9.71 Functional MRI of High-Level Vision
Fall 2007

9.71: fMRI of High-level Vision

Nancy Kanwisher

Fall 2007

Lecture 2A: Introduction to the Ventral Visual Pathway

Lecture 2B: Experimental Design & Data Analysis

Outline for Today

Lecture 2A: Introduction to the Ventral Visual Pathway

I. Basic Organization of the VVP
including FFA, PPA, EBA, LOC
II. Controversies about the VVP & Unanswered Questions

Lecture 2B: Experimental Design & Data Analysis

I. Basic Kinds of Experimental Designs
II. Basic Data Analysis Methods
III. Five Common Problems with fMRI Experiments

[Lecture 2C: Critiquing fMRI Experiments: Some Tips

Discussion of Lie Detection]

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Two Visual Pathways

Image removed due to copyright restrictions.

Fig. 4 in Felleman, Daniel J. and David C. Van Essen.

"Distributed Hierarchical Processing in the Primate Cerebral Cortex."

Cerebral Cortex 1, no. 1 (1991): 1-47.

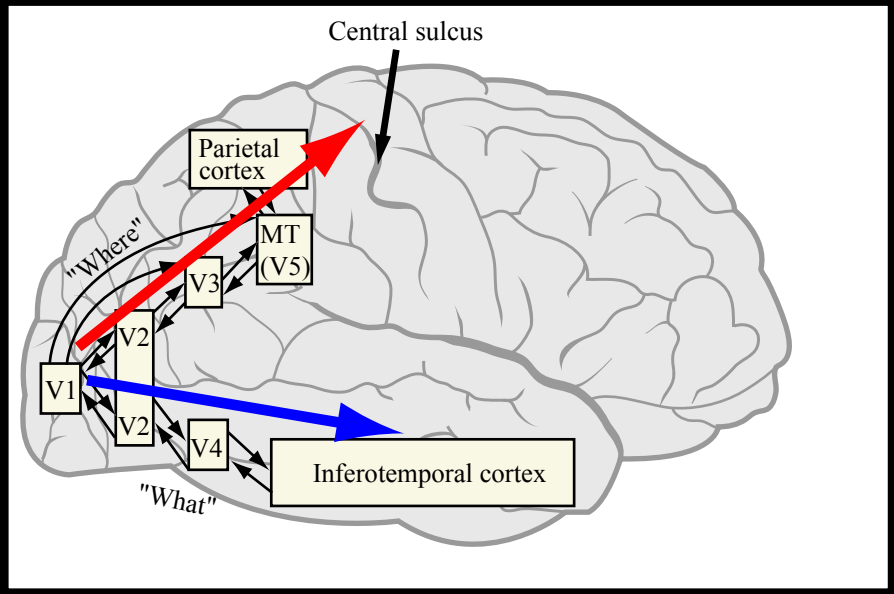


Figure by MIT OpenCourseWare.

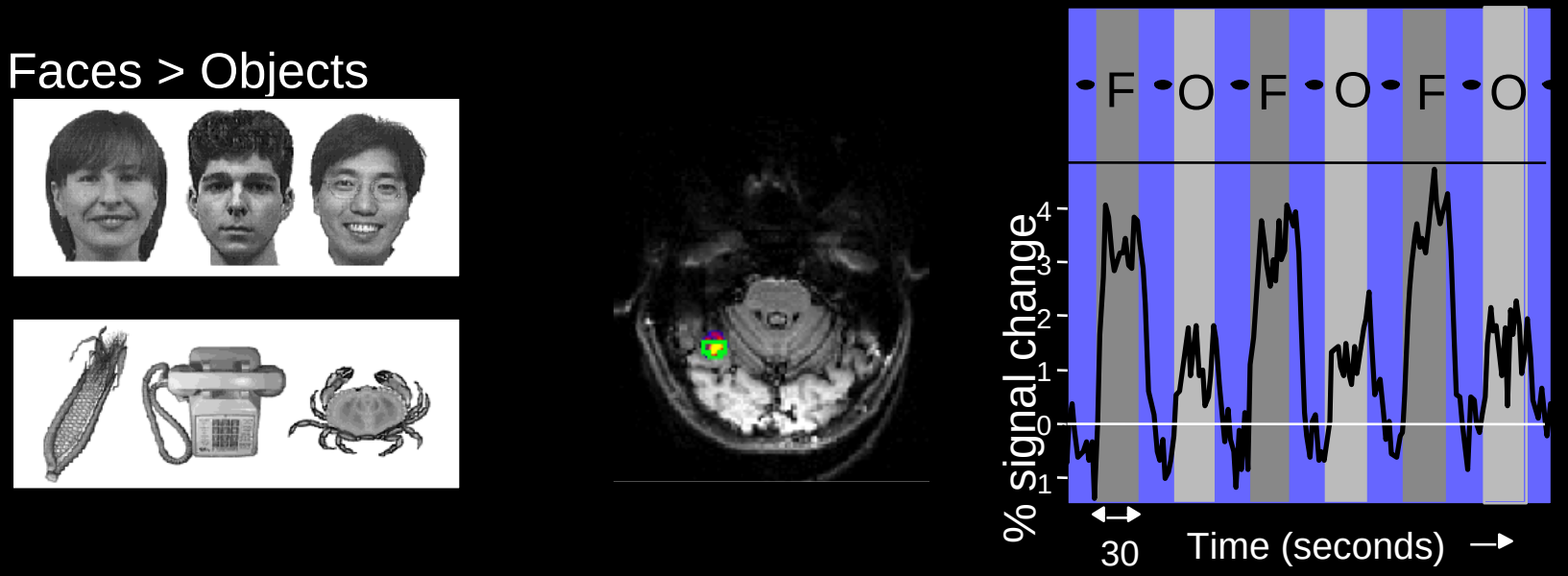
The Ventral Visual Pathway: Object Recognition

How is it organized?

Slide adapted from Jody Culham

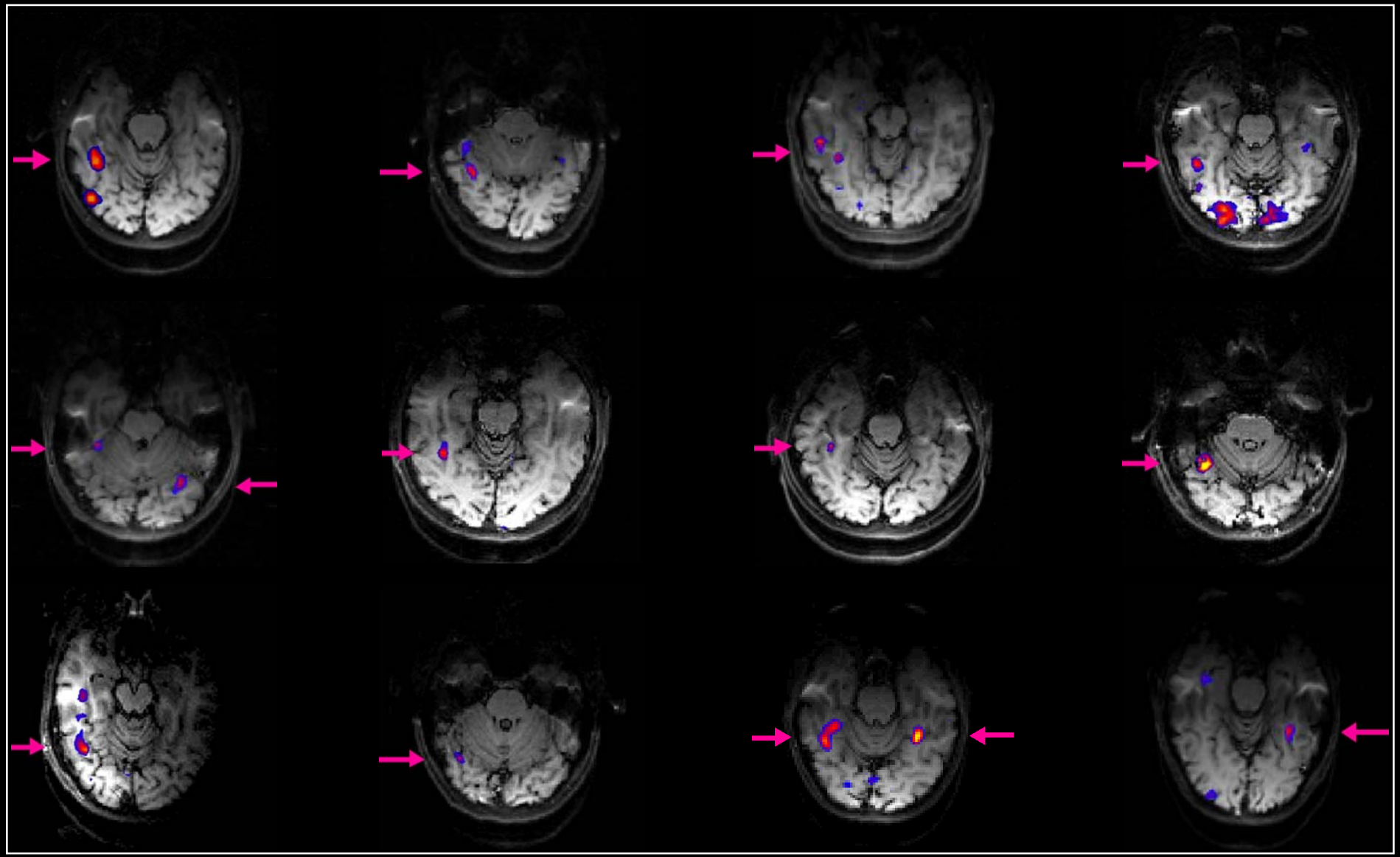
Courtesy of http://psychology.uwo.ca/culhamlab/

Are different parts of the ventral visual pathway active when we look at different kinds of objects?



