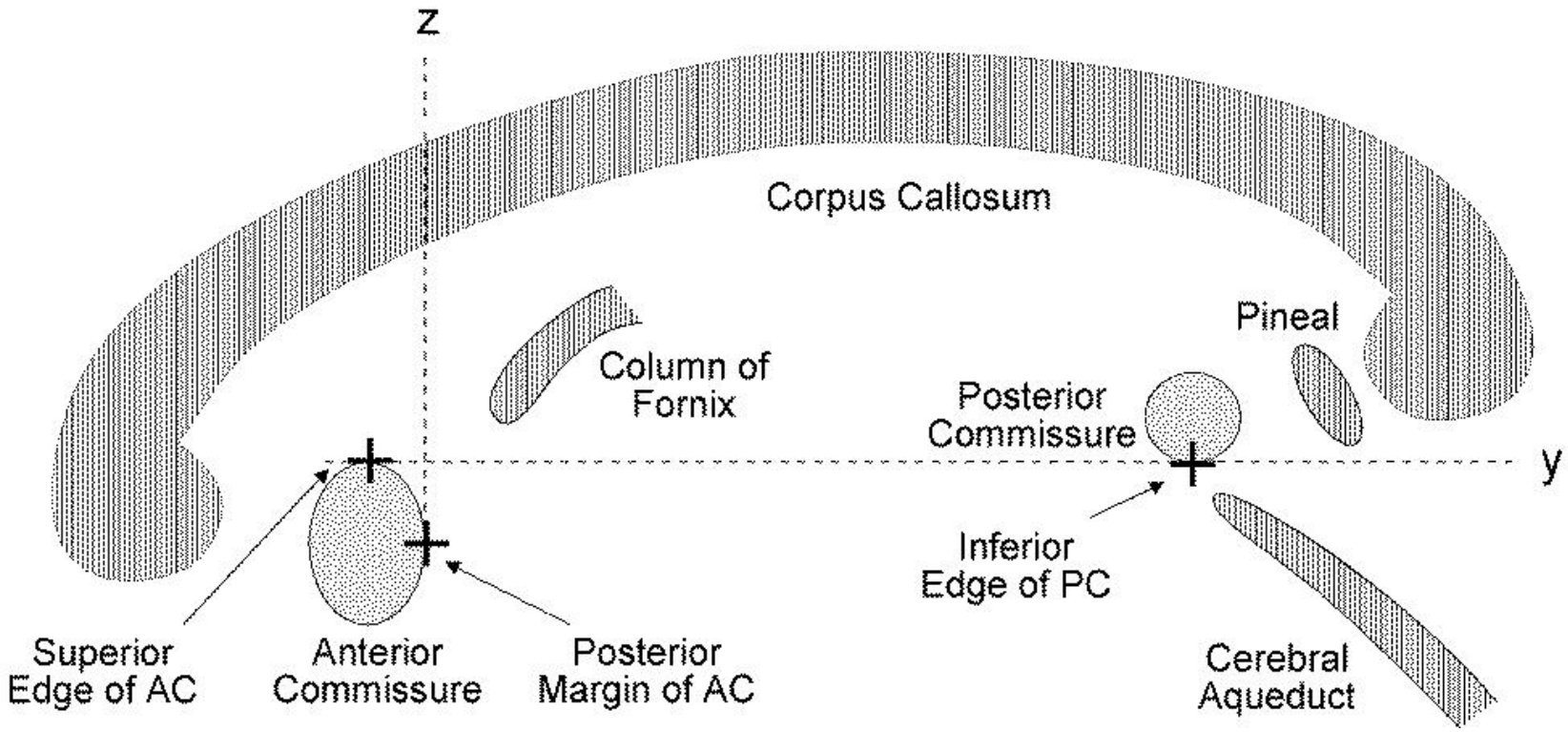
- Marking is best done on a high-resolution T1-weighted structural MRI volume
- The transformation defined by the manually placed markers then carries over to all other datasets in the same directory
  - ◇ This is where the importance of getting the relative spatial placement of datasets done correctly in to3d really matters
  - ◇ You can then write functional datasets to disk in Talairach coordinates
    - ↪ Purpose: voxel-wise comparison with other subjects
    - ↪ May want to blur functional maps a little before comparisons, to allow for residual anatomic variability: AFNI program `3dmerge`

