

9.13 The Human Brain Class 7

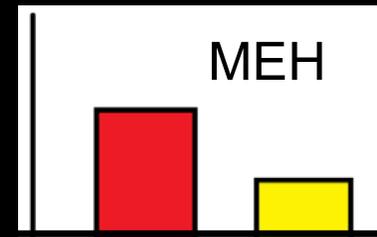
Category Selectivity, Controversies, and MVPA

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

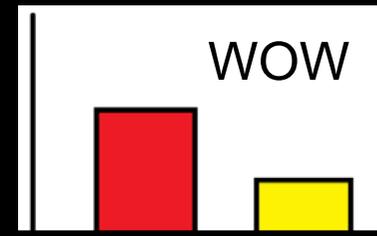
Decisions toward an Actual Experiment

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



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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?

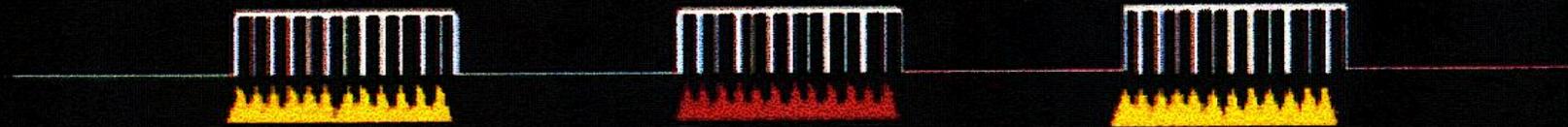
9. What order of stimuli/conditions within or across runs?

Many tradeoffs here...

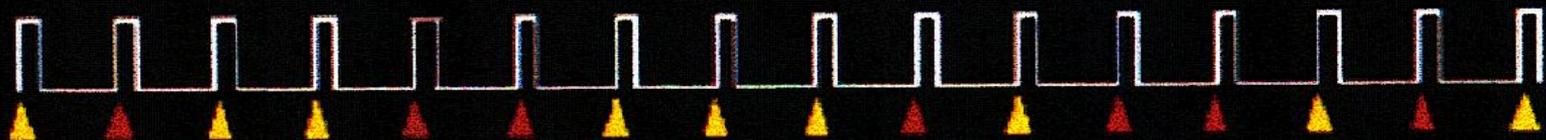
10. How exactly will you analyze your data?

Blocked (clumped) vs. Event-related (mixed)

BLOCKED:



SPACED MIXED TRIAL:



RAPID MIXED TRIAL:



Source: Buckner 1998

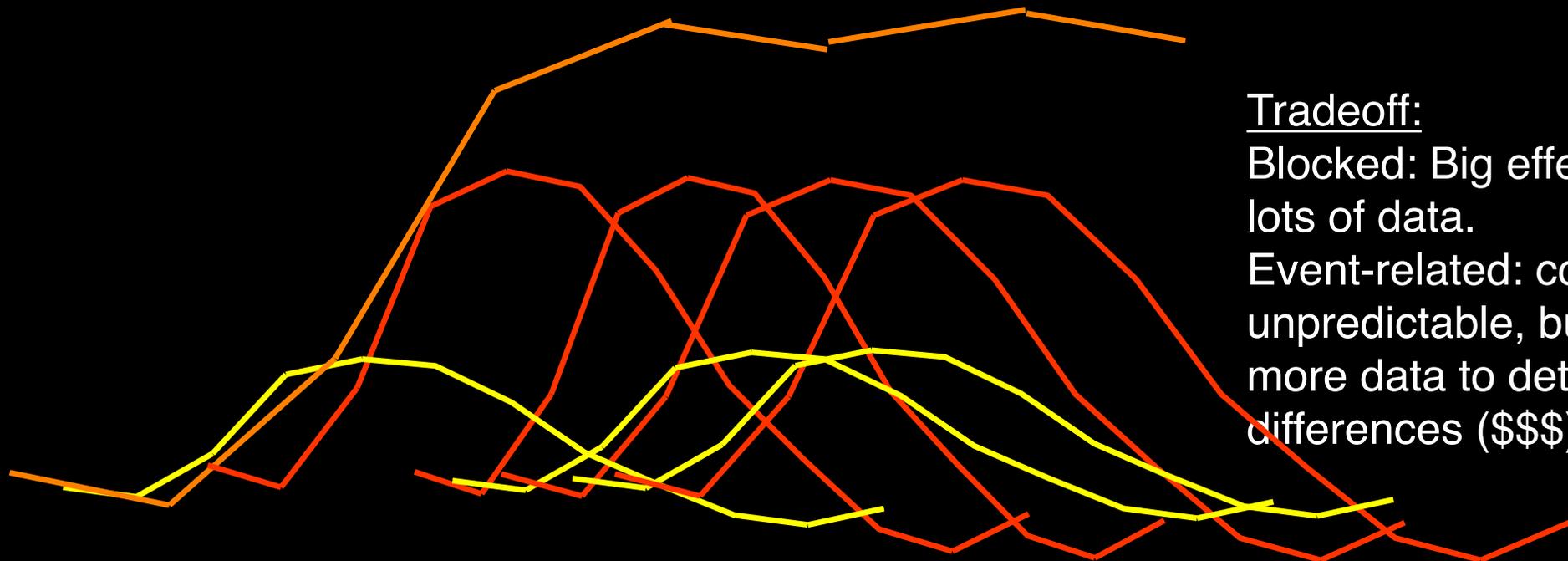
What is the challenge with rapid mixed?

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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9.13 The Human Brain Class 6

Experimental Design

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Why Use Functional Regions of Interest (fROIs) Defined in Each Subject Individually with a Localizer Scan

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 chose 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.

