Outline:
I. Leftovers from Experimental Design
   event-related versus blocked designs
   why use functional regions of interest?
   two-factor designs, main effects, interactions
II. Category Selective Regions of Visual Cortex
    and Haxby’s Important Critique
III. Neural Decoding
IV. Short Quiz at 12:17
Decisions toward an Actual Experiment

1. What exact conditions will you run in each experiment?
   strive for minimal pairs that manipulate just one mental process
   this is the crux of the matter in experimental design

2. What task will subject do in the scanner?
   for visual experiments usually passive viewing or 1-back
   don’t have diff tasks for diff stimuli, that could introduce a ________?

3. Will you have “baseline” conditions? Of what? Why?
   for vision, staring at a cross (no eye movements)
   useful to have a baseline of minimal visual processing
   to look at not just the difference in response, but the RATIO

[Graph showing bar chart with categories labeled MEH]
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   for vision, staring at a cross (no eye movements)
   useful to have a baseline of minimal visual processing
   to look at not just the difference in response, but the RATIO
   need some kind of baseline to measure selectivity.
   one the other hand there is no perfect baseline
Decisions toward an Actual Experiment

Suppose you get to scan ten subjects for one hour each.

4. Will you assign different conditions to different subjects, or have each subject do all conditions?
   Whenever possible, run all conditions within subjects.
   Suppose 1/3 of class was always graded by Heather, 1/3 always by Dana, and 1/3 always by Anya? Would that be fair?

Neither is it “fair” to use different people’s brains for different conditions.
When is a completely within-subjects design not possible?

5. How many “runs” will you include, and which conditions will happen in each run (e.g., 1 cond/ run, or all conds in each run, etc.)?
   Have all conditions within each run if possible, so differences across runs (e.g. in how sleepy the subject is) affect all conditions equally.

7. If multiple conditions per run, will they be clumped or interleaved?

8. What rate of presentation?

9. What order of stimuli/conditions within or across runs?
   Many tradeoffs here...

10. How exactly will you analyze your data?
Blocked (clumped) vs. Event-related (mixed)

What is the challenge with rapid mixed?

Source: Buckner 1998
Observed: the sum of all of these:
Uh-oh.
The crazy thing:
All these events add up almost linearly, so with enough repetitions of each condition, you can pull out the response to each condition. It just takes a lot of trials.

Tradeoff:
Blocked: Big effects w/out lots of data.
Event-related: conditions unpredictable, but need more data to detect differences ($$$).
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Brains differ from one another and so cannot be perfectly aligned.

It is like trying to align faces: No matter how hard you try, someone’s mouth will land on someone else’s chin.

If you were a dermatologist studying skin cancers that arise on the upper lip, it would be sloppy to just align photos and choose one location. That may or may not be the upper lip in any individual face. Instead, find each person’s upper lip, then study that.

Similarly, the exact location of the FFA varies from subject to subject. So, if you want to study it, you have to first find it with a localizer scan in each subject, then you can measure its response to new conditions.
So far, we’ve been talking about the simplest possible experimental design:

• Manipulate one factor with two levels (“conditions”), e.g.: e.g., faces & objects, snakes & nonsnakes, moving & stationary... of course, we could have more than two conditions:

or we could get fancy and...

• Manipulate 2 factors orthogonally (a “2x2 design”), e.g........

for example...
“Factorial Designs”

<table>
<thead>
<tr>
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<th>objects</th>
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<td>F/O</td>
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<td><img src="image2" alt="Object" /></td>
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<tr>
<td>Attended</td>
<td><img src="image3" alt="Face" /></td>
<td><img src="image4" alt="Object" /></td>
</tr>
<tr>
<td>Un-</td>
<td><img src="image5" alt="Face" /></td>
<td><img src="image6" alt="Object" /></td>
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<tr>
<td>Attended</td>
<td><img src="image7" alt="Face" /></td>
<td><img src="image8" alt="Object" /></td>
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</tbody>
</table>

This design enables us to ask.....

1. Does the response (in a given region) depend on stimulus category?
### “Factorial Designs”

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<thead>
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<tbody>
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<td><img src="image2.png" alt="Chair" /></td>
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<tr>
<td><strong>Un-Attended</strong></td>
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<td><img src="image4.png" alt="Chair" /></td>
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</table>

A “main effect” of stimulus type

1. Does the response (in a given region) depend on stimulus category?

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## “Factorial Designs”

<table>
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<tr>
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<td><img src="a.png" alt="Image" /></td>
<td><img src="a.png" alt="Image" /></td>
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</tbody>
</table>

A “main effect” of attention

2. Does the response (in a given region) depend on attention?

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**“Factorial Designs”**

<table>
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<th>objects</th>
<th>F - O</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attended</strong></td>
<td><img src="image1" alt="Attended Faces" /></td>
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<td><img src="image5" alt="Un-Attended Objects" /></td>
<td><img src="image3" alt="Triangle" /></td>
</tr>
</tbody>
</table>

What might the data look like and what would the different outcomes mean?.....