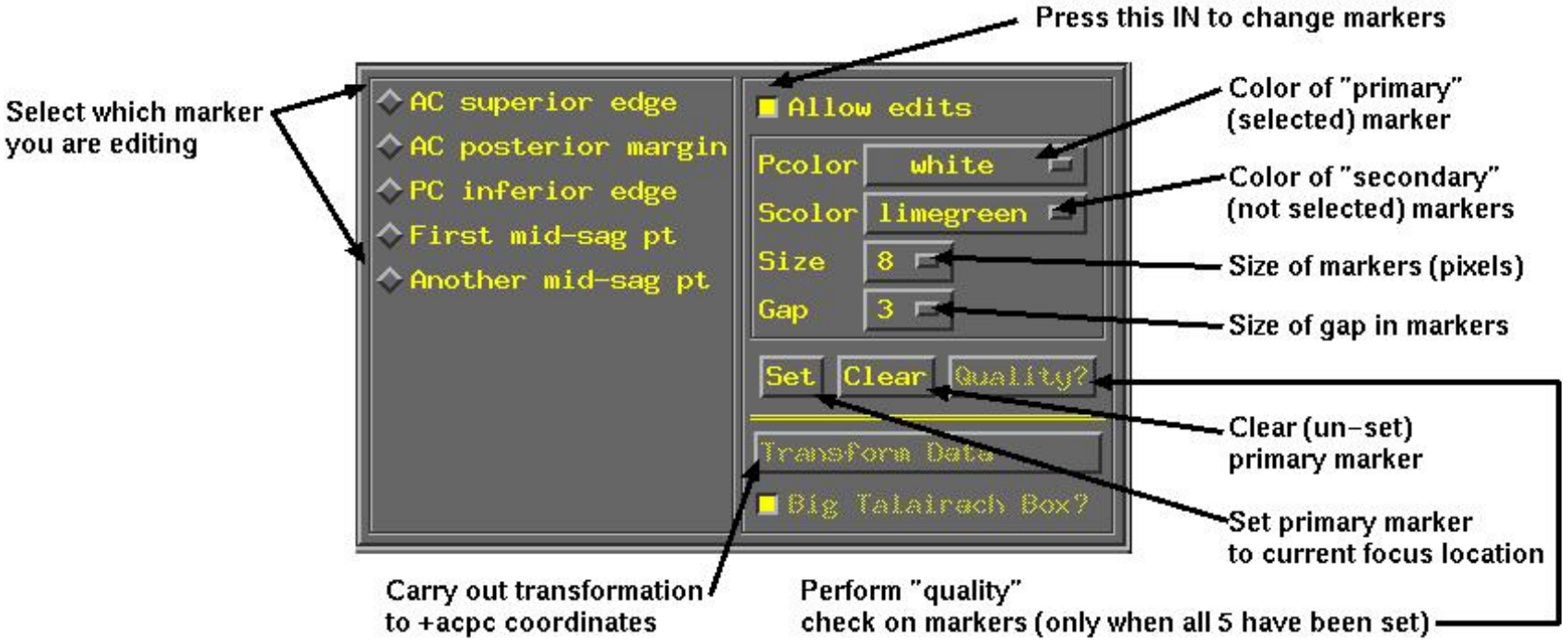
- Transformation proceeds in two stages:
  1. Alignment of AC-PC and I-S axes (to `+acpc` coordinates)
  2. Scaling to Talairach-Tournoux Atlas brain size (to `+tlrc` coordinates)
  3. Using the results for fun and profit
- Alignment to `+acpc` coordinates:
  - ◇ Anterior commissure (AC) and posterior commissure (PC) are aligned to be the y-axis
  - ◇ The longitudinal (inter-hemispheric or mid-sagittal) fissure is aligned to be the yz-plane, thus defining the z-axis
  - ◇ The axis perpendicular to these is the x-axis (right–left)
  - ◇ Five markers that you must place using the `Define Markers` control panel:

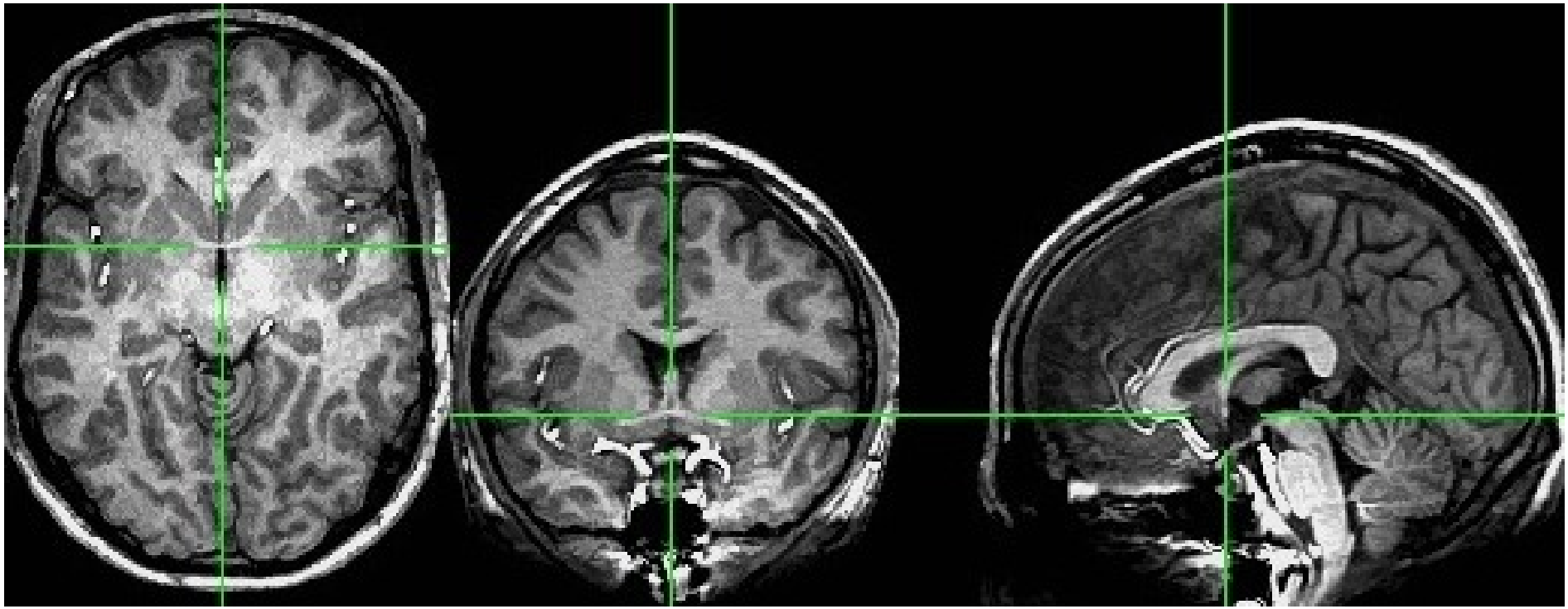
`AC superior edge`	=	top middle of anterior commissure
`AC posterior margin`	=	rear middle of anterior commissure
`PC inferior edge`	=	bottom middle of posterior commissure
`First mid-sag pt`	=	some point in the mid-sagittal plane
`Another mid-sag pt`	=	some other point in the mid-sagittal plane