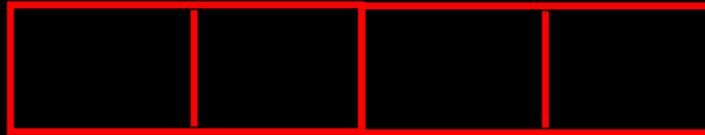
So, if you want to study it, you have to first find it with a localizer scan in each subject, then you can measure its response to new conditions.



Standard Designs

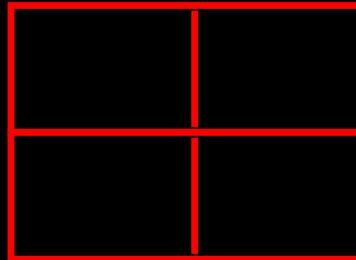
So far, we've been talking about the simplest possible experimental design:

- 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”

- What are the two factors?
- What are the levels (conditions) within each?

	faces	objects
F/O Attended		
F/O Un-Attended		

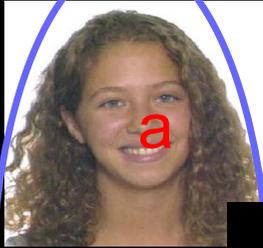
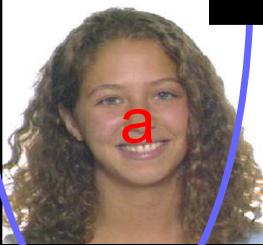
Monitor for Face/obj repetitions

Monitor for letter Repetitions

This design enables us to ask.....

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

“Factorial Designs”

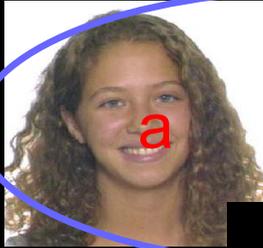
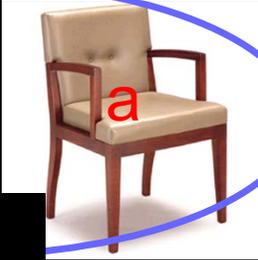
	faces	objects
Atten- ded		
Un- Atten- ded		

vs.

A “main effect” of stimulus type

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

“Factorial Designs”

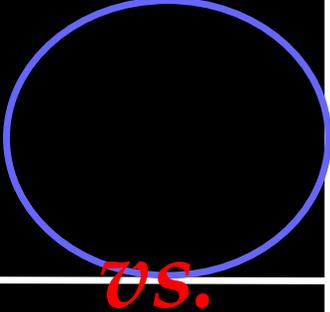
	faces	objects
Atten- ded		
	<i>vs.</i>	
Un- Atten- ded		

A “main effect” of attention

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

“Factorial Designs”

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

	faces	objects	F - O
Atten- ded			
Un- Atten- ded			

A difference of differences

An *interaction* of stim categ x attention

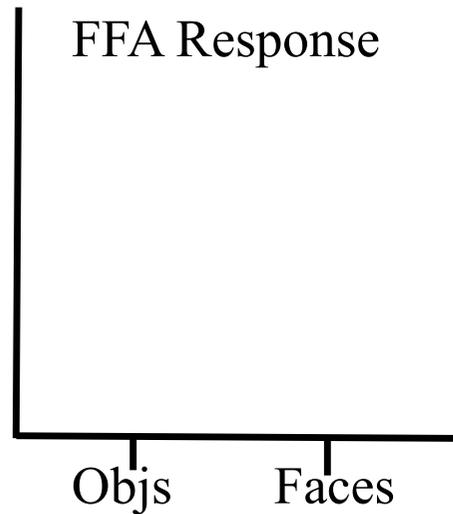
3. Does the effect of stim category *depend on attention*?

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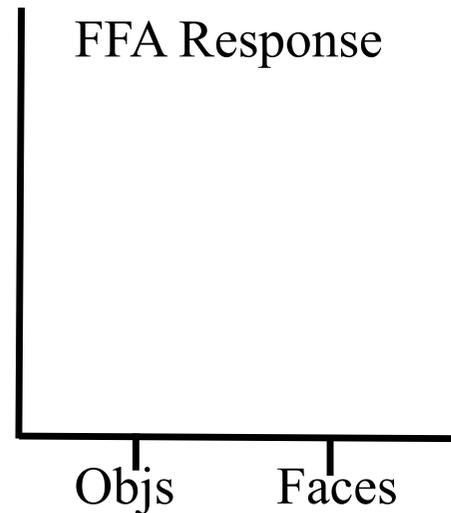
Main Effects vs Interactions

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

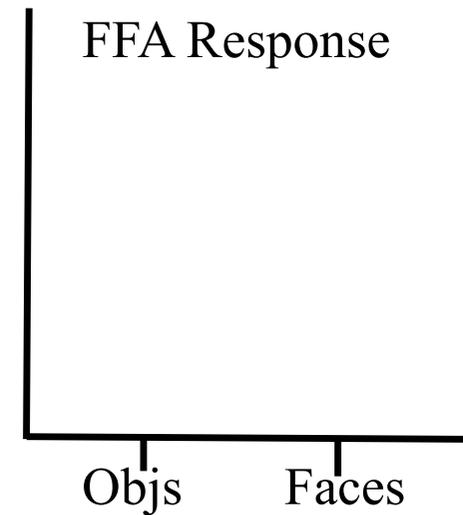
An interaction of factor X and factor Y: The *effect of X depends on Y* (& vv)



Main effect of stim type
 No main effect of atten
 No intxn of st x att.
 What does this *mean*?



Main effect of stim
 Main effect of atten
 No intxn of st x att.
 What does this *mean*?



Main effect of st
 Main effect of atten
 Intxn of st x att.
 What does this *mean*?

What is the key sign of an interaction?

Do the lines need to cross?