How systematic is this across subjects?

Areas Responding More to Faces than Objects in 12 Ss



Does the face activation reflect:

- Visual attention?
- Processing any human body parts?
- Processing only front views of faces?
- Fine-grained within-category discrimination?
- Luminance or other low-level confounds?
- Face-specific visual processing?
- Et cetera…..

Region of Interest Approach:

Does the face activation reflect

- Greater attention to faces than other stimuli?

1. Localize the face area individually in each subj:
   the fusiform region in which faces>objects

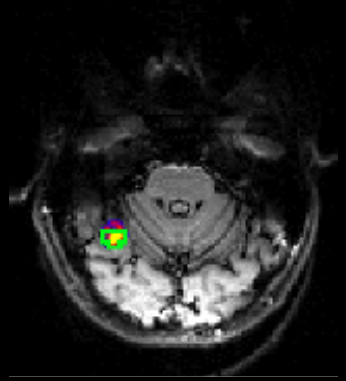
2. Measure the response in this area in new scan:

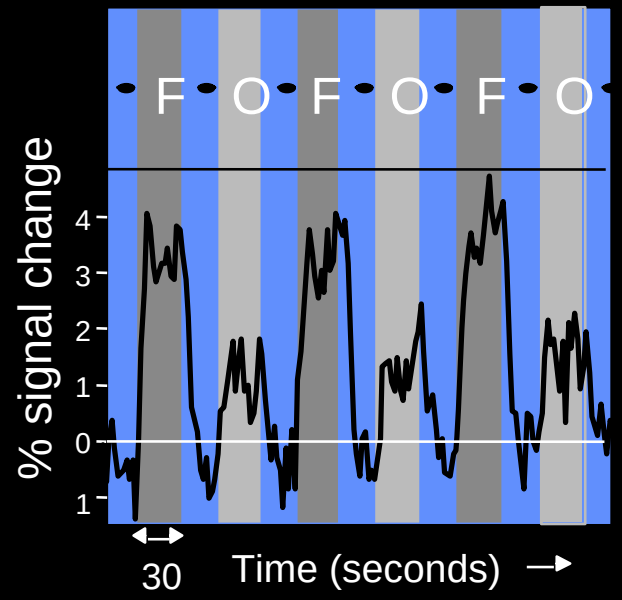
"1-back" task on:

vs.

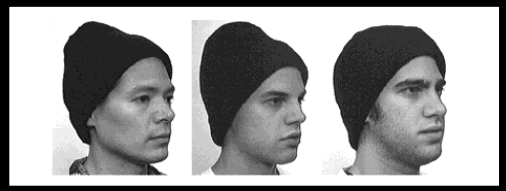
Results

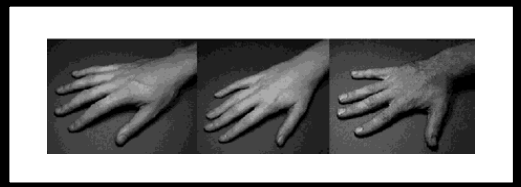
4a. Faces > Objects

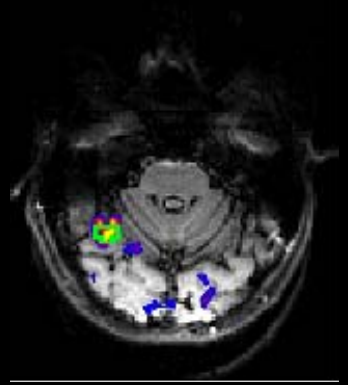


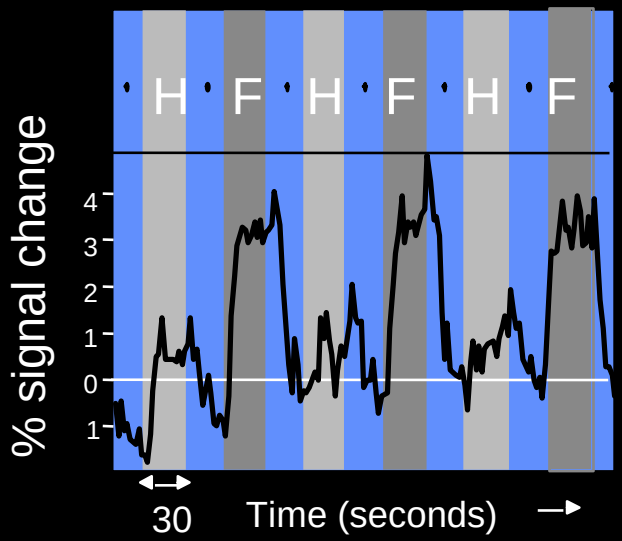


4b. 3/4 F > H (1-back)







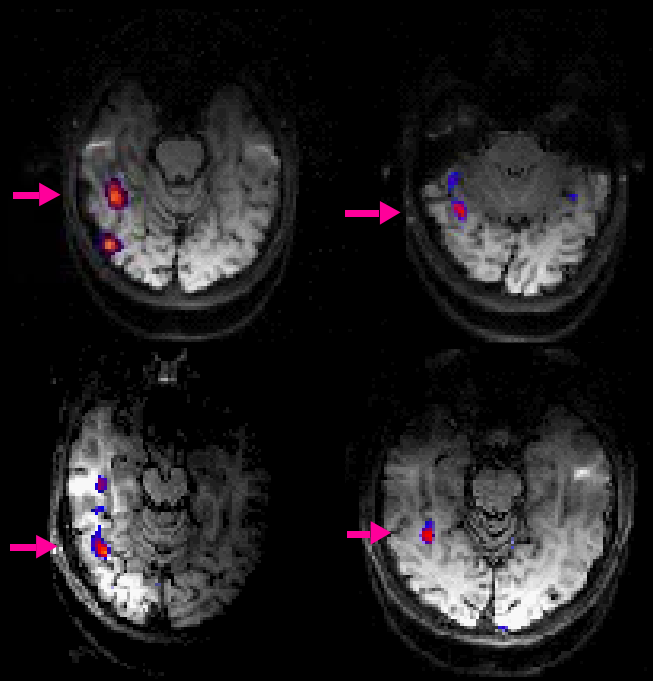


Does the face activation reflect:

- Visual attention? no
- Processing any human body parts? no
- Processing only front views of faces? no
- Fine-grained within-category discrimination? no
- Luminance or other low-level confounds? ?
- Face-specific visual processing?
- Et cetera…..

Fusiform Face Area

Kanwisher, Tong, McDermott, Chun, Nakayama, Moscovitch, Weinrib, Stanley, Harris, Liu



Courtesy of Society for Neuroscience. Used with permission.

Face photos modified by OCW for privacy considerations.

Front-View	Profile-View	"Mooney"	Cat Face	Cartoon
1.9-2.3	1.8	2.0	1.6	1.7

Image removed due to copyright restrictions.

Inv. Grey	No Eyes	Human Head	Animal Head	Inv. Cartoon
1.6	1.7	1.7	1.3	1.4

Image removed due to copyright restrictions.

Eyes Only	Inv. Mooney	Whole Animal	Human Body	External Ftrs
1.3	1.3	0.9	1.0	1.1

Hand	Buildings	Back of Head	Animal Body	Object
0.7	0.6	1.0	0.8	

Are some brain regions selectively activated by specific categories of stimuli?

Yes, apparently, at least for faces.
Any others?