  - ◇ This procedure tries to follow the Atlas as precisely as possible

  ↪ Even at the cost of confusion to the user (e.g., you)


z
Corpus Callosum
Column of
Fornix
Pineal
Posterior
Commissure
y
Inferior
Edge of PC
Superior
Edge of AC
Anterior
Commissure
Posterior
Margin of AC
Cerebral
Aqueduct


Press this IN to change markers
Select which marker
you are editing
AC superior edge
AC posterior margin
PC inferior edge
First mid-sag pt
Another mid-sag pt
Allow edits
Pcolor
white
Scolor
limegreen
Size
8
Gap
3
Set
Clear
Quality?
Transform Data
Big Talairach Box?
Color of "primary"
(selected) marker
Color of "secondary"
(not selected) markers
Size of markers (pixels)
Size of gap in markers
Clear (un-set)
primary marker
Set primary marker
to current focus location
Carry out transformation
to +acpc coordinates
Perform "quality"
check on markers (only when all 5 have been set)



◇ First goal is to mark top middle and rear middle of AC

↪ Sagittal: look for AC at bottom level of corpus callosum, below fornix

↪ Coronal: look for "mustache"; Axial: look for inter-hemispheric connection

↪ Get AC centered at focus of crosshairs (in Axial and Coronal)

↪ Move superior until AC disappears in Axial view; then inferior 1 pixel

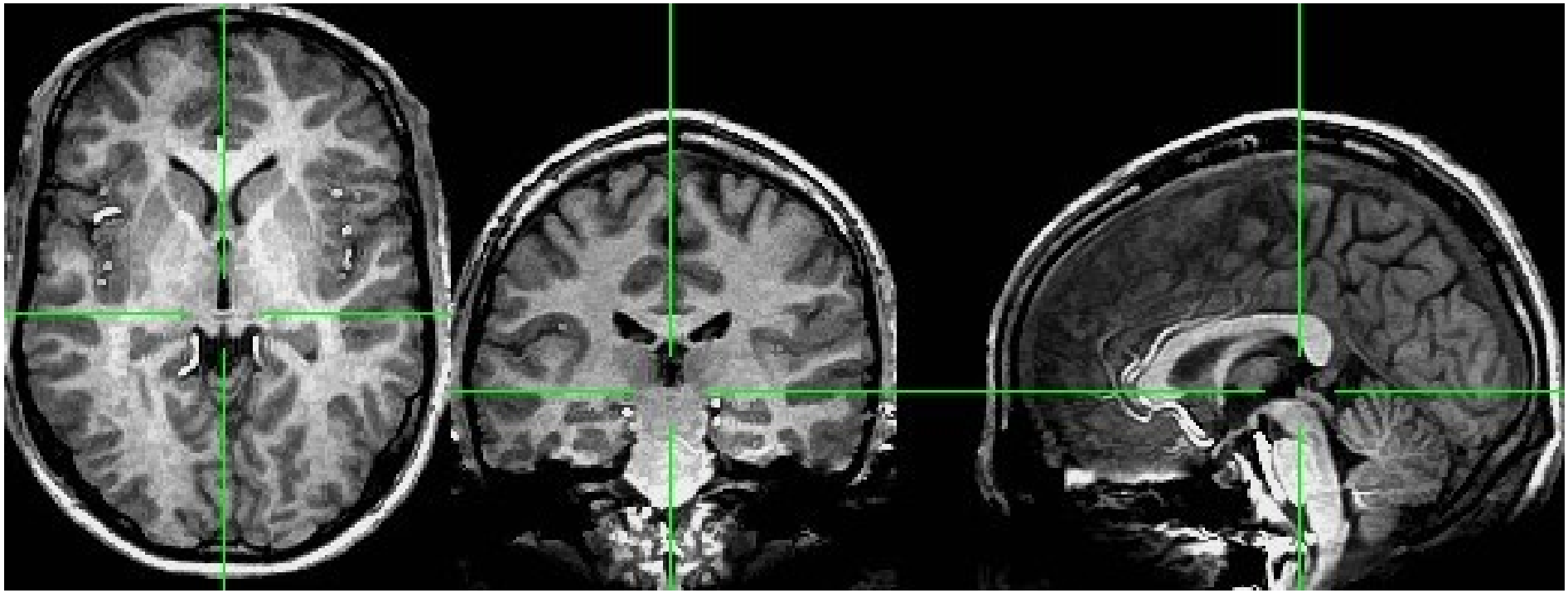
↪ Press IN `AC superior edge` marker toggle, then `Set`