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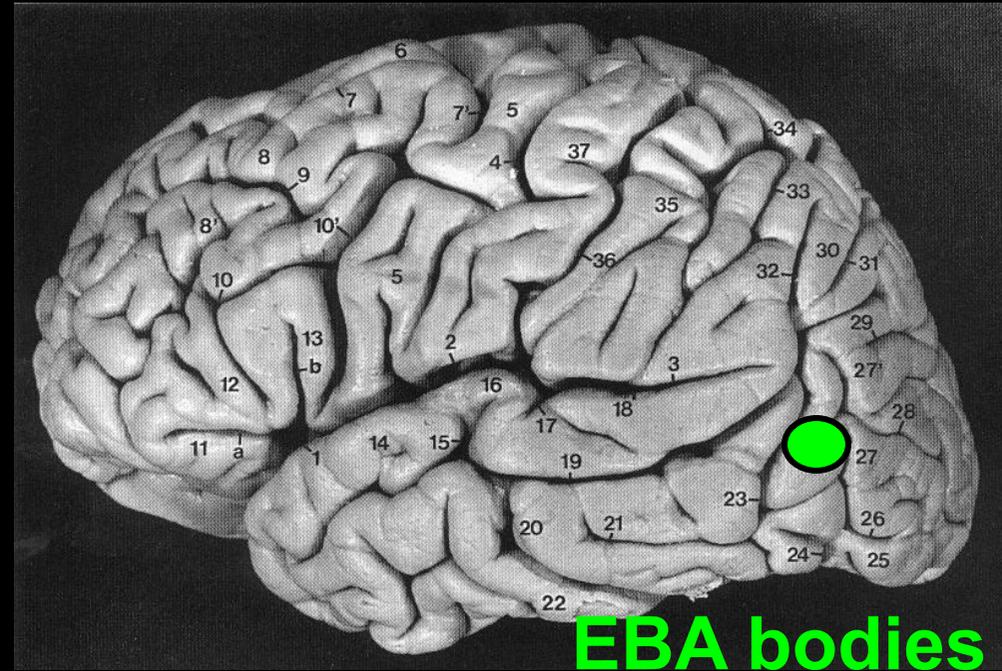
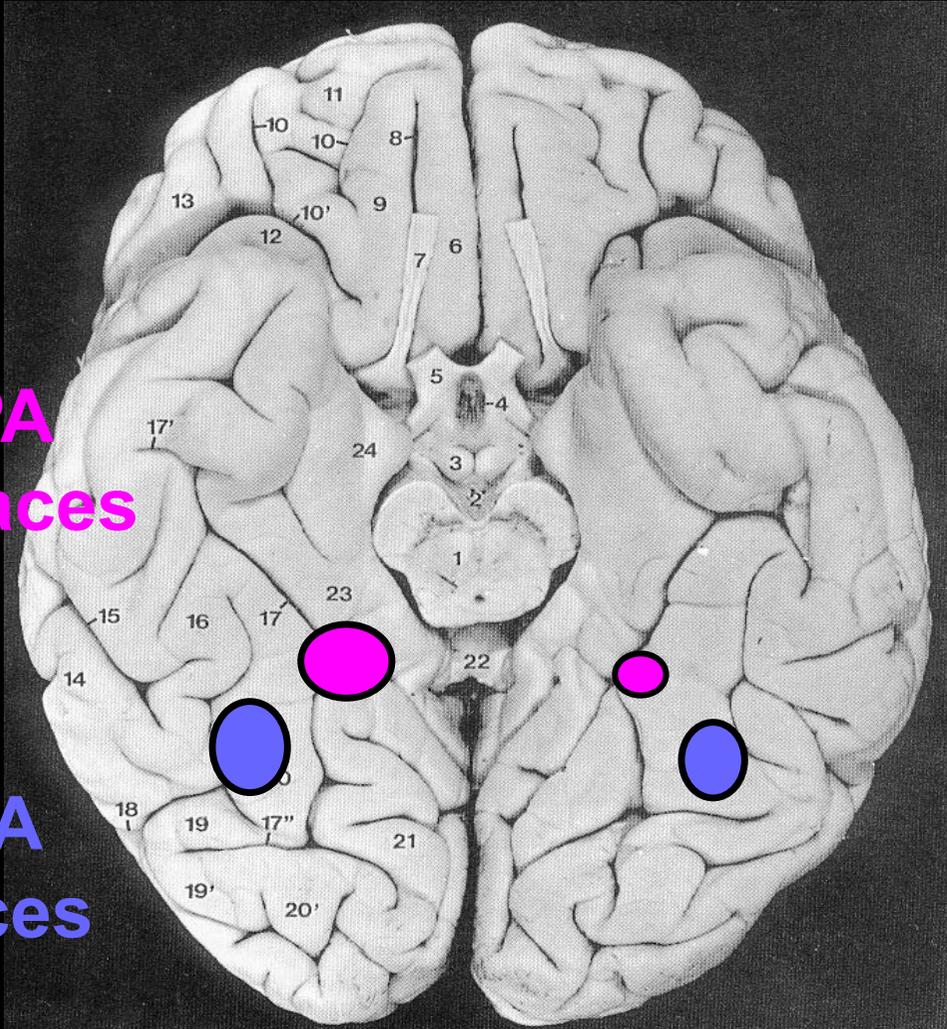


Category Selective Regions in Visual Cortex

Faces Bodies Places

PPA
places

FFA
faces



What else?

Do other regions exist that are selective for other categories?

Some disagreement about:
Tool regions?
Hands?



