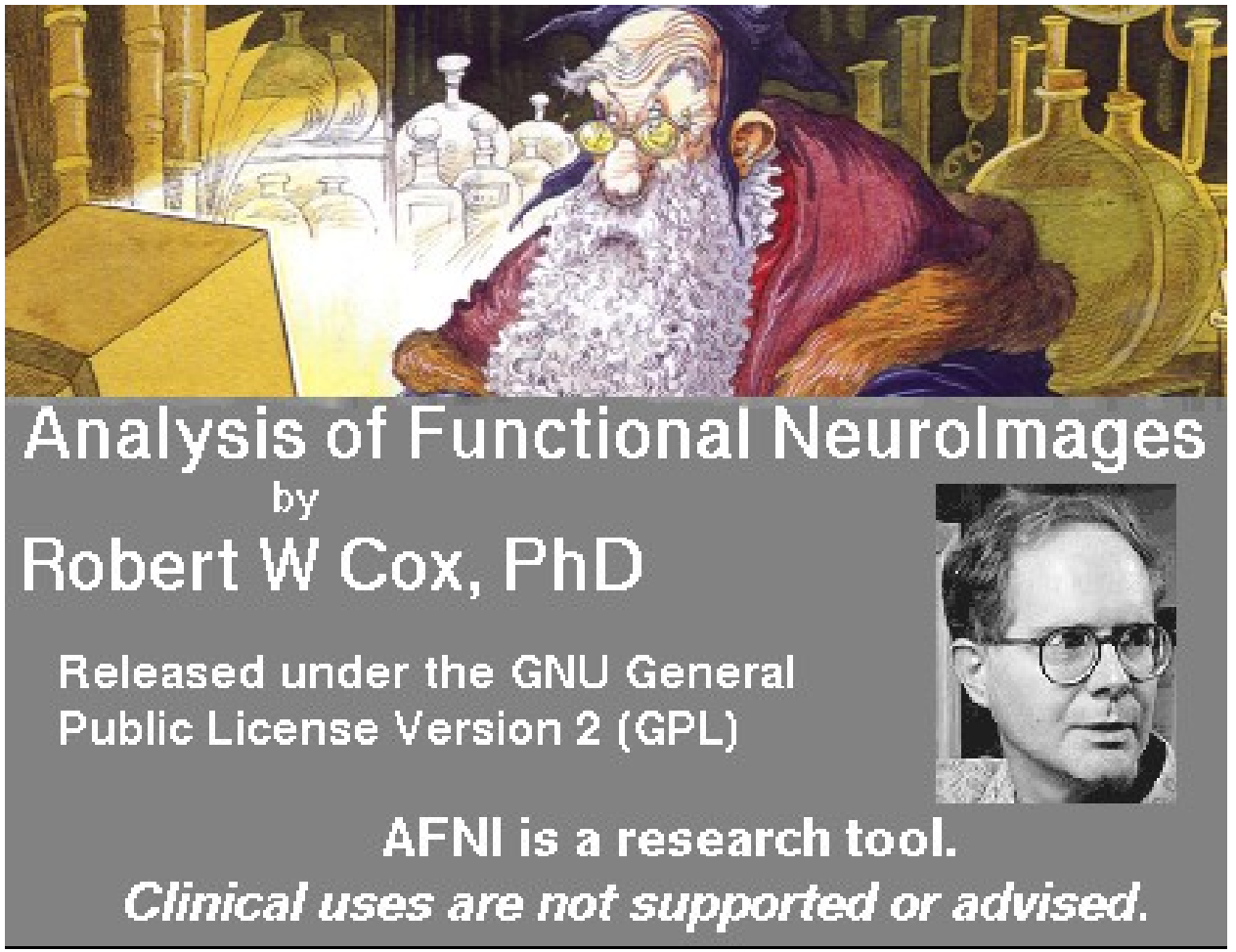
AFNI: Introduction and Concepts



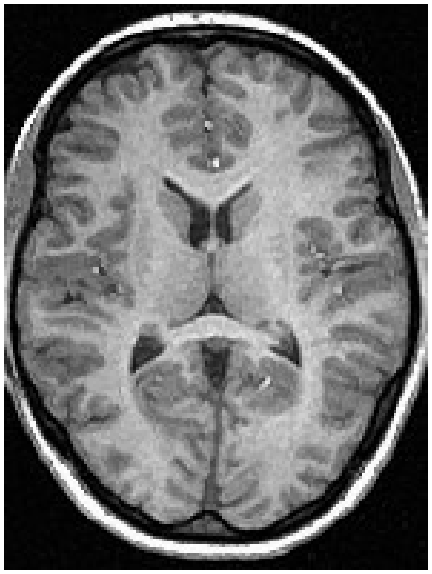
[The Infamous AFNI Splash Screen]

A Few Fun Tools from the AFNI Package

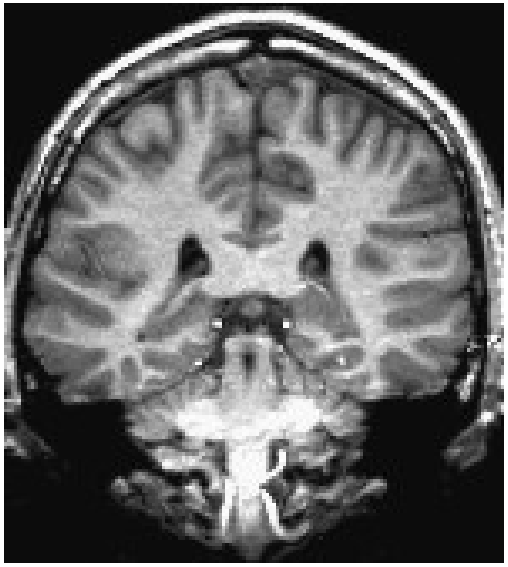
- Switch viewing/analysis between many different datasets
- Image display in axial, sagittal, and/or coronal views (with multi-image montages)
- Time series graphing of square regions linked to image viewers
  — i.e., click on a pixel and see the graph of its data
- Linked image/graph viewing of multiple 3D datasets
  — i.e., linked scrolling through multiple brains
- Computation of activation maps using correlation, linear and nonlinear regression
- Color overlay of activation maps onto higher-resolution anatomical images