↪ Move focus back to middle of AC

↪ Move posterior until AC disappears in Coronal view; then anterior 1 pixel

↪ Press IN `AC posterior margin`, then `Set`

- Second goal is to mark inferior edge of PC
  - ◇ This is harder, since PC doesn't show up well at 1 mm resolution
  - ◇ Fortunately, PC is always at the top of the cerebral aqueduct, which does show up well (at least, if CSF is properly suppressed by the MRI pulse sequence)



  - ◇ Therefore, if you can't see the PC, find mid-sagittal location just at top of cerebral aqueduct and mark it as `PC inferior edge`
- Third goal is to mark two inter-hemispheric points (above corpus callosum)
  - ◇ The two points must be at least 2 cm apart
  - ◇ The two planes AC-PC-#1 and AC-PC-#2 must be no more than 2° apart

- Once all 5 markers have been set, the Quality? button is ready
  - ◇ You can't Transform Data until Quality? check is passed
  - ◇ In this case, quality check makes sure two planes from AC-PC line to mid-sagittal points are within 2°

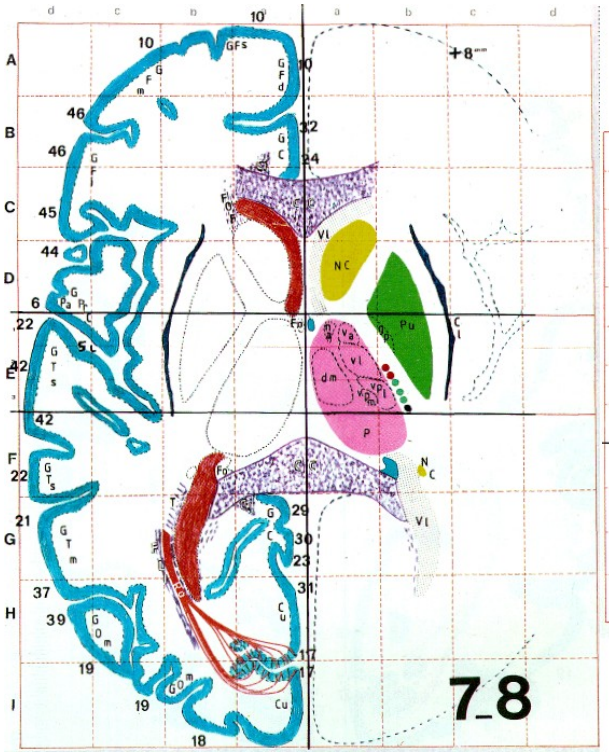
```
*** MARKERS QUALITY REPORT ***

*** ERROR:  The AC + PC + mid-sag pts do not form a good plane.
Angular deviation between AC+PC+mid-sag pts:   2.43 degrees
Mismatch between AC-PC line and Talairach origin:   0.04 mm
Total rotation to align AC-PC and mid-sag:     4.41 degrees
```

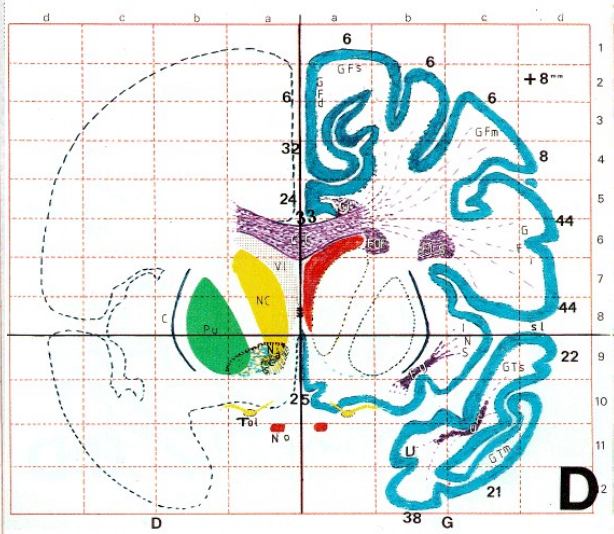
  - ◇ Sample above shows 2.43° deviation between planes ⇒ must move one of the points a little