Downing et al. (2006)

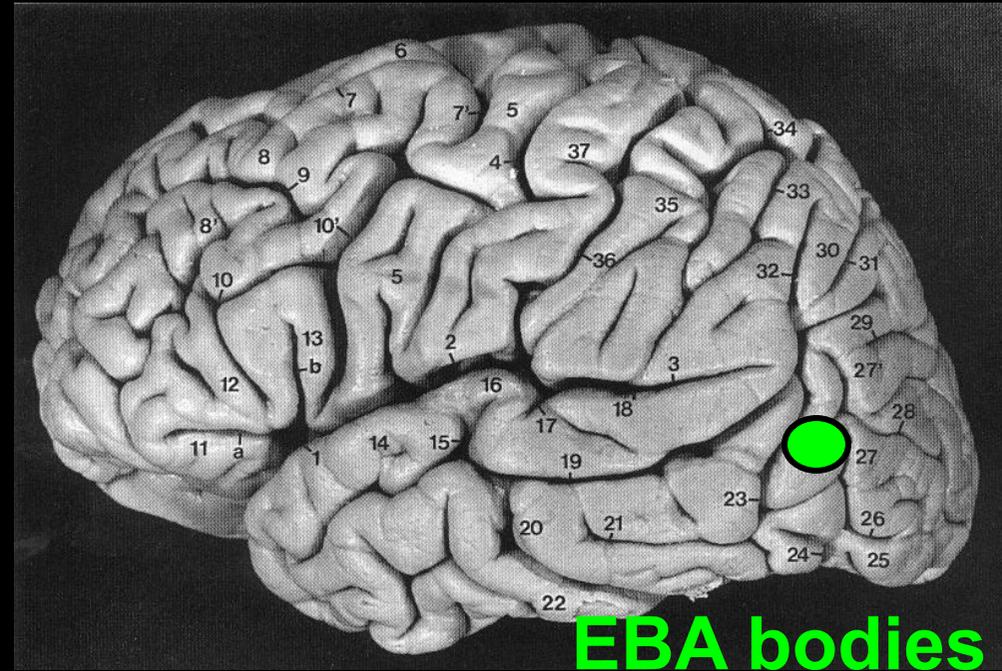
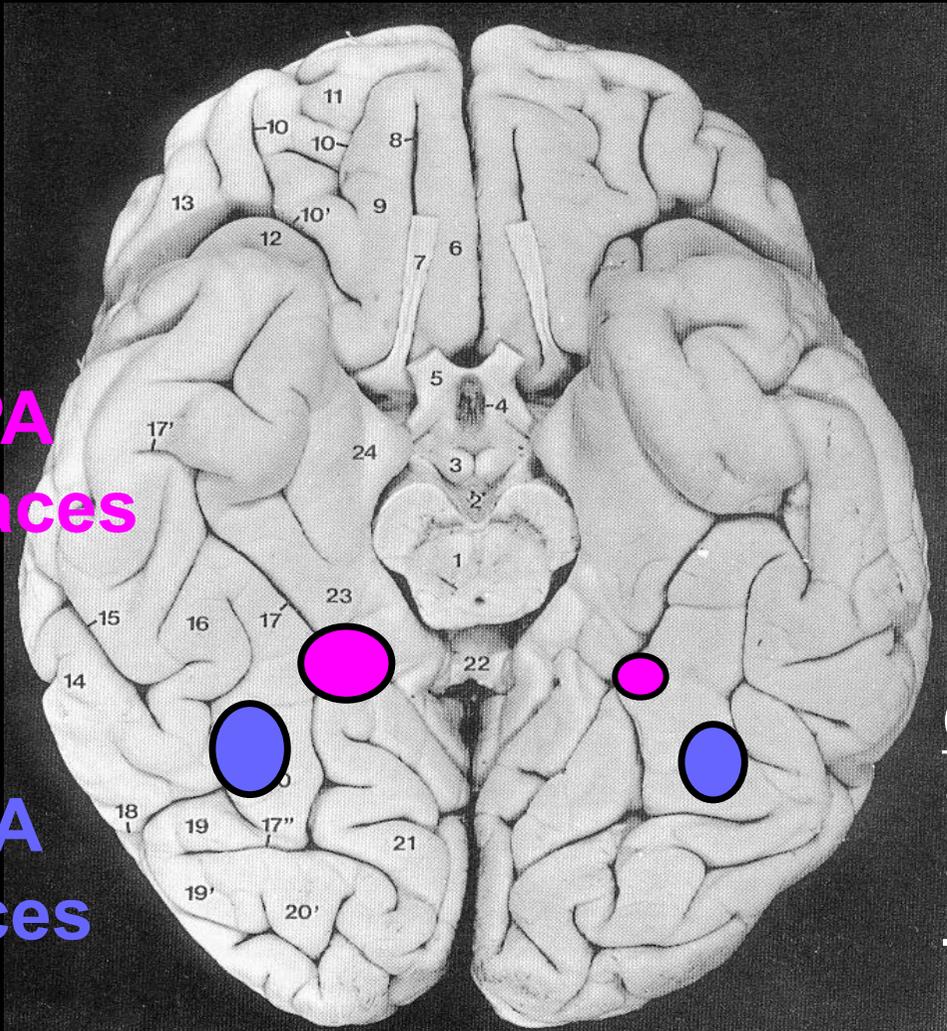
No one finds selective responses for cars, chairs, food, or lots of others. So, some categories are “special”. Or are they?

Visual Cortical Regions Selectively Responsive to visual categories:

Faces **Bodies** **Places**

PPA
places

FFA
faces



Ongoing Controversies:

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

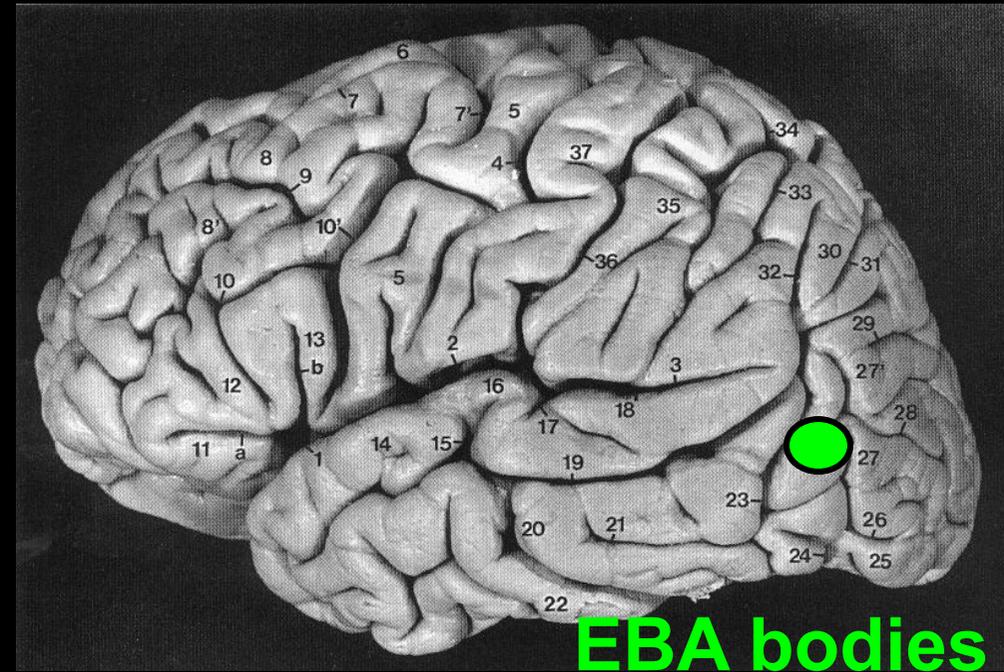
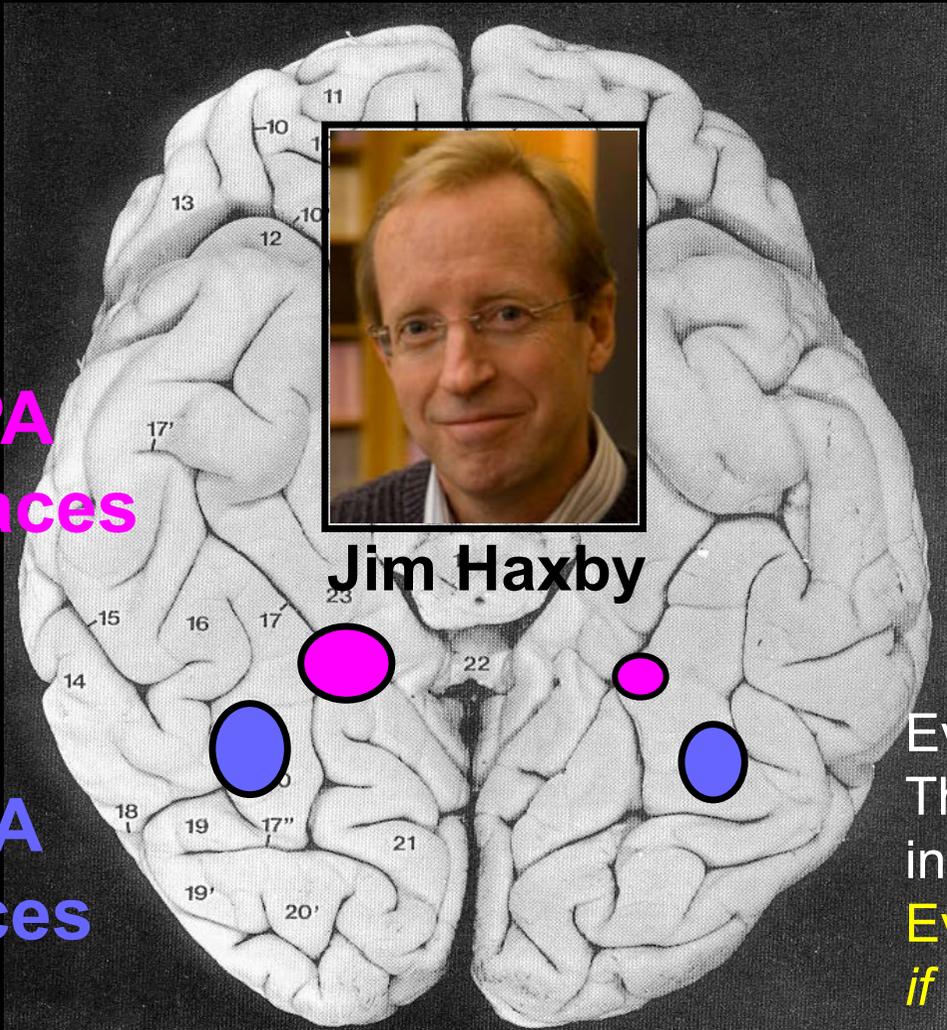
The most serious challenge... 18

Visual Cortical Regions Selectively Responsive to visual categories:

Faces **Bodies** **Places**

PPA
places

FFA
faces



Even if FFA responds weakly to chairs & cars, That does not mean it does not represent information about chairs and cars.