  — resampling of lower-resolution functionals is handled on the fly
- Display of volume rendered anatomy with activation maps embedded
- Interactive thresholding of functional overlays
- Transformation to Talairach coordinates
  — followed by voxel-wise statistical analysis of inter-subject data (e.g., ANOVA)
- Manual selection of regions-of-interest (ROIs)
  — followed by statistical analysis of ROI-averaged data

FMRI Background Concepts

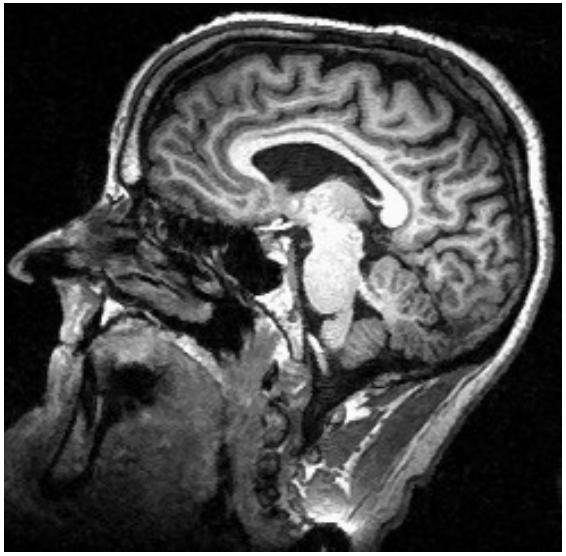
- Typical FMRI experiment produces at least two kinds of images:
- High-resolution T1-weighted anatomical (AKA structural) volumes
  - ◇ Imaging methods are called SPGR by GE, MP-RAGE by Siemens, ...
  - ◇ Takes 3–9 minutes to acquire one volume at about 1 mm^3 resolution



[Axial SPGR]