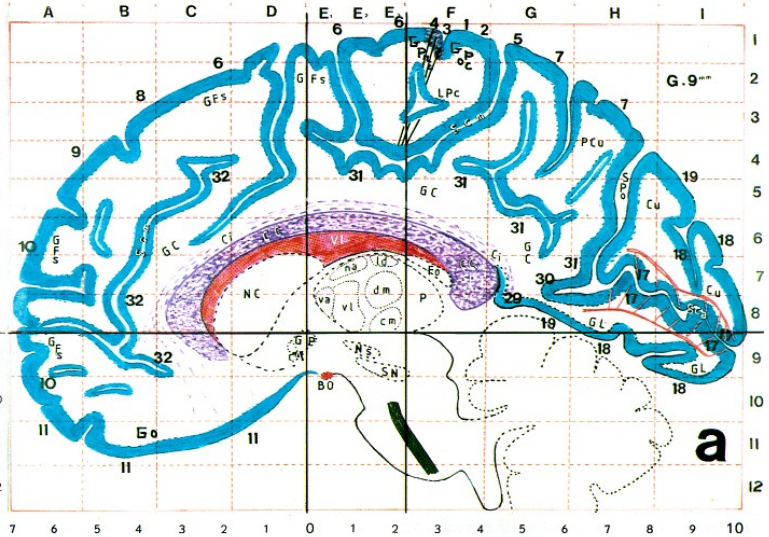
```
*** MARKERS QUALITY REPORT ***

Angular deviation between AC+PC+mid-sag pts:   1.33 degrees
Mismatch between AC-PC line and Talairach origin:   0.06 mm
Total rotation to align AC-PC and mid-sag:     4.59 degrees
```

  - ◇ When Transform Data is available, pressing it will close Define Markers panel, write marker locations into the dataset header, and create the +acpc datasets that follow from this one
    - ↪ The AC-PC Aligned coordinate system is now enabled in the main AFNI controller window
    - ↪ In the future, you could re-edit the markers, if desired, then re-transform dataset (but you wouldn't make a mistake, would you?)
    - ↪ If you don't want to save edited markers to the dataset header, you must quit AFNI without pressing Transform Data or Define Markers

- Scaling to `+tlrc` coordinates:
  - ◇ We now stretch/shrink the brain to fit the Talairach-Tournoux Atlas brain size (sample TT Atlas pages shown below, just for fun)



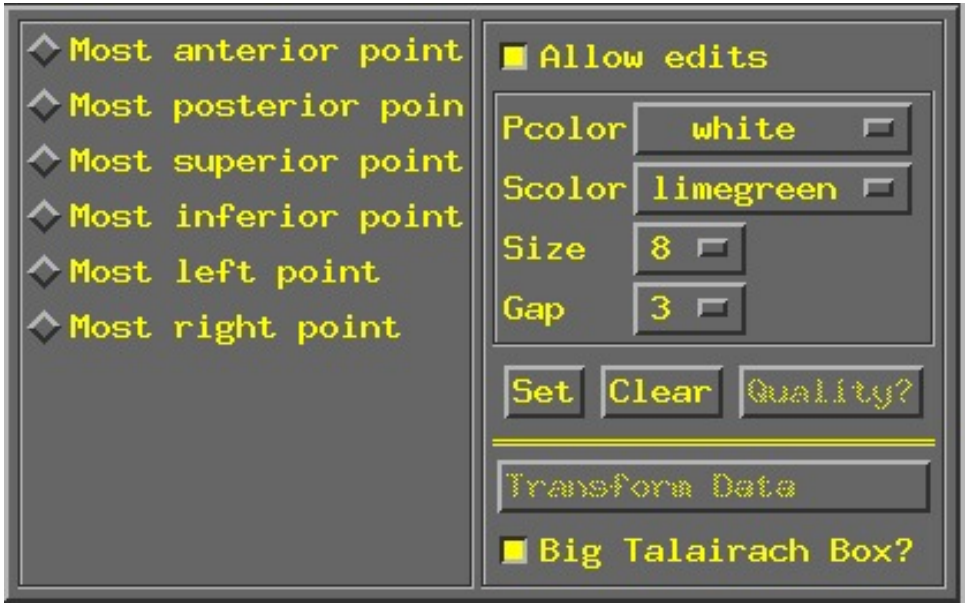




Most anterior to AC	70 mm		
AC to PC	23 mm		
PC to most posterior	79 mm	Length of cerebrum	172 mm
Most inferior to AC	42 mm		
AC to most superior	74 mm	Height of cerebrum	116 mm
AC to left (or right)	68 mm	Width of cerebrum	136 mm

◇ There are 12 sub-regions to be scaled (3 A-P × 2 I-S × 2 L-R)

◇ To enable this, the transformed +acpc dataset gets its own set of markers:



◇ Using the same methods as before (i.e., select marker toggle, move focus there, Set), you must mark these extreme points of the cerebrum

↪ Using 2 or 3 image windows at a time is useful

↪ Hardest one is Most inferior point in the temporal lobe, since it is near other (non-brain) tissue