Scenes > Objects in 9/9 Subjects

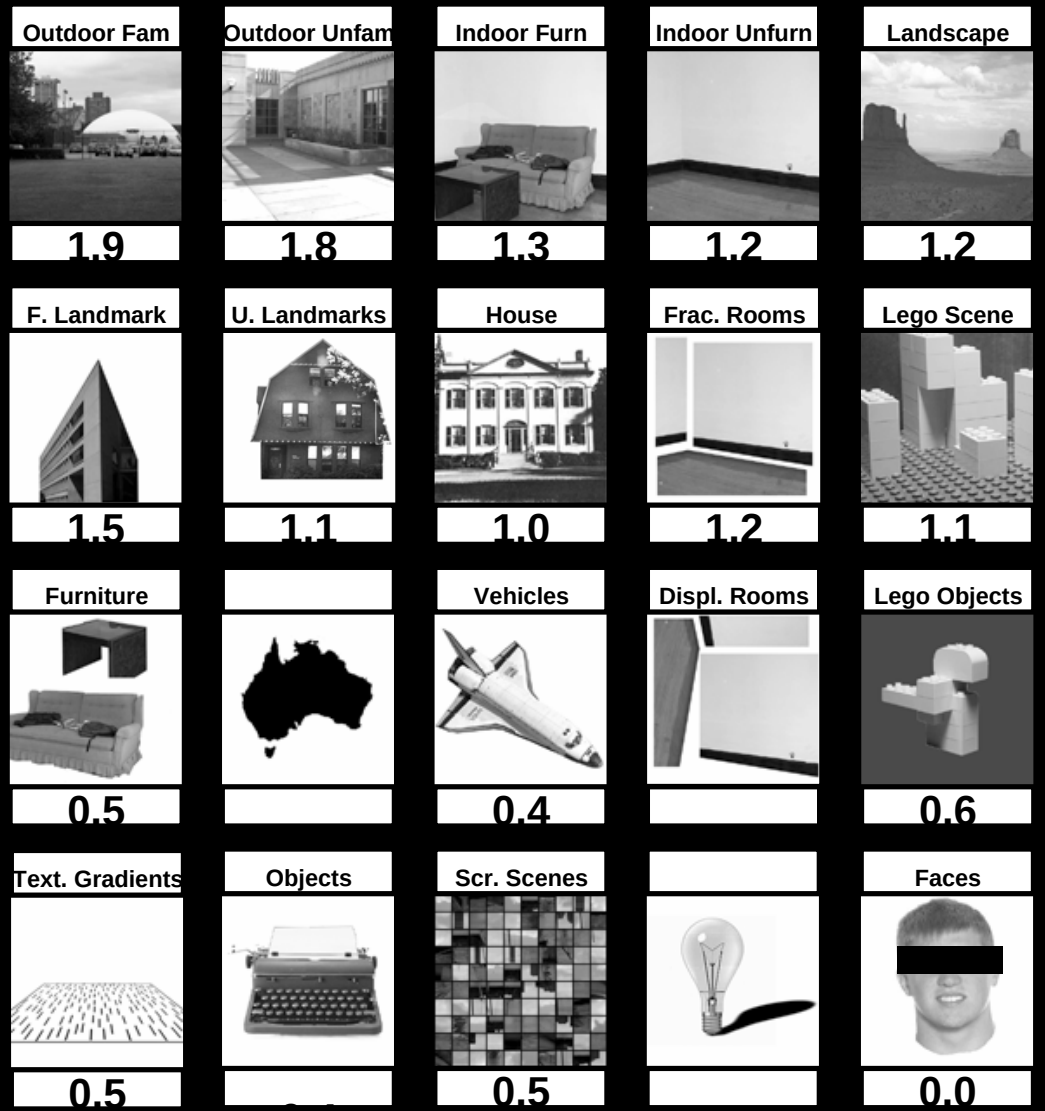
Images removed due to copyright restriction.
Fig. 2a. in Epstein, Russell and Kanwisher, Nancy. "A cortical representation of the local visual environment." *NATURE* 392 (9 APRIL 1998): 598-601.

Used in lecture slides by Prof. Kanwisher.

Epstein & Kanwisher 1998

Parahippocampal Place Area

Epstein & Kanwisher (1998)



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Category-Specific Regions in Human Extrastriate Cortex

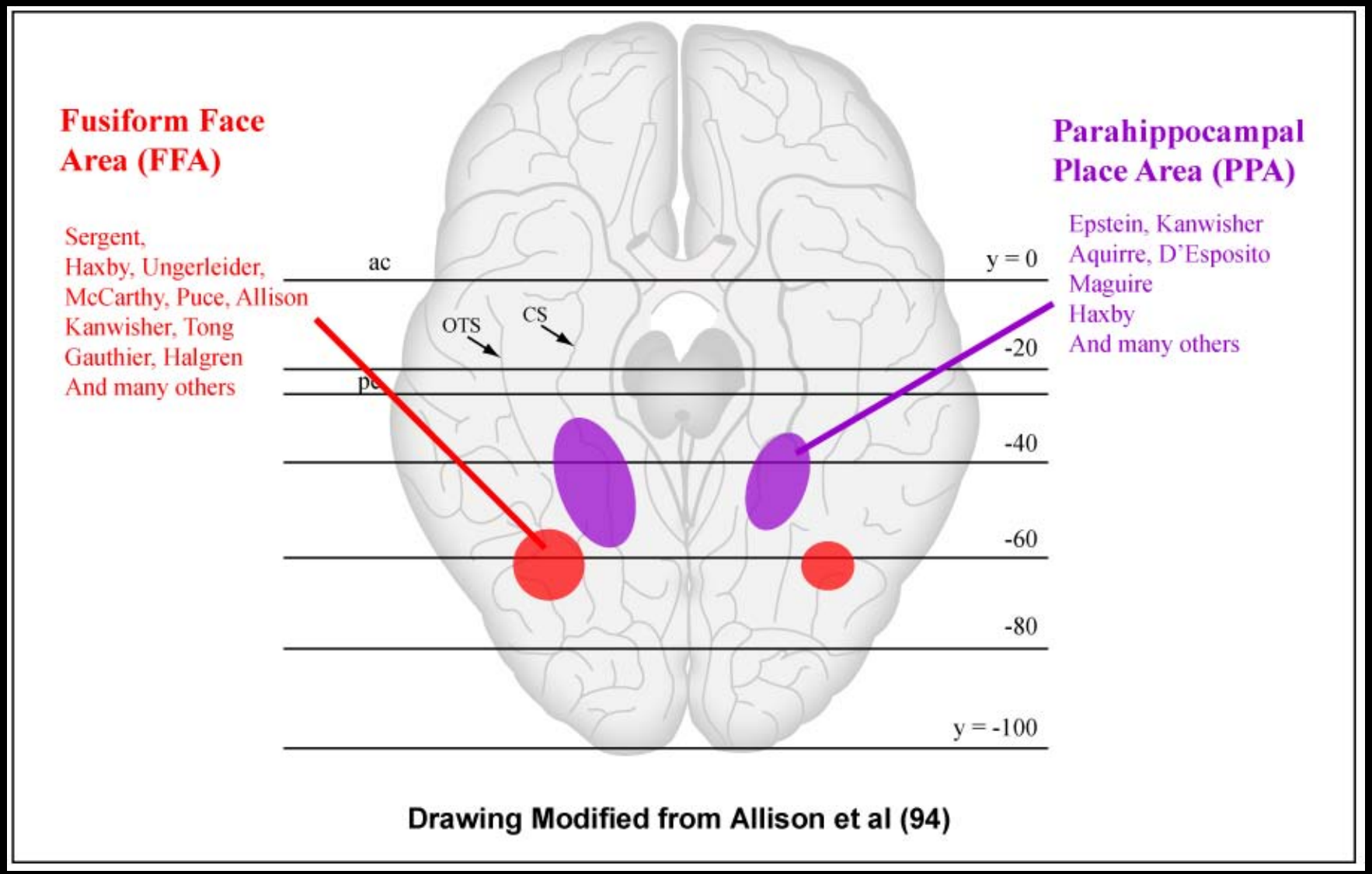


Figure by MIT OpenCourseWare. After Allison, 1994.

How many of these category-specific regions are in there, anyway?

Paul Downing and I tried to find out,
by testing every category that seemed plausible.

Other Category-Specific Regions in Visual Cortex?

Downing & Kanwisher

Images removed due to copyright restriction.

This slide and the next slide show that Faces and Places are really special in the Visual Cortex region.

Other Category-Specific Regions in Visual Cortex?

Downing & Kanwisher

Images removed due to copyright restriction.

This slide and the next slide show that Faces and Places are really special in the Visual Cortex region.

Faces & Places really are special!

But there was one new category that *did* selectively activate a region of cortex…..