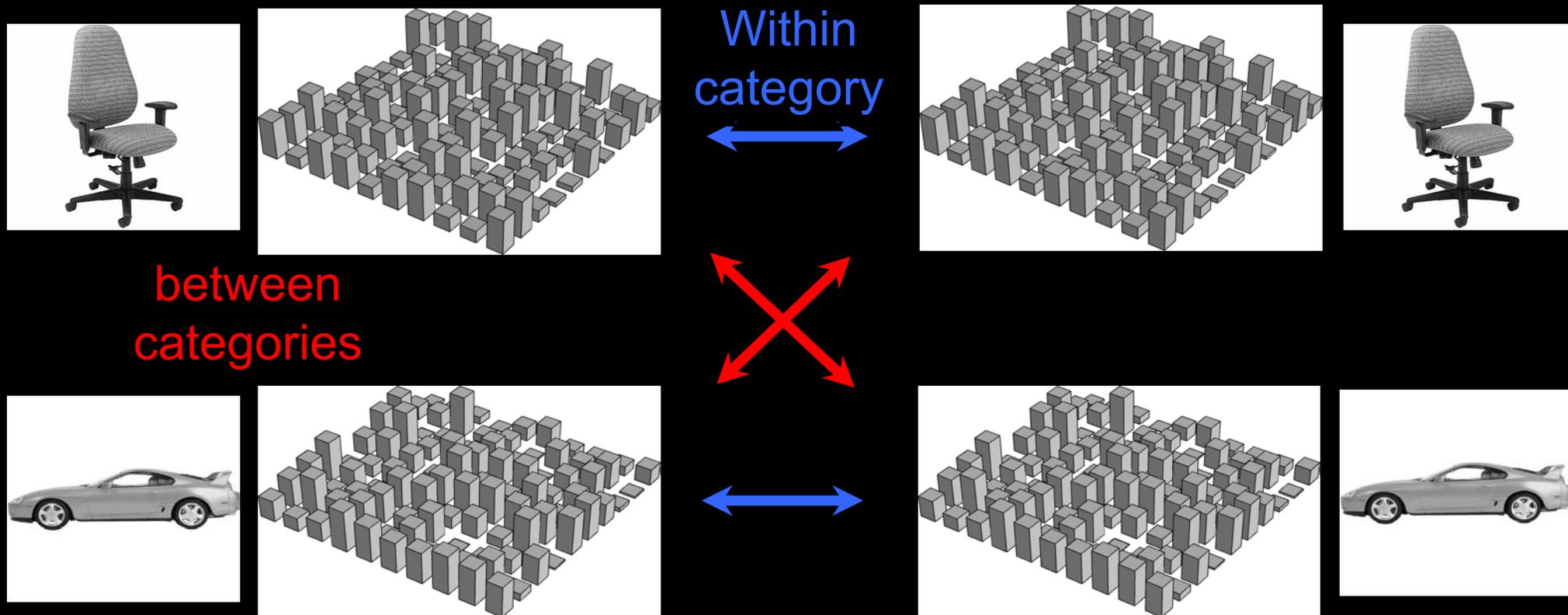
Even low responses could hold information if the pattern of response across voxels is different for each category.

How would we tell?

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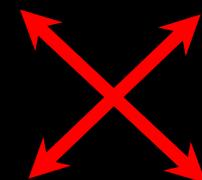
Does the FFA hold Information about Nonfaces (e.g., cars versus chairs)?

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**



between
categories

Within
category



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!**



Haxby et al (2001): 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

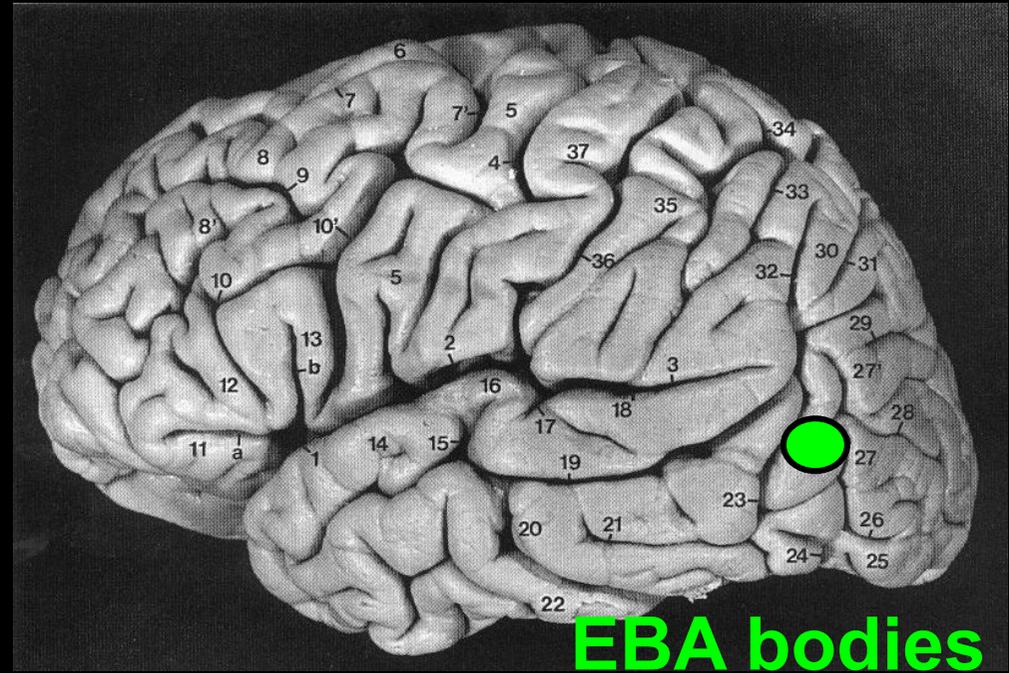
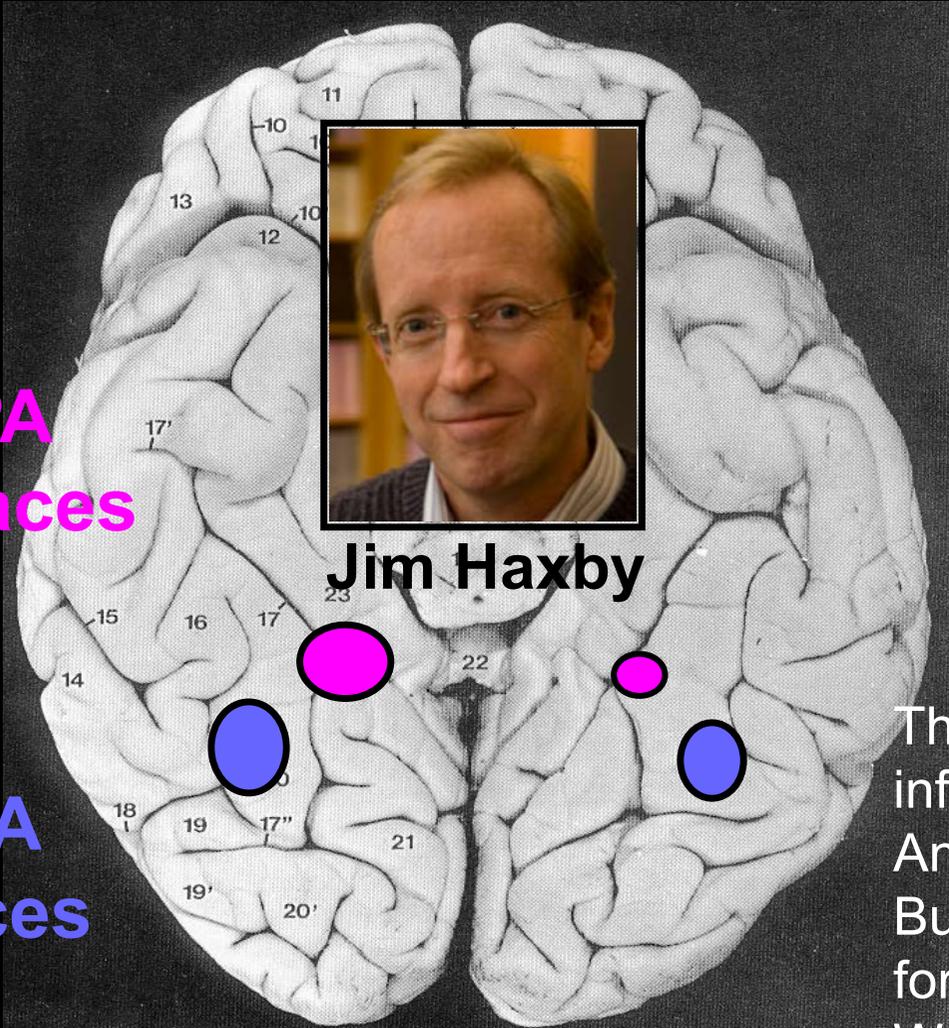
OK does that mean I am toast?