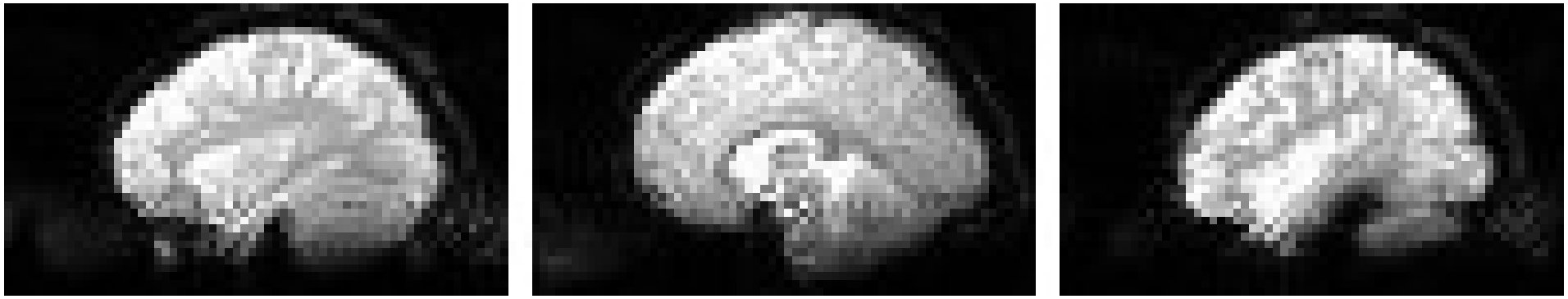
[Coronal SPGR]



[Whole Head Sagittal SPGR]

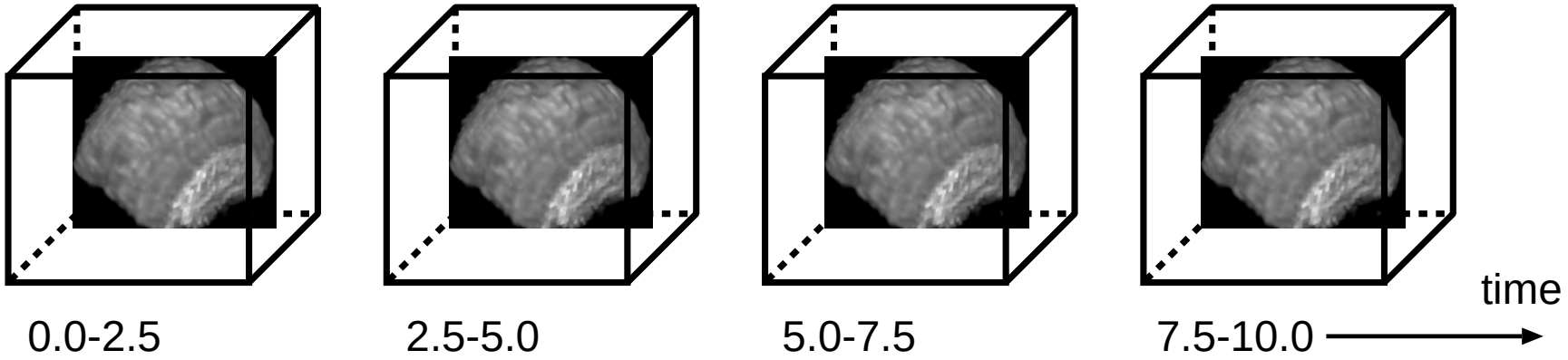
  - ◇ FMRI purposes for such images:
    - ↪ Anatomical localization (recognizing where you are in the brain)
    - ↪ Recognition of gray and white matter regions by image intensity
    - ↪ Extraction of cortical surface (e.g., gray-white boundary)

- Low-resolution T2-, T2*-, or perfusion-weighted functional volumes
  - ◇ Several similar imaging methods (pulse sequences) are in use:
    EPI (echo-planar imaging), Spiral, PRESTO, Burst/DUFIS
  - ◇ Takes $\approx$ 100 ms to acquire a single 2D slice
    (exact speed depends on pulse sequence and scanner hardware)



[Three Sagittal EPI Slices]

- ◇ Speed of acquisition $\Longrightarrow$ can acquire $\approx$ 100 brain volumes in a few minutes