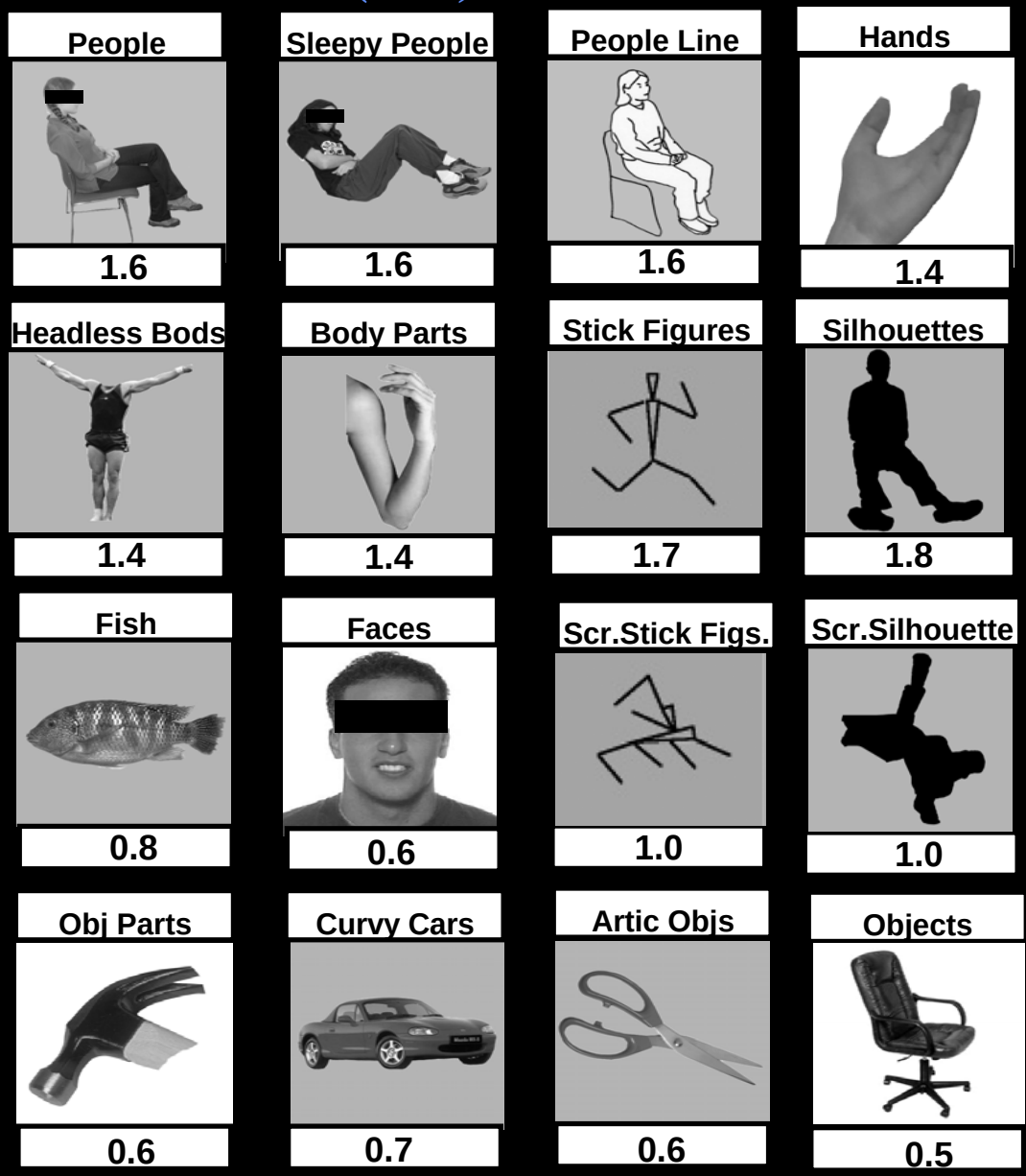
Downing & Kanwisher

Human bodies and body parts:

Extrastriate Body Area

Downing, Jiang, Shuman, & Kanwisher (2001)

Face photos modified by OCW for privacy considerations.

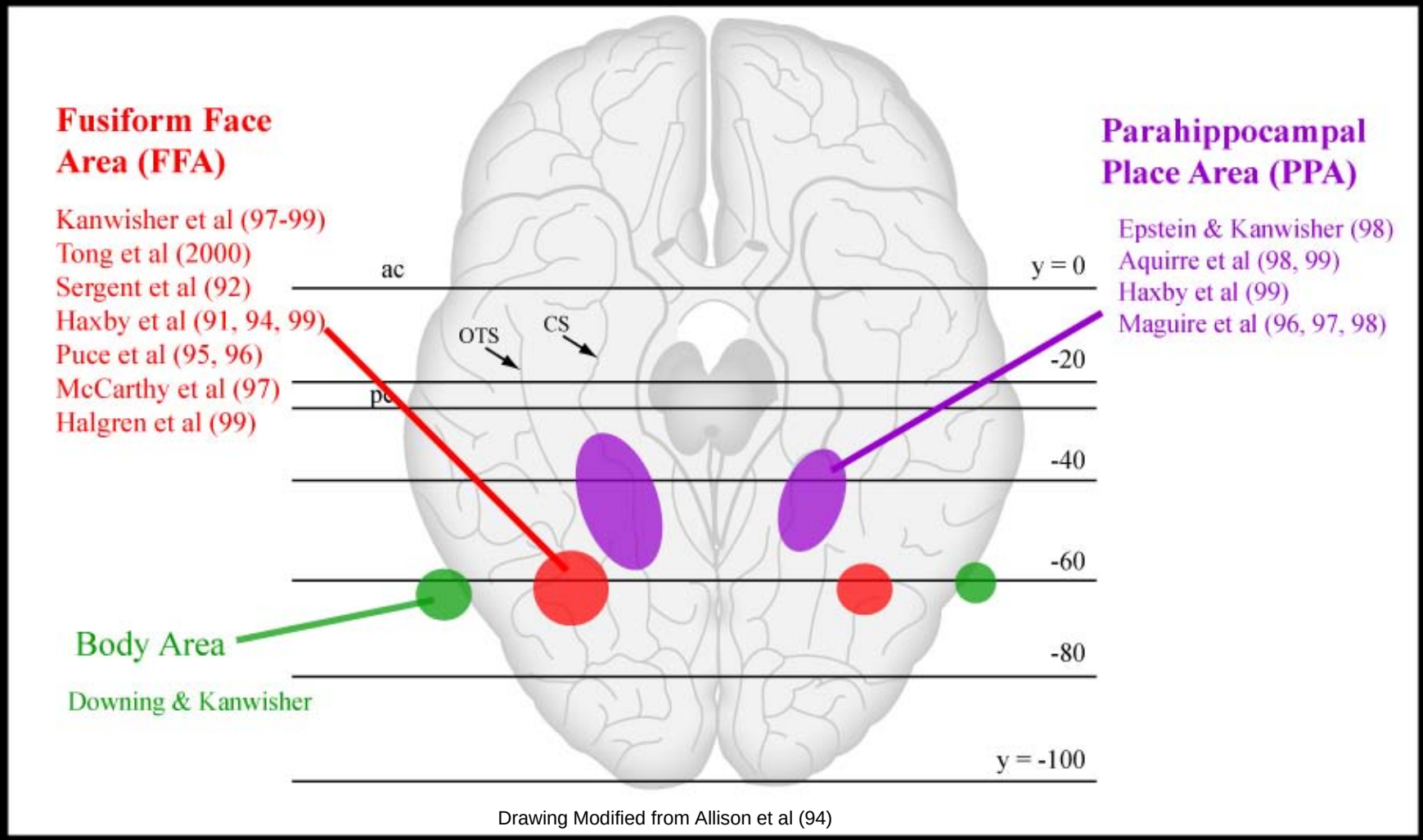


Images removed due to copyright restriction.

Fig. 1 in Downing, Paul E. et. Al. "A Cortical Area Selective for Visual Processing of the Human Body." *Science* 293 (28 SEPTEMBER 2001): 2470-2473.

(http://web.mit.edu/bcs/nklab/media/pdfs/DowningJiangShumanKanwisherScience02.pdf)

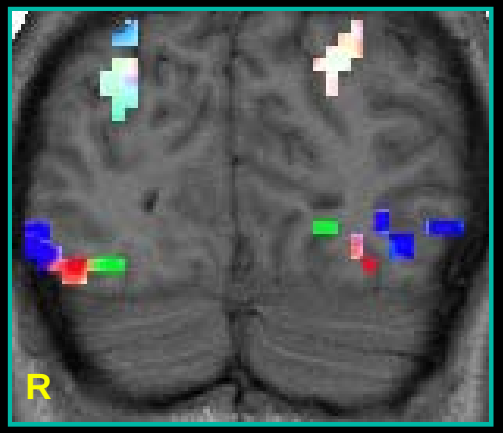
Faces, Places, Bodies



Drawing Modified from Allison et al (94)

Figure by MIT OpenCourseWare. After Allison, 1994.

What about chairs (Ishai et al)?



Faces

Chairs

Houses

Face photos modified by OCW
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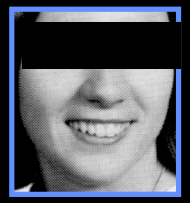
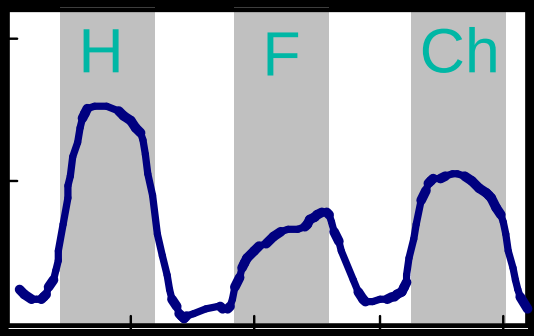
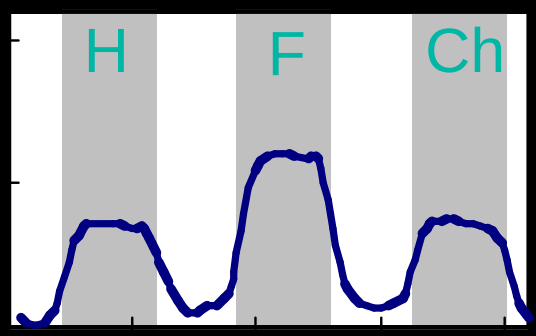
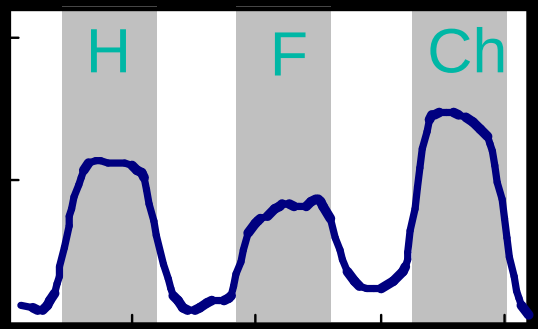








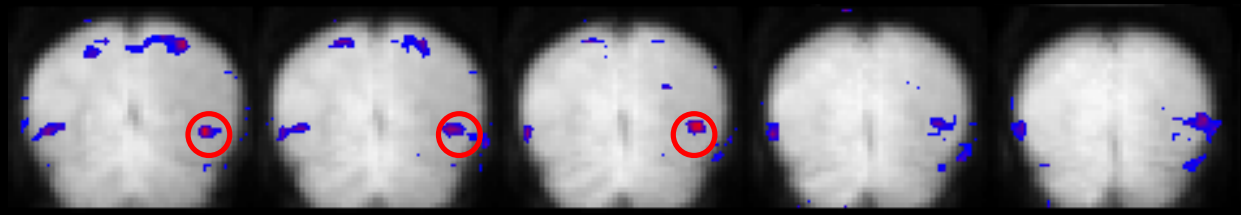
% Signal Change

Scans (TR = 3 sec)

