Visualization and quantification of fMRI results
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Outline
1. Volume-based visualization
2. Surface-based visualization
3. Quantification

Volume-based visualization
- Select SPM.mat
- Select/create contrast
- Define threshold
- Overlay thresholded SPM(t)-map on an anatomical image

Objects > texture
Movement > still
Outline

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2. Surface-based visualization
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Surface-based visualization

- **Why?**
  - Cortex highly folded
  - Several brain areas contain a topographic representation (e.g., retinotopy in visual areas) that follows cortical surface and not volumetric coordinate system
  - Surface-based inter-subject averaging

- **How?**
  - Brain structures segmented from an anatomical MRI
  - Cortical surface reconstructed based on the border between gray and white matter
  - Reconstructed cortex inflated into a smooth 3D surface and/or unfolded onto a 2D sheet

Surface-based visualization

"FreeSurfer is a set of automated tools for reconstruction of the brain’s cortical surface from structural MRI data, and overlay of functional MRI data onto the reconstructed surface."

http://surfer.nmr.mgh.harvard.edu

- FreesurferWiki
- Freesurfer Mailing List Archive

Other software options with surface-based visualization tools: SUMA, BrainVoyager, Caret,…

fMRI data from SPM8 to Freesurfer

1. Convert the high-resolution anatomical image to NIFTI format with Freesurfer: `mri_convert orig.mgz anat.nii`
2. Copy new fMRI data to Freesurfer subject directory (e.g., spmT-maps, mean functional image, low-resolution anatomical image measured in the same session with functional data)
3. Coregister with SPM8: `Coregister (Estimate)`
   - Reference image: anat.nii
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   - Source image: mean functional image, spmT-maps, ...
4. Create register.dat file with Freesurfer: `tkregister2 --mov mean*img --s Subject --nghheader --new --reg register.dat`
5. Check coregistration with Freesurfer: `tkregister2 --mov mean*img --s Subject --reg register.dat --surf`
6. Visualize data with Freesurfer: `tksurfer Subject rh inflated`
Flattening occipital cortical surface

1. Make cut along calcarine sulcus
2. Specify cutting plane
3. Save the patch of cortex

Surface-based averaging across individuals

- Assigning data to average surface in Freesurfer
  - mri_vol2surf
    - assigns data from a volume image to cortical surface vertices
    - target and source subjects can differ – inter-subject registration via the spherical cortical surfaces
    - output: .w files
- Averaging data in matlab
  - Read individual data assigned to average cortical surface with matlab function read_wfile.m
  - Average the values with matlab
  - Save the averaged data with write_curv.m or write_wfile.m

Surface-based visualization – References

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Quantification of fMRI results

- fMRI is an indirect measure of neural activity!
- Absolute magnitude of an fMRI response is typically not very useful, because it depends on:
  - voxel size, proportion of gray matter in a voxel, local vascular density, number of voxels in a cluster, physiological variability in signal strength, field strength,...
  - fMRI provides a relative measure of neural activity
    - Percent signal change over baseline
      (a) relative tuning to various stimuli at a single cortical location
      (b) spatial maps
      (see, e.g., Logothetis, Wandell. Annu Rev Physiol. 2004.)

Quantification of fMRI results

\[ Y = X\beta + \varepsilon \]

\[ \% \text{ signal change} = \left( \frac{\bar{Y}_{\text{fROI}}}{Y_B} \right) \times 100 \]

Functional region-of-interest (fROI) analysis

- Substantial variation in locations and sizes of well-known brain areas across individuals!
- Functional region-of-interest (fROI) analysis
  1. For each subject, regions-of-interest identified with independent functional localizers.
  2. Test hypothesis within these fROIs / Calculate summary measures of responses within these fROIs.
  3. Combine results across subjects.

fROI analysis

1. Get beta values for each voxel
   (SPM8:spm_get_data(imagefile,XYZ))
2. Calculate % signal changes for each voxel
3. Average across voxels within an fROI
4. Average across subjects
fROI analysis

Selectivity index: \( \frac{R_1 - R_2}{R_1 + R_2} \)

Group average selectivity index map

Towards quantitative fMRI with calibration?

- BOLD response depends on changes in cerebral metabolic rate of oxygen consumption (CMRO2), cerebral blood flow (CBF), and cerebral blood volume (CBV)
  - Variability in the amount of deoxyhemoglobin at the baseline condition – ceiling on the BOLD effect
  - Variability in coupling of CBF and CMRO2 changes
  - Calibrated fMRI (Davis et al., PNAS 1998)
  - Measure BOLD and CBF responses (technique called Arterial Spin Labeling, ASL)
  - Activation during stimulation/task and during mild hypercapnia (breathing a gas with 5% CO2)


Conclusions

- Without calibration, fMRI provides only a relative measure of neural activity
  - It’s typically not a good idea to compare fMRI response amplitudes at two locations or between subjects
  - Spatial maps, tuning functions, selectivity indexes, ...
  - Be careful how you define your ROIs and quantify the result!
Thank you!