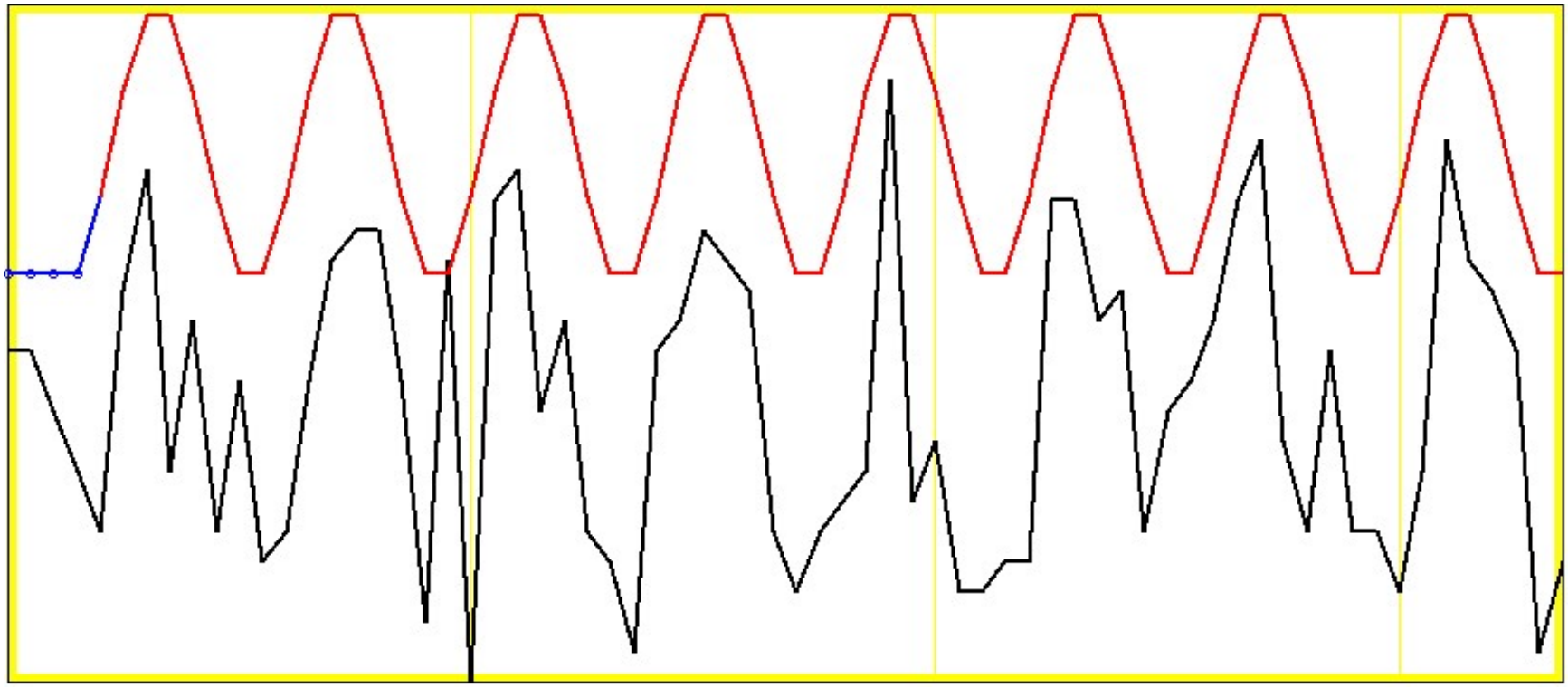
[Cartoon of 3D Brain Image Time Series, with TR=2.5 s]

◇ Typical brain size (L-R) $\approx$ 140 mm $\Longrightarrow$ usually use 3-6 mm slice thickness

◇ FMRI purposes for such images:

↪ MRI signal intensity depends on blood flow and oxygenation changes

↪ Blood flow and oxygenation fluctuate with neuronal metabolism on a 5–10 s timescale:

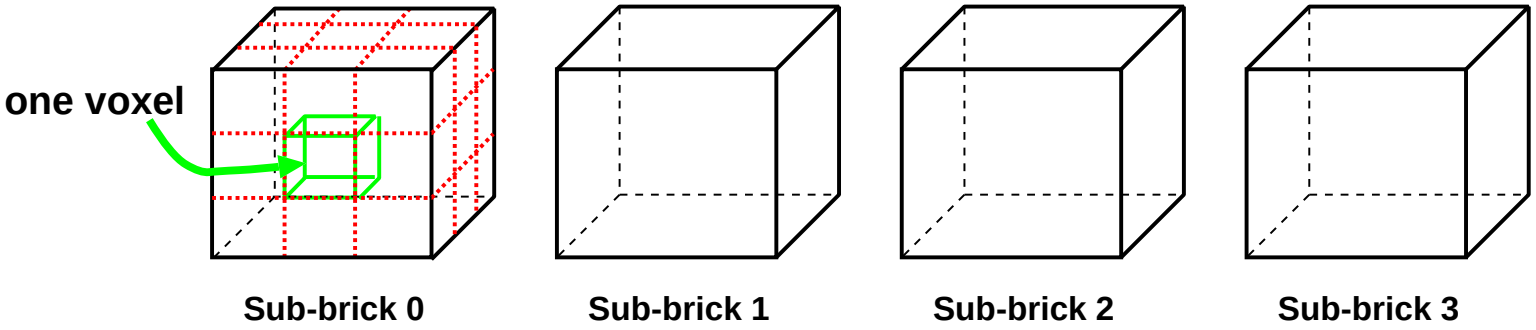


[Graph of Data Time Series from One Voxel, with Task Alternation Shown On Top]

- For background information on FMRI physics, see `http://afni.nimh.nih.gov/afni/mrip/index.html`

Fundamental AFNI Concepts

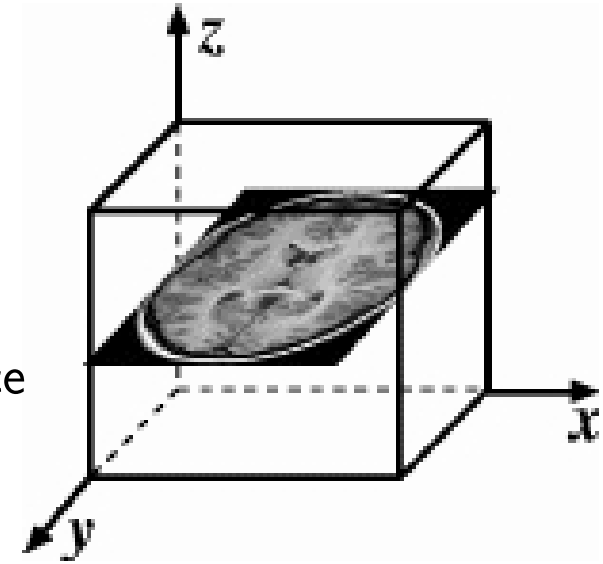
- AFNI is the name of both the original interactive program and the collection of batch (command line) programs that have grown up around it in the last 7 years.
- Basic unit of data in AFNI is the dataset:
  - ◇ A collection of 1 or more 3D arrays (tables) of numbers
    - ↪ Each entry in the array is in a particular spatial location in a 3D grid (a voxel)
    - ↪ Image datasets: each array holds a collection of slices from the scanner; each number is the signal intensity reported by the scanner for that particular voxel
    - ↪ Derived datasets: each number is computed from one or more other datasets (e.g., each voxel value is the average intensity at that spatial location from a number of different image acquisitions)
  - ◇ Each 3D array in a dataset is called a sub-brick; there is one number in each voxel in each sub-brick:



[Cartoon of a $3 \times 3 \times 3$ AFNI Dataset with 4 Sub-Bricks]

- Different types of numbers can be stored in datasets: 8 bit bytes (grayscale photos); 16 bit shorts (MR images); 32 bit floats (calculated values)
- Besides the voxel values, a dataset also contains auxiliary information, including (some of which is optional):
  - ◇ xyz-dimensions of each voxel (in mm)
  - ◇ Orientation of dataset axes;
    for example, x-axis = R-L, y-axis = A-P, z-axis = I-S $\Longrightarrow$ Axial slices