Alumit Ishai, LBC/NIMH

Chairs > (Faces + Scenes), 9 subjects group data

Downing & Kanwisher



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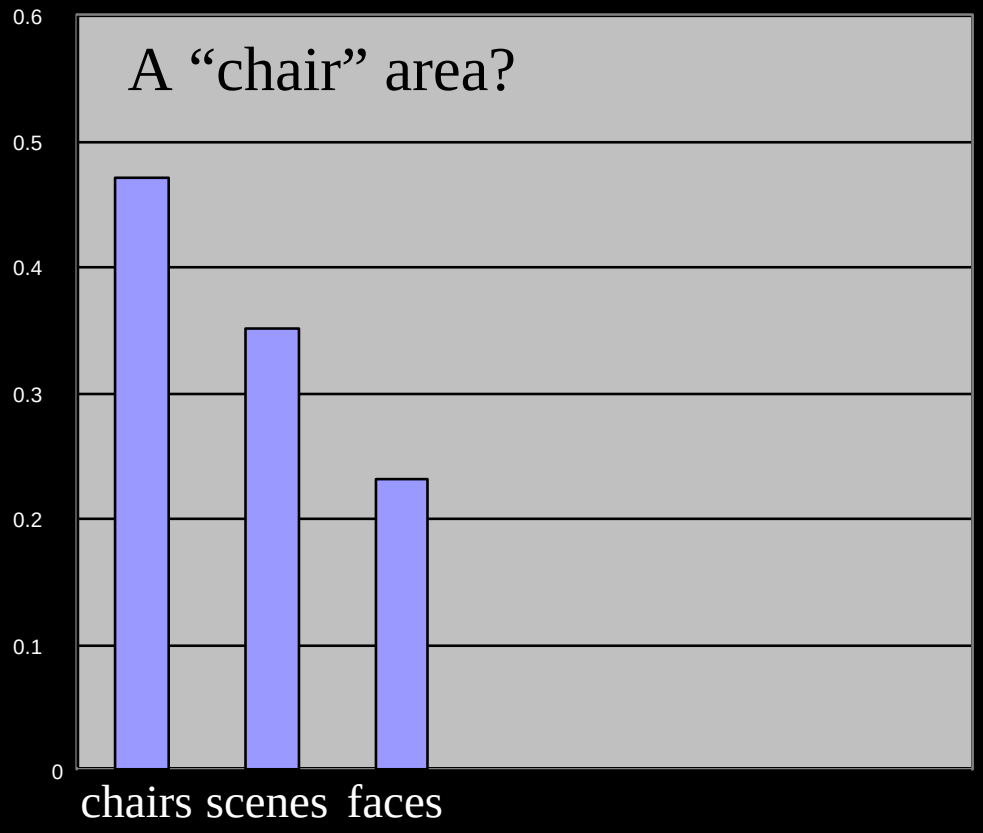

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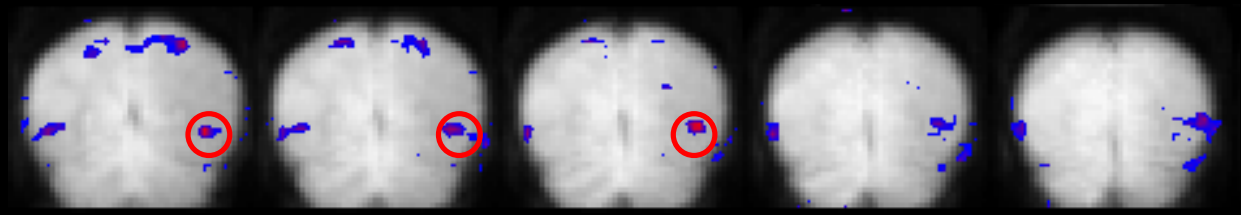
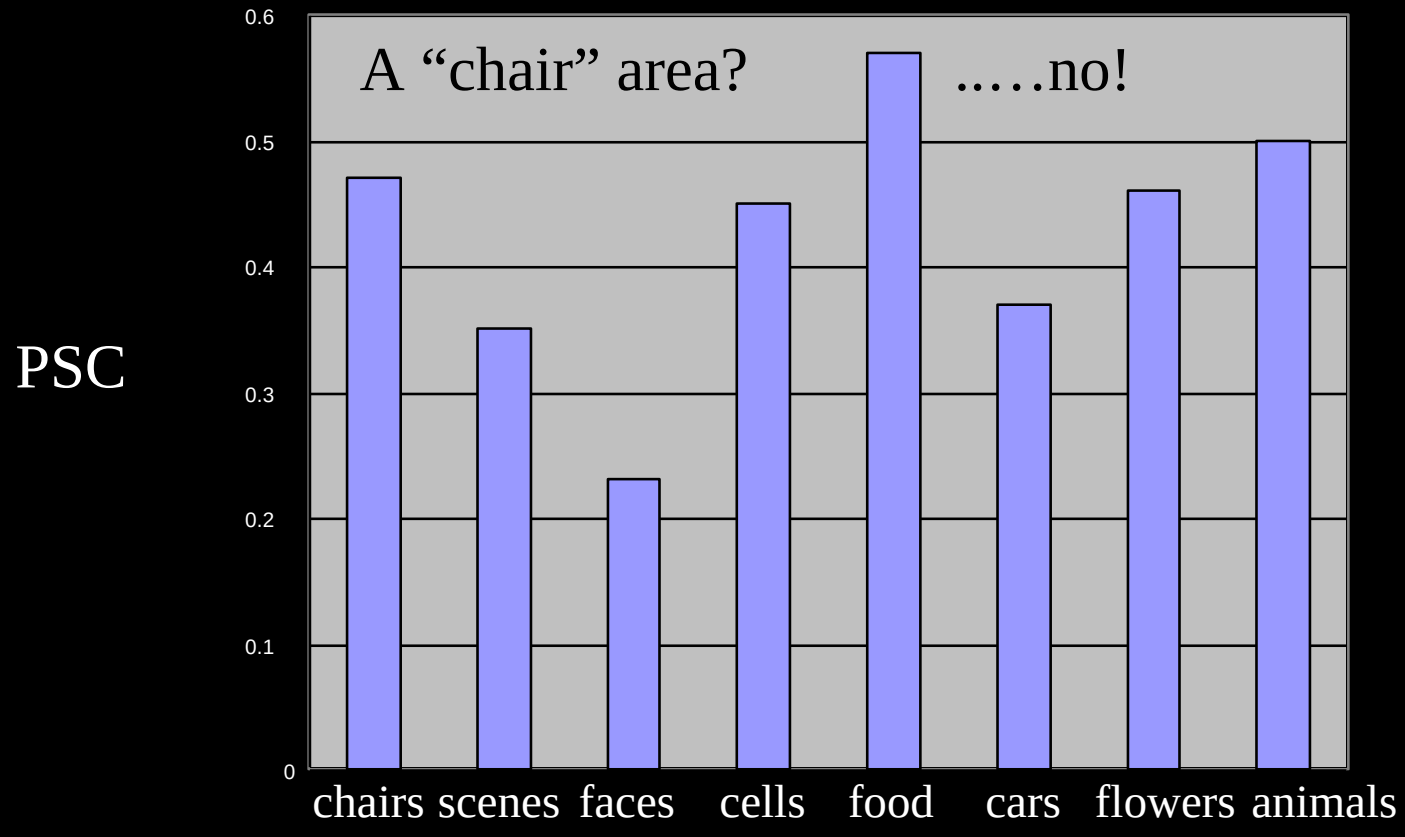


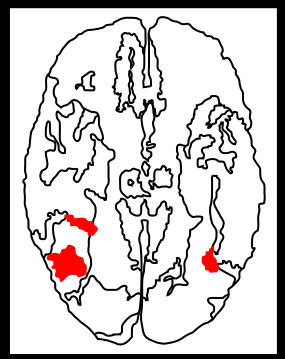


How do we recognize everything else?

The Lateral Occipital Complex (LOC):

Cortical Regions Involved in Processing Object Shape

I Malach et al (1995), "LO"



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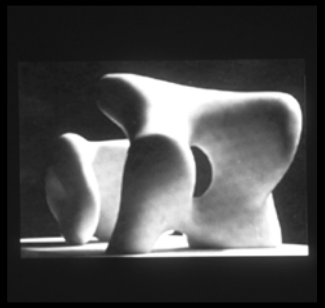

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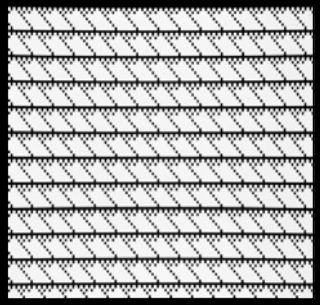
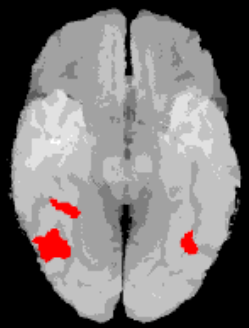


Figure by MIT OpenCourseWare.