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

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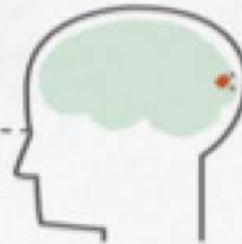
Neural Decoding with fMRI

*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):

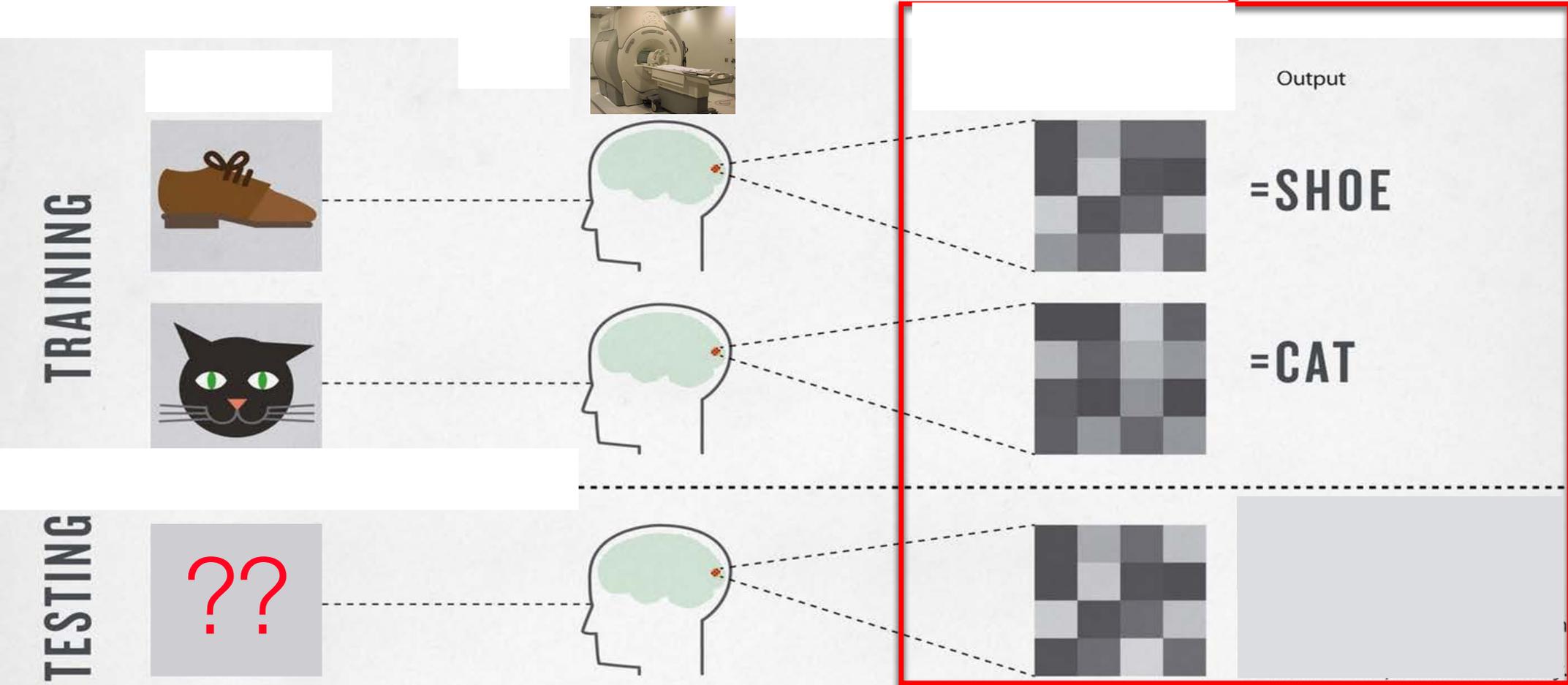


How can try this?