    R=Right, L=Left,
    A=Anterior, P=Posterior,
    S=Superior, I=Inferior



  - ◇ Location of dataset in scanner coordinates;
    in particular, the slice offset = z-coordinate of 1st slice
  - ◇ Time/date of creation
  - ◇ Time between sub-bricks (TR), for 3D+time datasets

  ↪ 3D+time datasets are the basic unit of FMRI data (one per imaging run)

  - ◇ Type of data stored in each sub-brick (anatomical? functional?)
  - ◇ Statistical parameters associated with each sub-brick;
    e.g., a t-statistic sub-brick has the degrees of freedom (a single number) stored

- Datasets are stored in 2 files:
  - ◇ The `.BRIK` file holds all the numbers in all the sub-bricks:
    a $100 \times 100 \times 100$ dataset would have 1,000,000 numbers per sub-brick
  - ◇ The `.HEAD` file holds all the auxiliary information
- Datasets can be in one of 3 coordinate systems (also called views):
  - ◇ Original or `+orig` view: The original (scanner) coordinate system
  - ◇ AC-PC Aligned or `+acpc` view: Where the dataset is rotated so that the anterior commissure (AC) and posterior commissure (PC) are horizontal, the AC is at $(x, y, z) = (0, 0, 0)$, and the longitudinal (inter-hemispheric) fissure is vertical
  - ◇ Talairach or `+tlrc` view: Where the dataset has been further squeezed/stretched to have its size conform to the Talairach-Tournoux atlas;
    coordinates in this view are often called Talairach or stereotaxic coordinates
- Dataset filenames consist of 3 parts:
  - ◇ The user-selected prefix (almost anything)
  - ◇ The view (one of `+orig`, `+acpc`, or `+tlrc`)
  - ◇ The suffix (one of `.HEAD` or `.BRIK`)
  - ◇ Example: files `ElvisPresley+tlrc.HEAD` and `ElvisPresley+tlrc.BRIK`
  - ◇ When creating a dataset with an AFNI program, you specify the prefix — the program does the rest

- Datasets are stored in directories called sessions
  - ◇ All the datasets in the same session, with the same view, are presumed to be aligned in xyz-coordinates — voxels with the same value of (x, y, z) are presumed to correspond to the same brain location
  - ◇ In the interactive AFNI program, you can overlay one dataset on top of another, even if their orientations and voxel sizes differ — this is how low-resolution functional data is combined with high-resolution anatomical data to produce cool looking images
  - ◇ Typical AFNI contents of a session directory are all the data derived from a single scanning session for one subject:
    - ↪ Anatomical dataset (1 sub-brick)
    - ↪ 10–20 3D+time datasets from EPI functional runs (100? sub-bricks each)
    - ↪ Statistical datasets derived from the 3D+time datasets, showing functional activation (we hope)
    - ↪ Datasets transformed from `+orig` coordinates to `+tlrc` coordinates — for comparison and integration with datasets from other subjects
- AFNI will load all the datasets in all the directories specified on its command line
  - — Might be 100s or 1000s of datasets
  - — current limit: max of 1024 datasets per session
  - — current limit: max of 80 sessions per AFNI run

Installing AFNI on Your Computer

- AFNI runs on Unix systems: Linux, Sun, SGI, HP
  — To find out when it will run on Microsoft Windows, see FAQ #2
- Best way to install: have a computer that somebody else manages for you, and get him/her to do this task
- Second best way: if you are at the NIH, then I can auto-install AFNI upgrades onto your system, if you give me an account there
- Third best way: install a pre-compiled binary package from the AFNI distribution computer using program wget;
  — the following command installs the Linux (Mandrake 7.2) binaries:

```
wget -nv -m -np -nH -P /usr/local/abin --cut-dirs=3 \
     ftp://afni.nimh.nih.gov/AFNI/bin/linux_mdk72
```

  — Solaris (Sun) 2.6 and 2.8 binaries also available at this time
- Fourth best way: download the source code and compile it
- AFNI Web site: `http://afni.nimh.nih.gov/afni`
  — Documentation, FAQ list, Installation instructions, Humor, ...
- AFNI is updated fairly frequently (monthly or so)
  — the auto-install method is a good way to stay current