II Kanwisher et al (1996) - a similar region



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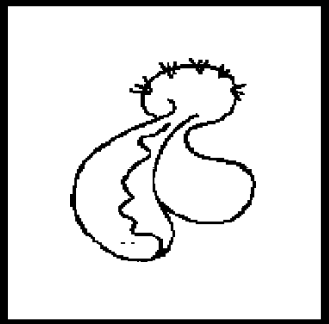

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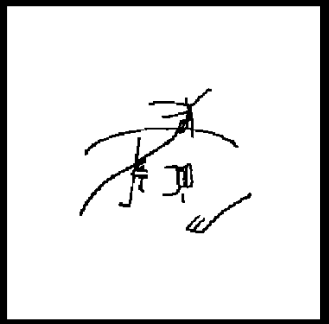

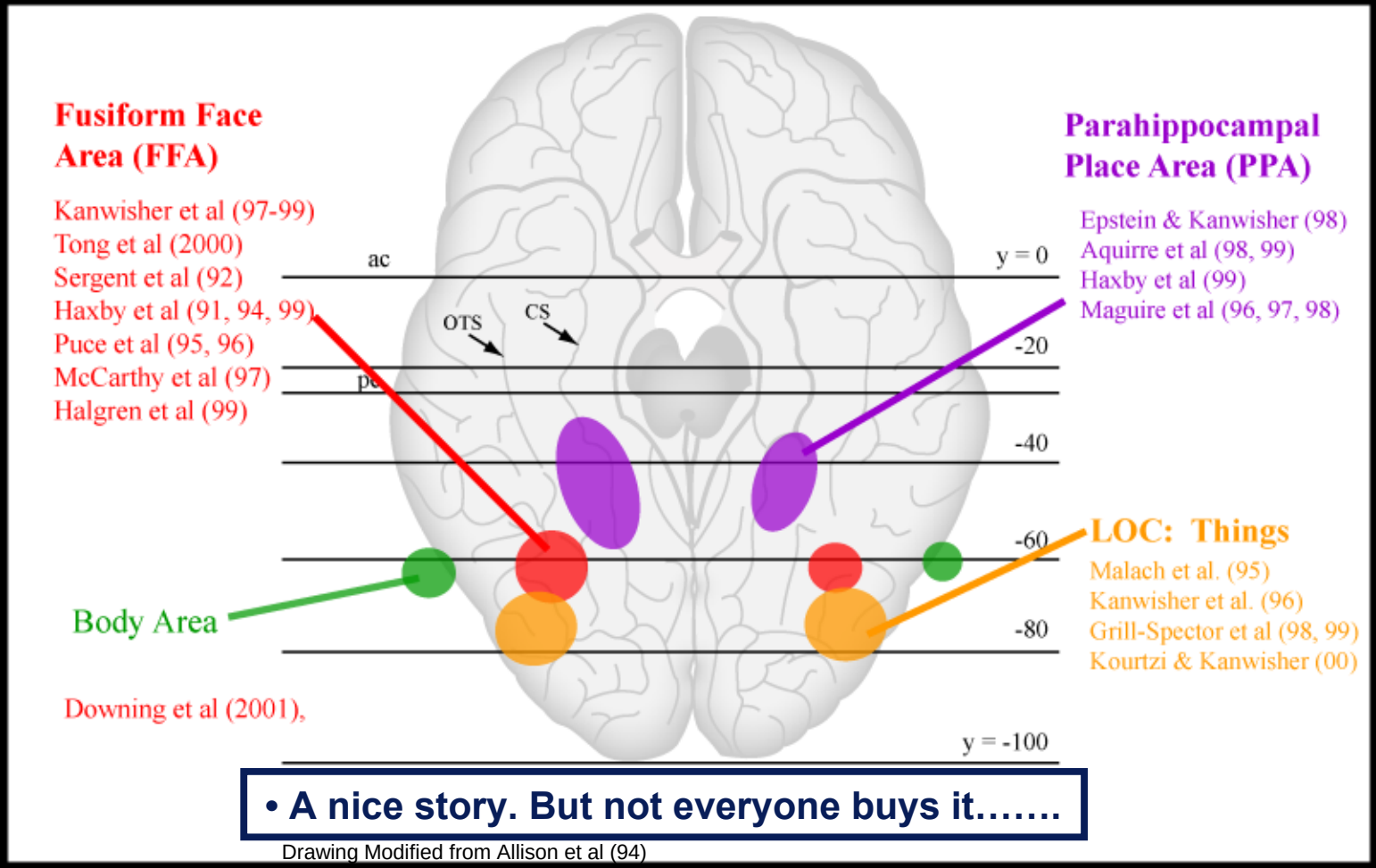

Figure by MIT OpenCourseWare. After Allison, 1994.

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Controversies and Questions about Category-selective Regions of Cortex

Alternative view I: The brain is not organized around content *domains* (e.g., faces or places), but instead around *processes* (e.g. fine-grained discrimination) that can be conducted on any stimulus type.

we'll cover some of these arguments in later lectures*

Alternate view II: faces, places, and objects are represented not by focal regions of cortex, but by distributed patterns of activation spanning centimeters of cortex.

Is face information spread far beyond the FFA?

Does the FFA contain information about nonfaces?

*Pernet C, Schyns PG, Demonet JF. Specific, selective or preferential: comments on category specificity in neuroimaging. Neuroimage. 2007 Apr 15;35(3):991-7.

Haxby et al (2001)

Main Idea:

Information about object categories is spread over a large swath of cortex, not restricted to small specialized regions.

Methods:

1. Scan each subject on 8 stimulus categories
2. Split the data in half.
3. Generate "known" activation patterns from each half of data:

Faces **Bottles** **Shoes** **Chairs** **Houses** **Scissors** **Cats** **Scrambled**

(fake data)

Haxby et al (2001)

Is the pattern of response across cortex more similar (i.e. more correlated) for the same category than for different categories?

Images removed due to copyright restrictions.

Fig. 3A and 3B in Haxby et. al. in "Distributed and Overlapping Representations of Faces and Objects in Ventral Temporal Cortex." *Science* 293, no. 5539 (28 Sep 2001): 2425-2430.

Yes:
Face1 - face2 is more similar
Than face1 - house 2

Yes:
Chairs1-chairs2 is more similar
Than chairs1 - shoes 2

So if you look at the response across cortex you “can tell” which object was seen.

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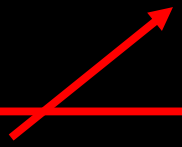
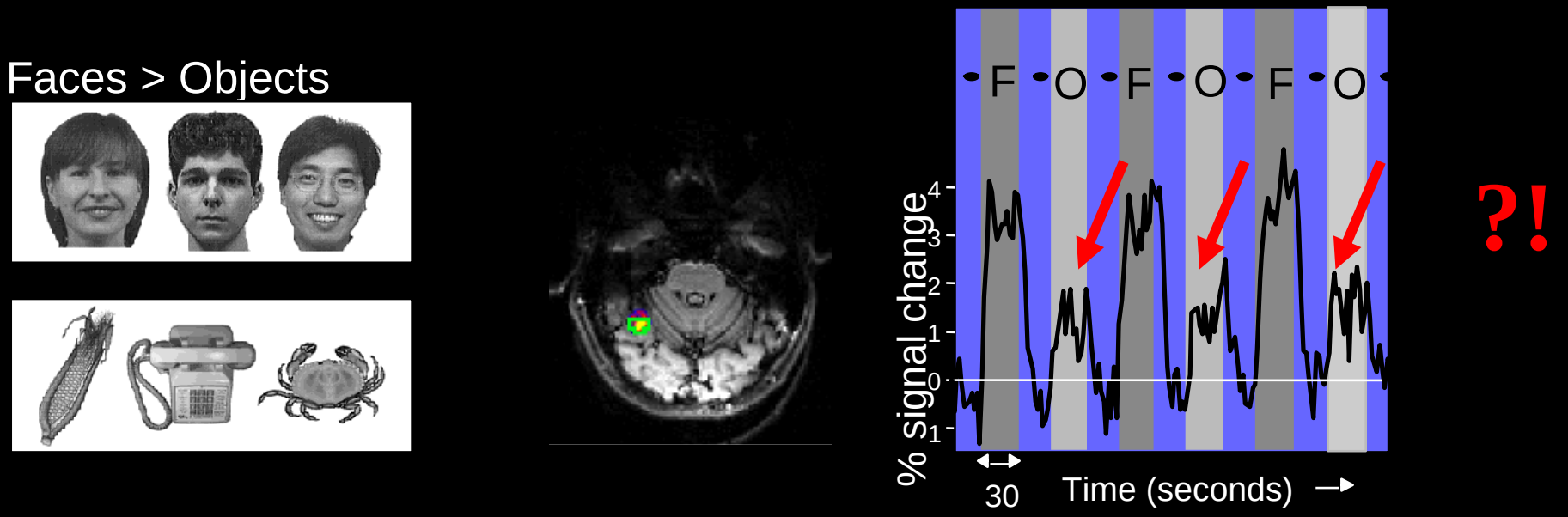