Neural Decoding with fMRI

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

Machine Learning Pattern Classifier



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...

Varieties of Neural Decoding

1. Can use decoding methods on many types of neural data.

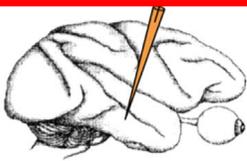


Magnetoencephalography (MEG)

Response across sensors (at t_x)

Time course of information extraction

let's compare



Monkey Neurophysiology

Firing Rate across Neurons

"Neural population decoding"

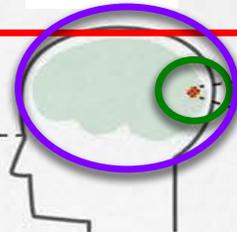
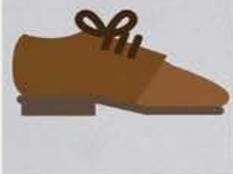


fMRI

BOLD Response across Voxels

"Multiple Voxel Pattern Analysis (MVPA)"

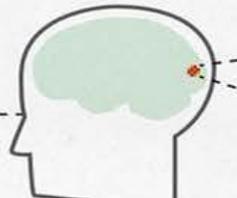
TRAINING



of an ROI of whole brain



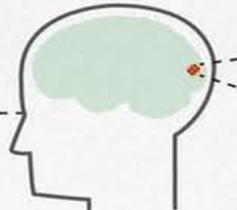
=SHOE



=CAT

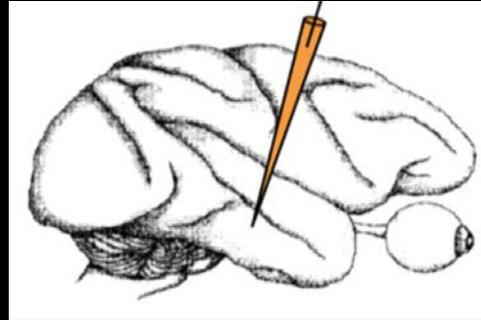
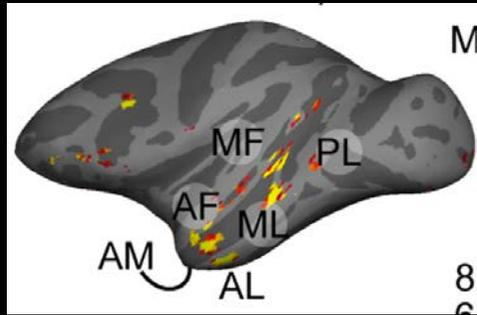
2. Many decoding methods: Haxby-style correlations, Machine Learning (SVMs, deep nets)

TESTING



=SHOE?

Neural Decoding: A Direct Comparison of fMRI versus Neurons



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

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?

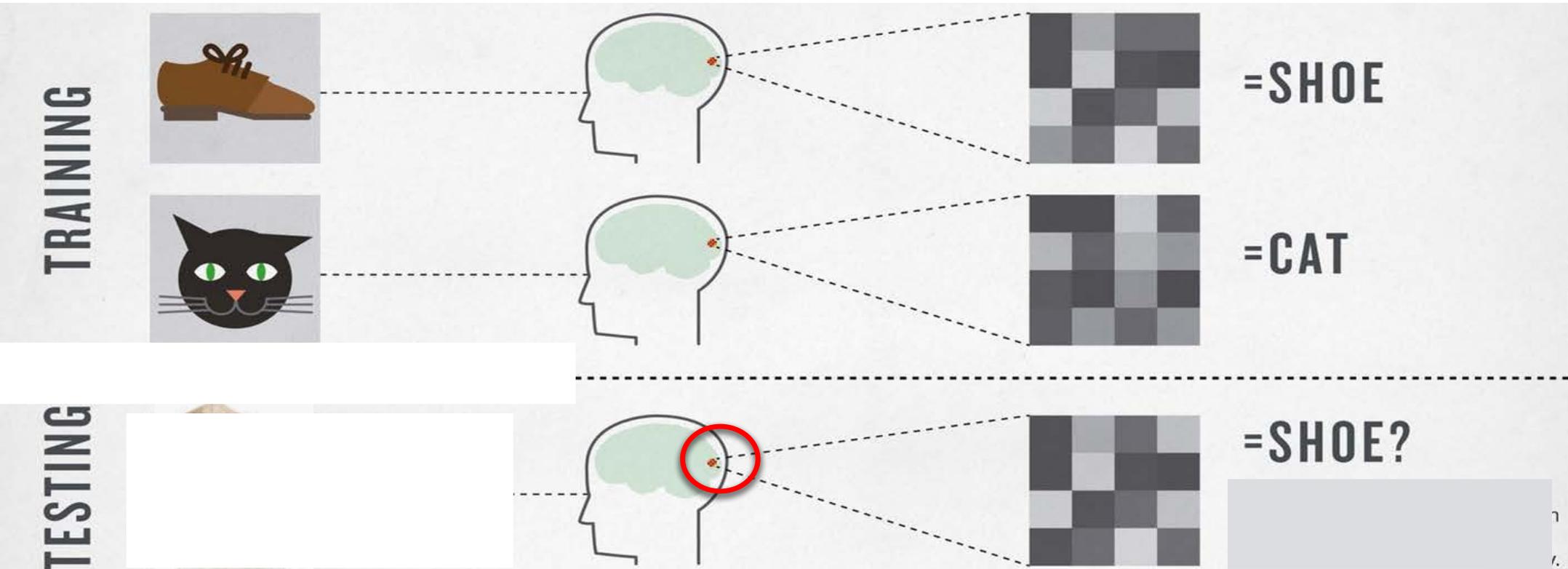
What are the implications?



Monkey 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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Spring 2019

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