↪ Once all 6 are set, use Quality? to check if the distances are reasonable, then Transform Data to make the +tlrc datasets

▷ Leave Big Talairach Box? pressed IN

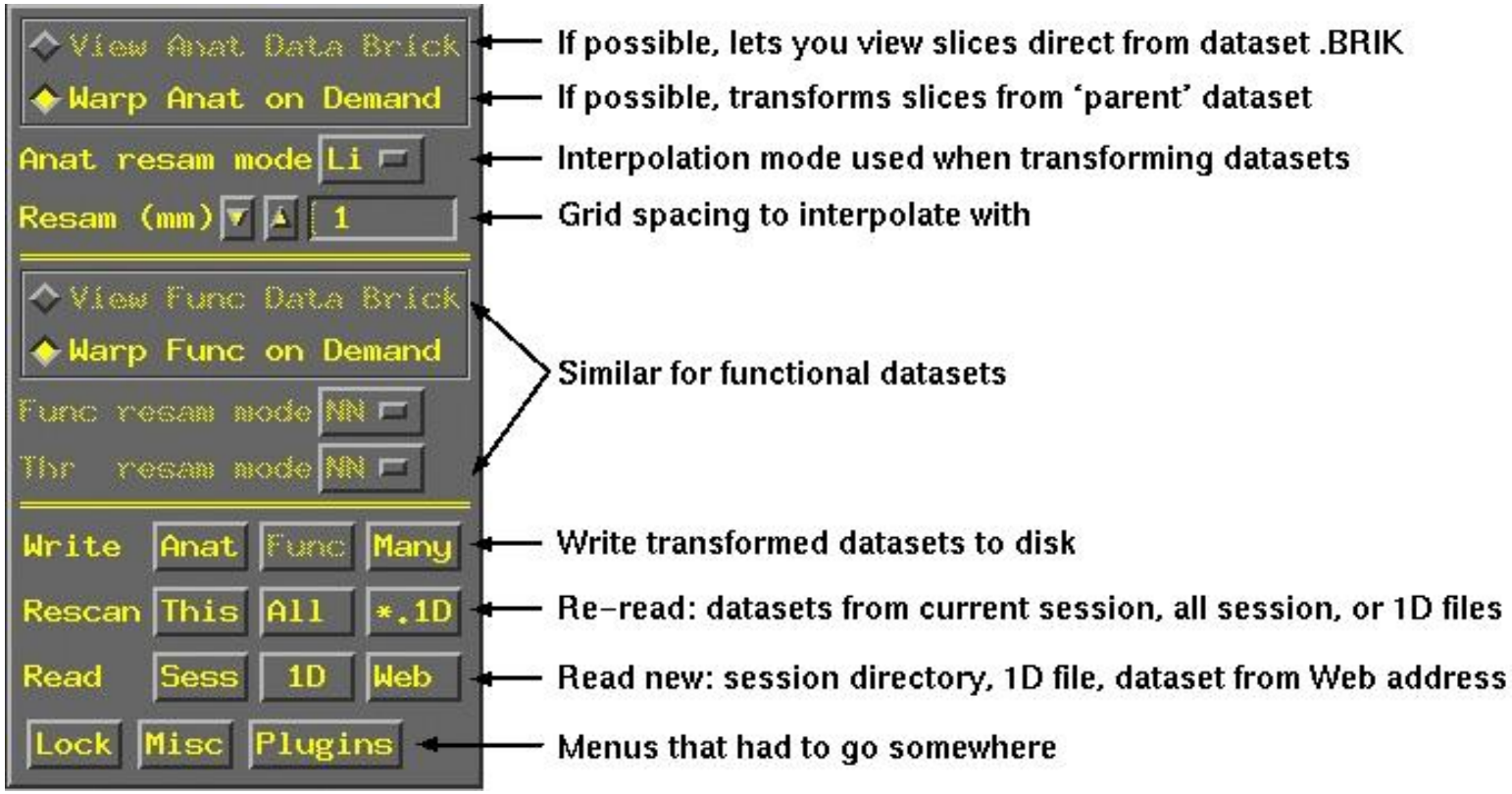
▷ Is a legacy from earliest (1994–6) days of AFNI, when 3D box size of +tlrc datasets was 10 mm smaller in I-direction than the current default

- Automatic creation of "follower datasets":
  - ◇ After an anatomical `+orig` dataset in a directory is transformed (i.e., gets a `+acpc` and `+tlrc` dataset), all the other datasets in that directory will get transformed datasets as well
    - ↪ These datasets are created automatically inside the interactive AFNI program, and are not written to disk
    - ↪ To write one to disk, use one of the `Define Datamode→Write` buttons (necessary if you want to process this in a command-line program such as `3dttest`)
    - ↪ How followers are created (arrows show geometrical relationships):

```
anat+orig  ⟶  anat+acpc  ⟶  anat+tlrc
    ↑             ↓             ↓
func+orig     func+acpc     func+tlrc
```