Nonpreferred Responses in the FFA

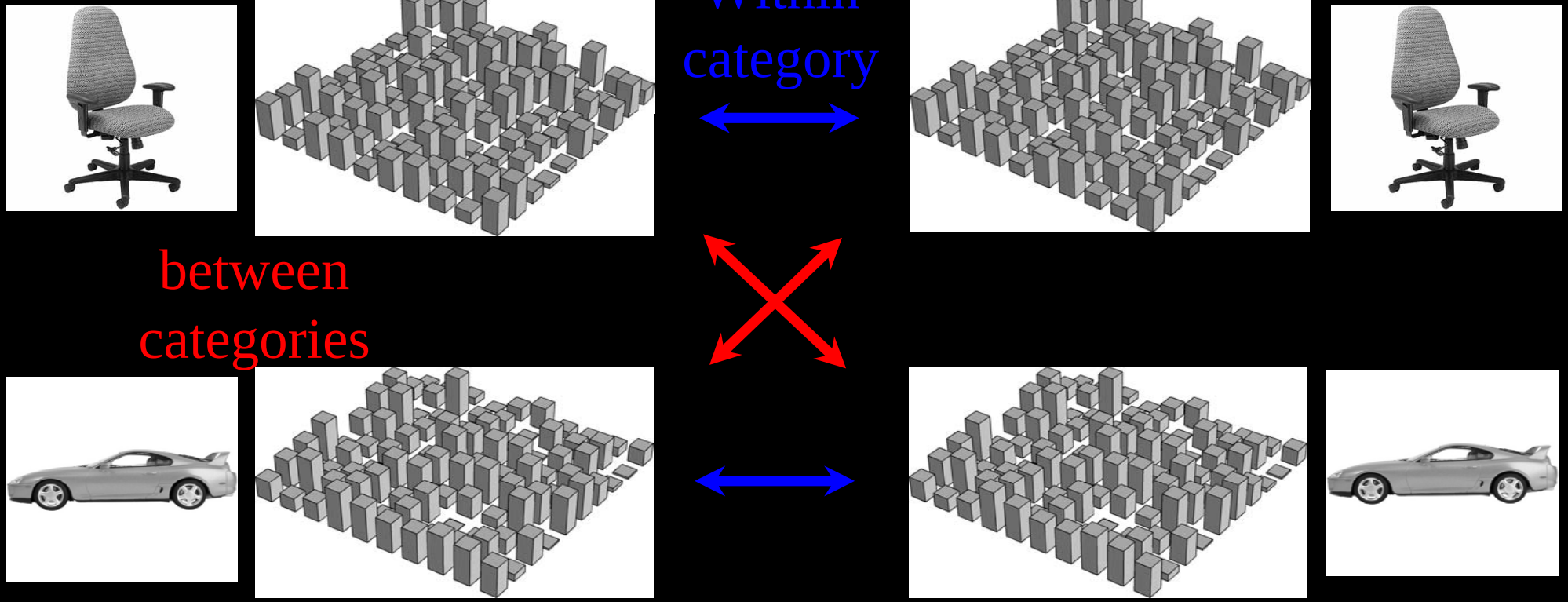


- Do “nonpreferred” responses carry information about nonpreferred stimuli?
- A potential challenge to the domain specificity of the FFA.

Using Haxby’s method to ask whether the FFA contains info about nonfaces….

Correlation-based Classification Analysis (Haxby et al., 2001)

1. Scan each subject while they view multiple stimulus categories.
2. Split the data in 1/2; generate activation maps for each category.
3. Compute correlation across activation maps.



If r(Within) > r(Between)
the region contains category information

What do we find for nonfaces in the FFA?

Does the Pattern of Response Across the FFA contain information that discriminates between nonfaces?

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

Tsao et al (2003), in face patches in monkey brains: no

O'Toole, Haxby et al. (2005): no (sort of):

"preferred regions for faces and houses are not well suited to object classifications that do not involve faces and houses, respectively."

Reddy & Kanwisher (submitted): yes (sort of).

BUT: maybe these tests are unfair, in two ways:

i) Spatial resolution limits of fMRI necessarily entail some influence of neural populations outside the region in question.

ii) The presence of discriminative information does not mean it plays an important role in perception!

Perhaps at a finer grain one could detect discriminative information in the nonpreferred responses. But even if so, is this information *used*?

Image removed due to copyright restrictions.
Figure 1 in Wada, Y. and T. Yamamoto. "Selective Impairment of Facial Recognition due to a Haematoma Restricted to the Right Fusiform and Lateral Occipital Region." *J Neurol Neurosurg Psychiatry* 71 (2001): 254-257.

Suggests: Information in the FFA is critical for face discriminations but not for object discriminations. (We will return to this topic in a couple weeks.)

Some Currently Hot Unanswered Questions

1. Do truly category-selective regions of cortex exist, or have the FFA, PPA, & EBA been mischaracterized, and they really do something much more general?

2. Do these regions work in fundamentally different ways from each other, or are they in some sense all performing variations of the ‘same” computations?

3. (hard!) How do these regions arise in development? What role does experience play in shaping the selectivity of these regions?

4. To what extent can these regions “move over” after brain damage, and to what extent must each of them live only in its standard location?

5. Why do we have selectivities for these categories and (apparently) not others?

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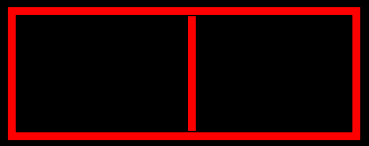
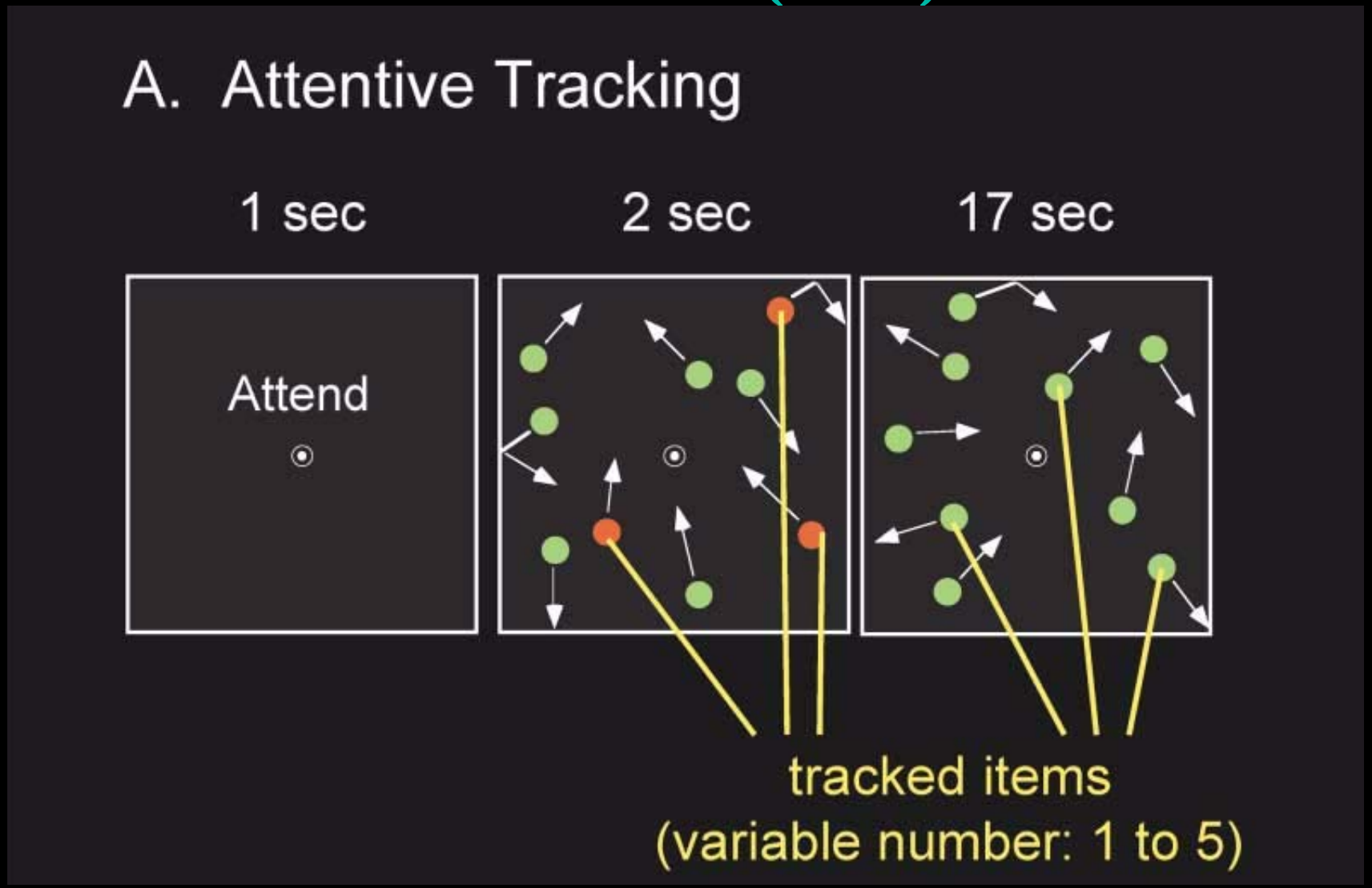
Standard Designs

- Manipulate one factor with two levels, e.g.:
  passive viewing of faces versus objects
  passive viewing of moving versus stationary rings/dots



