You have an fMRI dataset and are ready to write it up. How should you report and present the data?

One option

• Find an automated method to tell you where your activations are
• Black-box neuroanatomy

A better option

• Learn some neuroanatomy
• Visualize your data overlaid on anatomy
Atlases

Describing fMRI data
- Visualizing and presenting activation
- Labeling activation

Visualizing individual data
- Use mean functional image

Visualizing group data
- Use a background image that reflects the anatomy and any applied smoothing
Using full color maps to visualize statistical maps

Rendering group data: Beware of SPM rendering

Rendering group data to a population surface atlas in CARET

Labeling activation
Brodmann’s areas

Why T&T+BA is a bad idea

- T&T guesstimated where BA's fell
- We can’t determine where BA's are in imaging studies
- They are in different places for different people
- Not clear that BA's are functional areas

http://www.bic.mni.mcgill.ca/cytoarchitectonics/

A better option

- Probabilistic anatomical maps are available for many areas
  - SPM Anatomy toolbox
  - FSLView integrated atlases
**Why use region of interest analysis?**

- Characterize/explore signal
- Limit correction for multiple comparisons
- Examine functionally characterized regions

**ROIs for exploration**

- With complex designs, it is often difficult to tell what is going on simply by looking at maps
- Plotting signal from ROIs can be enlightening

**ROIs for statistical control**

- Control for multiple tests over the whole brain can be highly conservative
- Limiting the number of tests (voxels) can increase power
  - Only when you have a pre-existing anatomical hypothesis
  - Can’t do this based on the results of another analysis of the same data!
Example

• P<.001, whole brain (2410 resels)
  – Cluster with 41 voxels
    • P=0.465
• P<.001, small volume correction for 10 mm radius sphere (5.7 resels)
  – Same cluster: p=.002

Functional characterization

• Regions defined by functional localizer scans
  – E.g., visual retinotopy
• Ensures that you are studying a functionally coherent area
  – Different voxels for different subjects

Furmanski et al., 2004
Circular analysis

Run whole-brain analysis
Extract signal from significant voxel/cluster
Perform statistics on extracted data
Of course it's strongly correlated!

• Independent:
  • ROI determined independently from the data being analyzed

• Non-independent:
  • ROI determined from the same data being analyzed

• Correlations are substantially higher for non-independent analyses

Vul et al., 2009

How much bias do non-independent analyses introduce?

<table>
<thead>
<tr>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voxel</td>
<td>Test r</td>
<td>Train r</td>
</tr>
<tr>
<td>297</td>
<td>0.503</td>
<td>0.761</td>
</tr>
<tr>
<td>296</td>
<td>0.230</td>
<td>0.793</td>
</tr>
<tr>
<td>311</td>
<td>0.406</td>
<td>0.760</td>
</tr>
<tr>
<td>301</td>
<td>0.475</td>
<td>0.675</td>
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<tr>
<td>346</td>
<td>0.641</td>
<td>0.002</td>
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<tr>
<td>492</td>
<td>0.320</td>
<td>0.061</td>
</tr>
<tr>
<td>488</td>
<td>0.470</td>
<td>0.793</td>
</tr>
<tr>
<td>624</td>
<td>0.511</td>
<td>0.025</td>
</tr>
<tr>
<td>711</td>
<td>0.906</td>
<td>0.797</td>
</tr>
<tr>
<td>1135</td>
<td>0.552</td>
<td>0.006</td>
</tr>
<tr>
<td>Bias</td>
<td>0.193</td>
<td>0.210</td>
</tr>
</tbody>
</table>

The columns include the number of voxels in the cluster, along with the correlation (Pearson r) between neural and behavioral loss aversion on the test (i.e. independent) and training (non-independent) data, respectively. Bias (presented in the bottom row) is computed by subtracting the mean correlation for test (independent) data from the correlation for training (non-independent) data across all clusters.

Poldrack & Mumford, in press

The importance of controlling for multiple tests

2 mm whole-brain data ➔ over 250,000 tests without correction, Type I error ~ 1
Heuristic corrections

- commonly used:
  - $p < .001 - .005$
  - 5 - 25 voxel extent

- These corrections are not adapted to the data (e.g., # of tests, smoothness) and are guaranteed to be incorrect (either too liberal or too conservative)!

How bad is this, really?

- Took data for 16 subjects (Tom et al., 2007)
- Created a random “individual difference” regressor across subjects
- Perform regression to find regions with “significant correlation”
  - $p < .001$, 25 voxel extent threshold
  - Extract signal and plot against regressor

Bias and small volume correction

- SVC should NEVER be based on knowledge of the results

beautiful results from noise!

No significant voxels using FWE or FDR control
What do you need to include in a paper describing an fMRI study? Ten simple rules

**Rule 1. Think about your readers, today and in the future.**

- Think of all the people who might read an fMRI paper
  - Physicists, neuroscientists, psychologists, statisticians, anatomists
  - Do your best to satisfy the requirements of all of them!
- In 20 years, will “Data were analyzed using SPM99” be meaningful to anyone?

**Rule 2. Describe both who the subjects were and who they weren’t.**

- Demographics
- Inclusion/exclusion criteria
- If scanned subjects were excluded after data collection, how many and why?

**Rule 3. Describe both what the subjects were asked to do, and what they actually did.**

- Task should be described in a way sufficient to reproduce it
- Behavior should always be described
  - Accuracy, response times
Rule 4. Know what “Talairach space” is and what it isn’t.

- “Talairach space” means different things to different people
- MNI ~= Talairach atlas space

Rule 5. Specify how regions of interest were determined.

- If functionally determined, say specifically how
- If anatomically determined, give specific rules for delineation

Rule 6. When using a new analysis method, provide enough detail to implement the analysis.

- If possible, provide actual code
- In paper, describe as algorithm or pseudocode
**Rule 7. When using an existing analysis method, provide enough detail to reproduce the analysis.**

- Simply saying “we used FSL” is not enough
- Give details for all processing steps
- Give software versions

**Rule 8. Report statistical tests to support all claims**

- “The Imager’s fallacy” (Henson, 2005)
  - “Striatum was more active in condition 2 than condition 1”
- Difference in significance does not imply a significant difference

<table>
<thead>
<tr>
<th>Condition 1</th>
<th>Condition 2</th>
</tr>
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</table>

Region X is activated in Condition 1 but not in condition 2. Does this mean that there is a difference between these conditions?

**Common problems**

- Differences between hemispheres
- Differences between regions
- All such differences need to be supported with specific statistical tests for the difference
Rule 9. Always describe and account for the multiple testing problem.

- Number of voxels
- Smoothness of data (actual, not applied, if known)
- Specify approach for control of FWE or FDR
- Uncorrected p-values must be labeled as such

Rule 10. Figures and tables should stand on their own.

- Captions should provide important details
  - Figures
    - Nature of map, thresholds applied
  - Tables
    - Statistics regarding cluster
    - Include effect sizes if possible
    - Means by which labels were determined

What details should I include?

- www.fmrimethods.org