A difference of differences

**An interaction** of stim categ x attention

3. **Does the effect of stim category depend on attention?**

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Main Effects vs Interactions

Main effect of factor X: an overall effect of X (i.e., difference between X1 and X2).

An interaction of factor X and factor Y: The effect of X depends on Y (and vice versa).

What does this mean? What does this mean? What does this mean?

Main effect of stimtype
No main effect of attention
No interaction of stim x attention
What does this mean?

Main effect of stim
Main effect of attention
No interaction of stim x attention
What does this mean?

Main effect of attention
Intervention of stim x attention
What does this mean?

What is the key sign of an interaction?
Do the lines need to cross?
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Category Selective Regions in Visual Cortex

**Faces**  **Bodies**  **Places**

- FFA (faces)
- PPA (places)
- EBA (bodies)

*What else?*
Do other regions exist that are selective for other categories?

Some disagreement about: Tool regions? Hands?

No one finds selective responses for cars, chairs, food, or lots of others. So, some categories are “special”. Or are they?
Visual Cortical Regions Selectively Responsive to visual categories:

- Faces
- Bodies
- Places

Ongoing Controversies:
- Discrete regions vs gradients.
- Categories, or their correlated features?
- How specific?

The most serious challenge...
Visual Cortical Regions Selectively Responsive to visual categories:

Faces  Bodies  Places

Even if FFA responds weakly to chairs & cars, That does not mean it does not represent information about chairs and cars. Even low responses could hold information if the pattern of response across voxels is different for each category. How would we tell?
Does the FFA hold Information about Nonfaces (e.g., cars versus chairs)?

1. Collect fMRI response to chairs and cars, for each voxel in FFA.
2. Repeat in same subject.
3. Now ask: is the pattern more similar within a category... than between categories

What does this method reveal about FFA?

If \( r(\text{Within}) > r(\text{Between}) \), the region contains info. distinguishing cars & chairs!
Does the Pattern of Response Across Voxels in the FFA Contain Information about Nonfaces? **YES!**

“Regions such as the .... ‘FFA’ are **not dedicated to representing only** ... human faces.. but, rather, are part of a more extended representation for all objects”.

Spiridon & Kanwisher (2002): no

O’ Toole, Haxby et al. (2005): not very much
“preferred regions for faces & houses **are not well suited to object classifications** that do not involve faces and houses, respectively.”

Reddy & Kanwisher (2007): uh, a little

**OK does that mean I am toast?**
Think about why? Why not?
**What other evidence suggests this is not the whole story?**
Visual Cortical Regions Selectively Responsive to visual categories:

- Faces
- Bodies
- Places

These regions contain small amounts of information about “nonpreferred” categories. An important critique of the selectivity story. But Haxby’s pattern analysis is also important for another reason....

We can ask: what information is present? That is, we can “decode” neural responses.
Neural Decoding with fMRI

*Can you read the mind with fMRI?*  
*Or at least tell what the person saw?*

1. Train your decoder.

Can we tell what stimulus the person saw?

Given a pattern of fMRI response across voxels in a particular brain region (e.g., V1 or FFA or EBA):

How can try this?
Neural Decoding with fMRI

Can you read the mind with fMRI?
Or at least tell what the person saw?

Does this work? A little bit. But don’t panic. Yet.

Won’t work for forcing testimony. But good enough for science. Sometimes. Many versions…

Machine Learning Pattern Classifier
Varieties of Neural Decoding

1. Can use decoding methods on many types of neural data.
   - Magnetoencephalography (MEG)
   - Time course of Magnetoencephalography (MEG) Response across sensors (at $t_x$)
   - Monkey Neurophysiology
   - Firing Rate across Neurons
   - "Neural population decoding"
   - Multiple Voxel Pattern Analysis (MVPA)

2. Many decoding methods: Haxby-style correlations, Machine Learning (SVMs, deep nets)

   **Let's compare**

   **TRAINING**
   - Shoe
   - Cat

   **fMRI**
   - of an ROI of whole brain

   **TESTING**
   - Shoe?

   "Multiple Voxel Pattern Analysis (MVPA)"
Neural Decoding: A Direct Comparison of fMRI versus Neurons

Question:
What information about faces is represented in AM?
Ask 2 ways….

Finding:
Can decode face identity from populations of neurons (neurophys), Not from populations of voxels in the same region (fMRI).

How can this be?
What are the implications?

Monkey Neurophysiology
167 neurons in AM
For each neuron, measure response to each of 5 different faces

Monkey fMRI
~100 voxels
For each voxel, measure BOLD response to each of 5 different faces

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A Powerful Use of MVPA: Testing Invariance

What information is represented here?

Very specific templates? Or more abstract (“invariant”) representations?

To find out: Train on one set of stimuli, and test on another.

e.g. Are there representations of shoes that are invariant to:

- color and viewpoint?
- the concept of shoe?

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