    - ↪ After `Transform Data` creates `anat+acpc`, other datasets in the same directory are scanned
      - ▷ If `func+acpc` doesn't already exist (from `Write`-ing, say), then AFNI creates it, and defines the geometrical transformation ("warp") from `func+orig` using the to3d-defined relationship between `func+orig` and `anat+orig`, and the markers-defined relationship between `anat+orig` and `anat+acpc`
      - ▷ Next time you run AFNI, the followers will automatically be created internally again when the program starts

- "Warp on demand" viewing of datasets
  - ◇ AFNI doesn't actually resample all follower datasets to a grid in the re-aligned/re-stretched coordinates
    - ↪ This could take quite a long time if there are a lot of big 3D+time datasets
  - ◇ Instead, the dataset slices are transformed (warped) from `+orig` to `+acpc` or `+tlrc` for viewing as needed (on demand)
  - ◇ This can be controlled from `Define Datamode` control panel:



AFNI titlebar shows warp on demand: {warp} [A] AFNI 2.31e: data/AFNI_sample_04/anat+tlrc

◇ When you create `anat+acpc` and `anat+tlrc` datasets by pressing `Transform Data`, only `.HEAD` files are written to disk for them

↪ So they can only be viewed in warp on demand mode

↪ You can use `Write Anat` to write the current anatomical dataset `.BRIK` out at the current grid spacing (cubical voxels), using the current anatomical interpolation mode

↪ After that, `View Anat Data Brick` will become available

↪ Command line program `adwarp` can also be use to write out `.BRIK` files for transformed dataset:

```
adwarp -apar anat+tlrc -dpar func+orig
```

will write out dataset `func+tlrc`

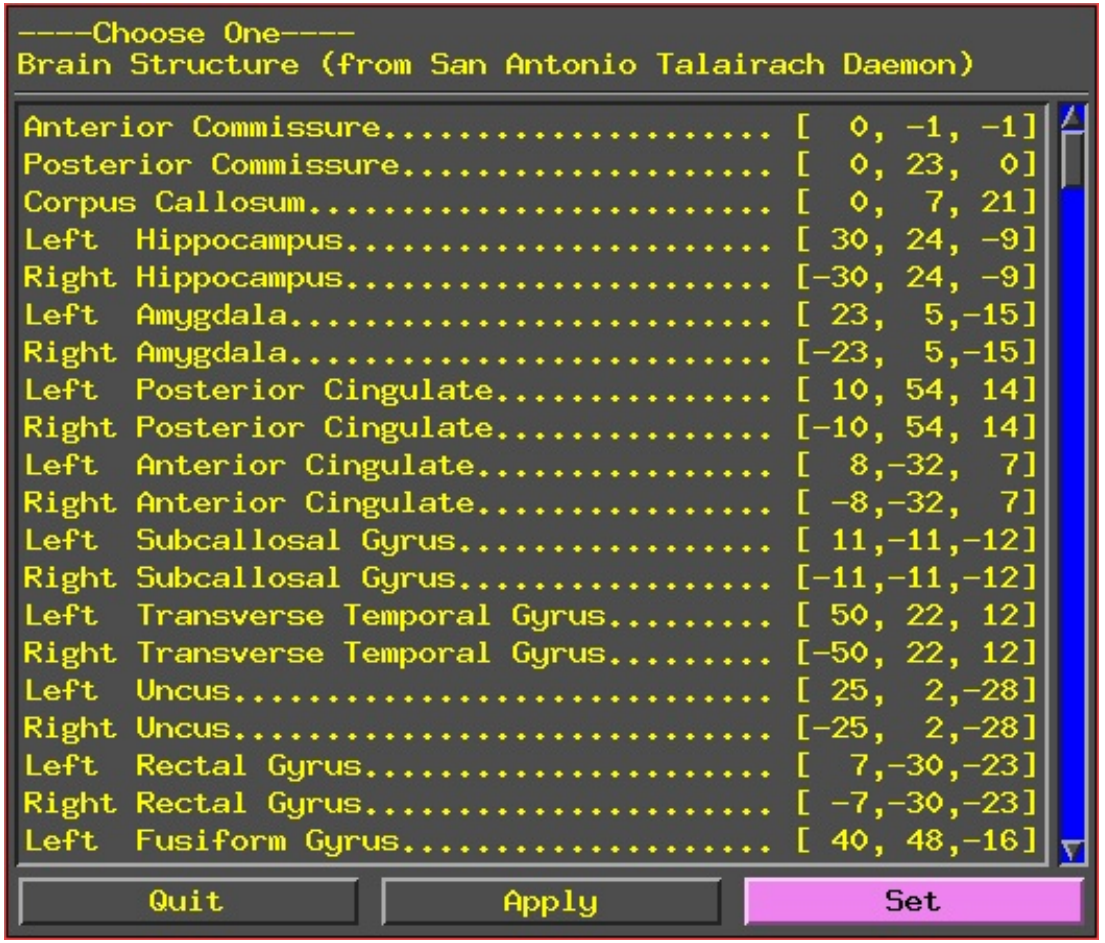
◇ Datasets without `.BRIK` files are of limited use:

↪ You can display 2D slice images from such a dataset

↪ You can't use such datasets to graph time series, do volume rendering, compute statistics, run any command line analysis program, run any plugin, ...

