Blurring FMRI Data to a Specified Smoothness

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Why Do Spatial Blurring?

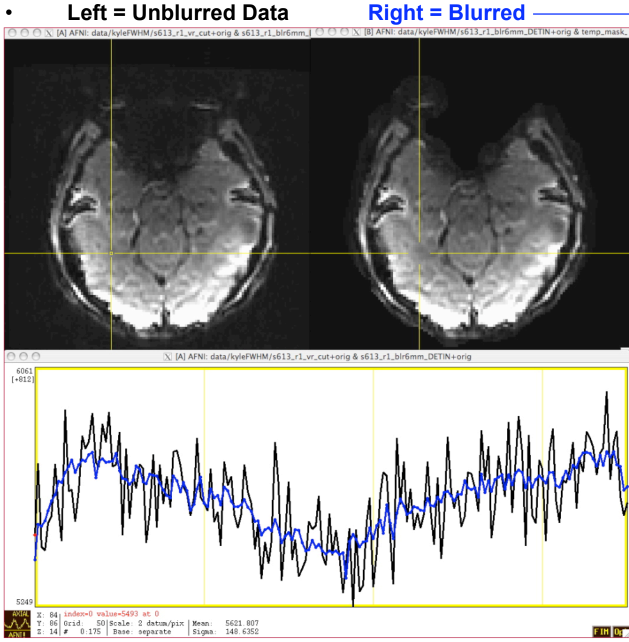
- Reduce noise variance (*i.e.*, by averaging)
- Reduce number of independent comparisons (*e.g.*, test peaks for significance using theory of excursions in smooth random fields)
- Tune the spatial detection to find blobs about the size you expect (*i.e.*, reinforce signals, cancel noise)
- Increase overlap for group analysis (*i.e.*, to allow for inter-subject anatomical variability)
- Make sure that all the data collected from various scanners and/or pulse sequences have similar noise properties, so that combining activation maps (*i.e.*, group analysis) makes sense [1]

Downsides to a Modest Amount of Blurring

- Reduction of spatial resolution (*e.g.*, two blobs on nearby gyri could be smeared together across a separating sulcus)
- Mixing of data from brain voxels with non-brain voxels (*i.e.*, can't possibly improve SNR this way, since non-brain voxels don't have useful signal)
- Can "overblur" some areas, if intrinsic spatial smoothness of images is not uniform

Example: 1.5 mm data 3D blurred to FWHM = 6 mm

- **Left = Unblurred Data** **Right = Blurred**



Smart Blurring: Goals

- Don't blur across user-specified boundaries (*e.g.*, brain edge; gray-white boundary)
- Blur until smoothness of noise reaches a specified value (*i.e.*, so images from diverse sources can be analyzed together)
- Control blurring locally, so that "over-smoothing" is avoided

Smart Blurring: Methods

- Blurring done by conservative finite difference approximation to linear non-uniform diffusion equation

$$u_t = \nabla \cdot [\mathbf{D}(\mathbf{x},t)\nabla u(\mathbf{x},t)]$$

  - Non-uniform $\mathbf{D}(\mathbf{x},t)$ (diagonal but non-isotropic) allows for speeding up blurring in less-smooth areas and slowing it down in areas near the target smoothness
  - Finite difference method allows imposition of Neumann (reflecting) boundary conditions, to prevent leakage outside region chosen for smoothing
    - Euler method pseudo-time step Δt must be controlled to prevent instability (or negative amplification factors)
- Image smoothness estimated in each direction, locally and globally, using variance of first differences [2]
  - Must also control for inter-voxel variance fluctuations!
  - Smoothing controlled by "blur master" dataset, which should be residuals (noise) from GLM regression model
    - Second best blur master: detrended EPI time series with inter-voxel variance equalization
- **Software**: new program `3dBlurToFWHM` in AFNI package
  - 2D (in-slice) or 3D blurring to user-specified global FWHM

See Also

- Poster **Mon PM #256** by Chen *et al*. (SEM in AFNI)
- Poster **Tue PM #336** by Saad *et al*. (What's New in AFNI & SUMA)
- Downloads at **http://afni.nimh.nih.gov/sscc/posters**
- Poster **Thu PM #268** by Friedman *et al*. (Multichannel Coils in FMRI)

References

[1] **L Friedman, GH Glover, D Krenz, V Magnotta.** Reducing inter-scanner variability of activation in a multicenter fMRI study: Role of smoothness equalization. *NeuroImage* **32**:1656-1668 (2006).

[2] **SD Forman, JD Cohen, M Fitzgerald, WF Eddy, MA Mintun, DC Noll.** Improved assessment of significant activation in functional magnetic resonance imaging (fMRI): Use of a cluster-size threshold. *Magnetic Resonance in Medicine* **33**:636-647 (1995).