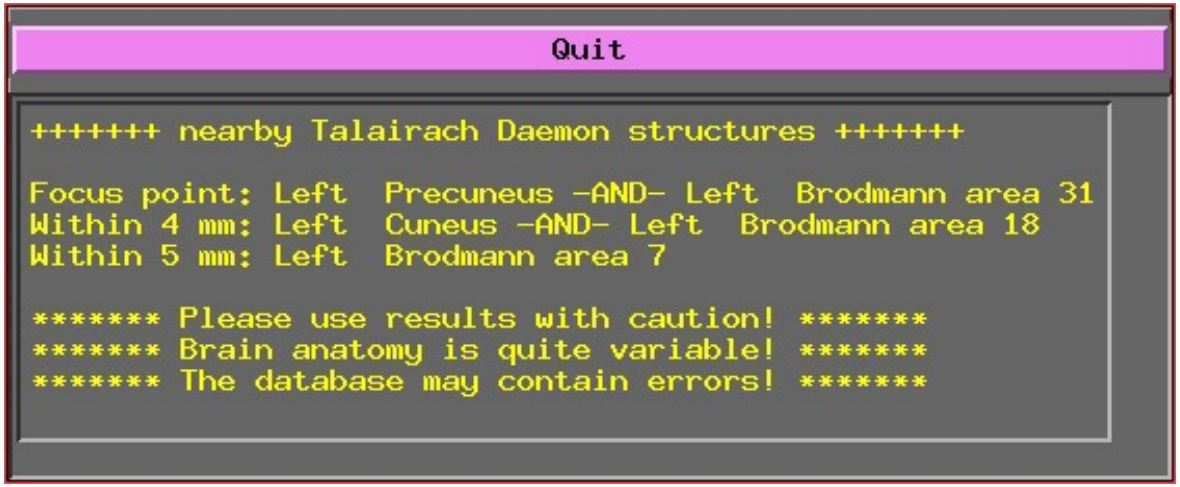
- Some fun and useful things to do with `+tlrc` datasets are on the 2D slice viewer Button-3 popup menu:

◇ Talairach to



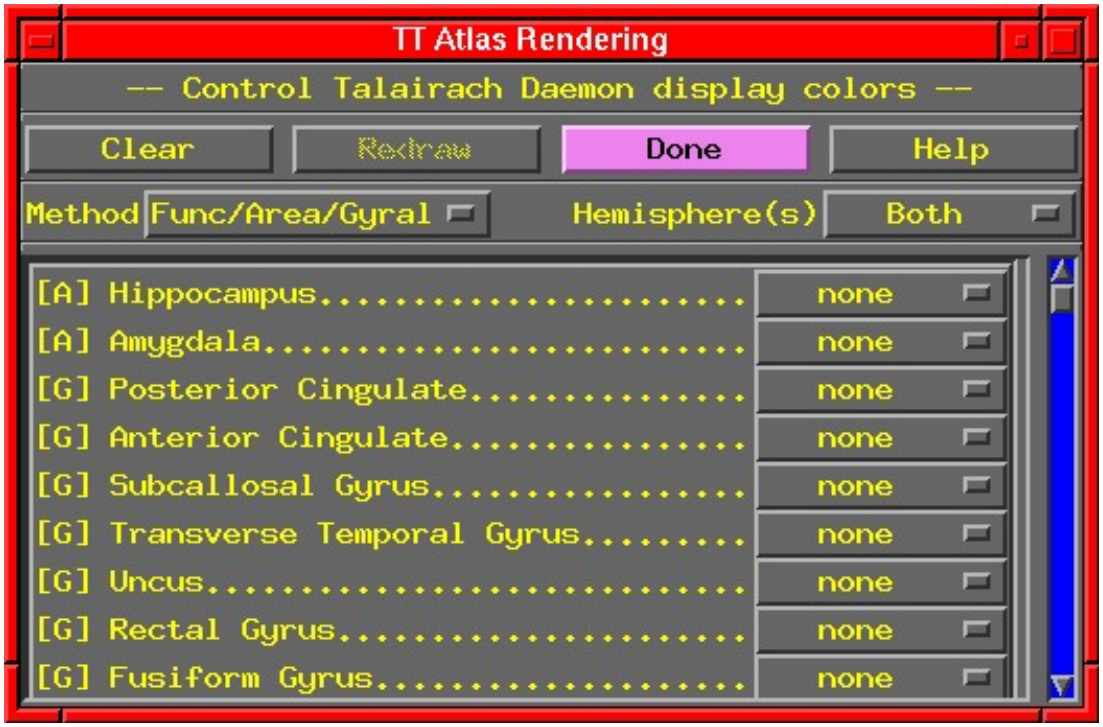
Lets you jump to centroid of regions in the TT Atlas (works in `+orig` too)

◇ Where Am I?



Shows you where you are in the TT Atlas (works in +orig too)

◇ Atlas colors



Lets you display color overlays for various TT Atlas defined regions, using the Define Function→See TT Atlas Regions control (works only in +tlrc)