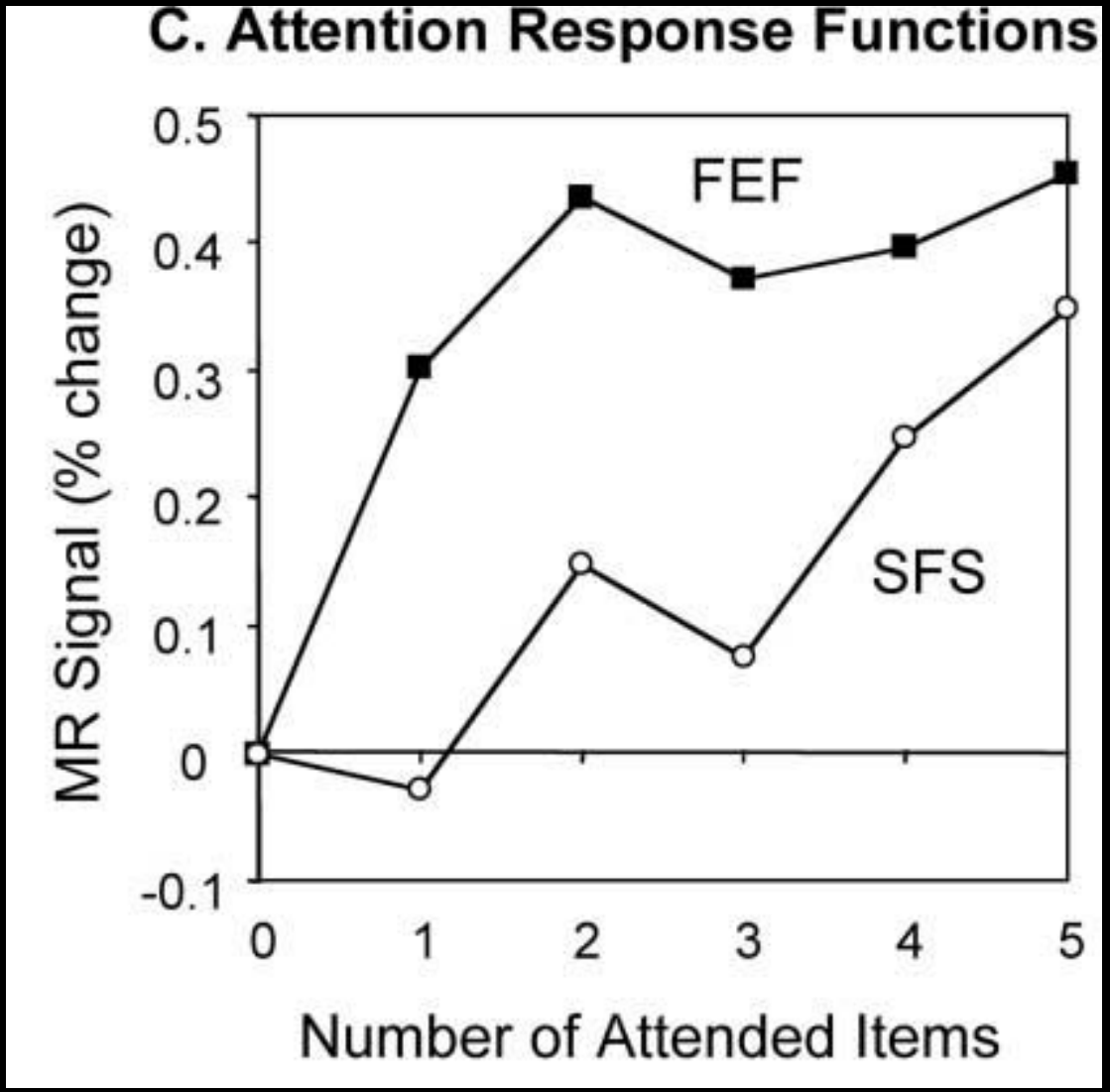
- Manipulate 1 factor *over several levels*: “parametric design”, e.g.:
  vary the # of attentively tracked balls (Culham et al 2001)….

A Parametric Study of Attentive Tracking
Culham et al (2001)



Attentive Tracking Demo

A Parametric Study of Attentive Tracking



Culham et al (2001)

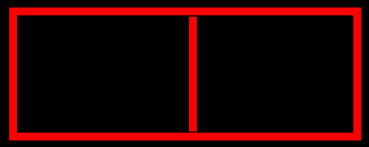
Region FEF is more simply task-dependent:
When you are doing the task, this region is active.

Region SFS is more monotonic:
Activity in this region increases with attentional load.

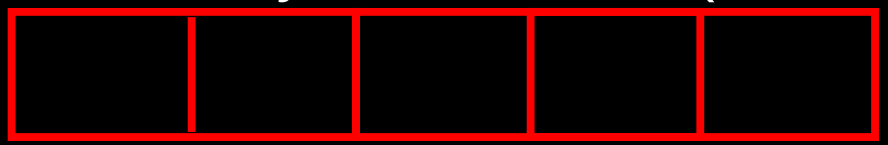
Suggests different functional roles of these two regions.

Standard Designs

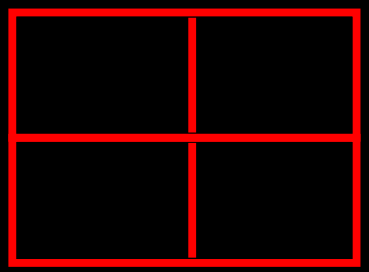
- Manipulate one factor with two levels, e.g.:
  passive viewing of faces versus objects
  comparing the number versus color of two dot arrays



- Manipulate 1 factor *over several levels*: “parametric design”, e.g.:
  vary the contrast of gratings or the speed of moving dots
  vary the # of attentively tracked balls (Culham et al 2001)….

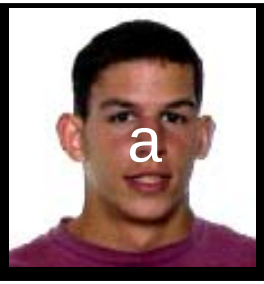
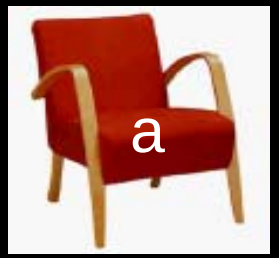


- Manipulate 2 factors *orthogonally*, e.g……..



"Factorial Designs"

Enables us to ask:
(How) Is selectivity for faces affected by attention?

	faces	objects
Atten-ded		
Un-Atten-ded		

Monitor for Face/obj repetitions

Monitor for letter repetitions

"Factorial Designs"

Enables us to ask:
(How) Is selectivity for faces affected by attention?

Selectivity found only when attended!

	faces	objects
Atten-ded	2	1
Un-Atten-ded	1	1

(Fake data)

This is an "interaction": the effect of one factor (face/obj) depends on what level we are at on the other factor (att/unatt).

Standard Designs

- Manipulate one factor with two levels, e.g.:
  passive viewing of faces versus objects
  comparing the number versus color of two dot arrays

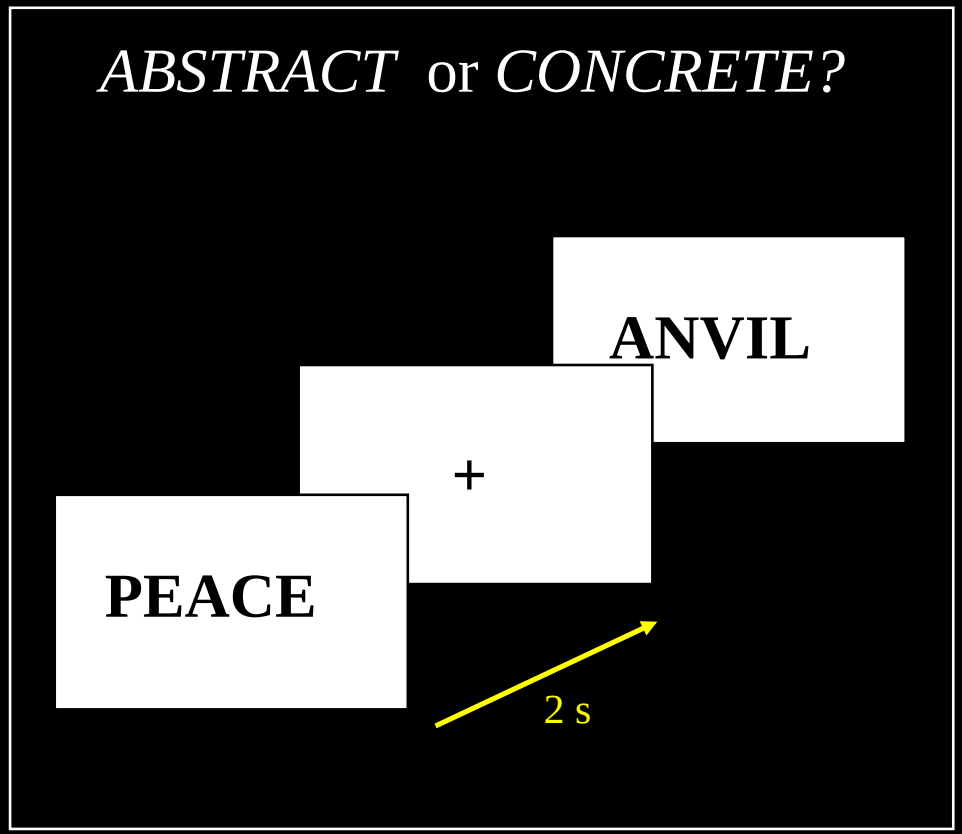
- Manipulate 1 factor *over several levels*: “parametric design”, e.g.:
  vary the contrast of gratings or the speed of moving dots
  vary the # of attentively tracked balls (Culham et al 2001)….

- Manipulate 2 factors *orthogonally*, e.g.:
  faces vs objects x attended versus unnattended (on same stimuli)
  enables you to ask (with the interaction term in an ANOVA) if the increase in activation for faces in a given region is affected by attention.

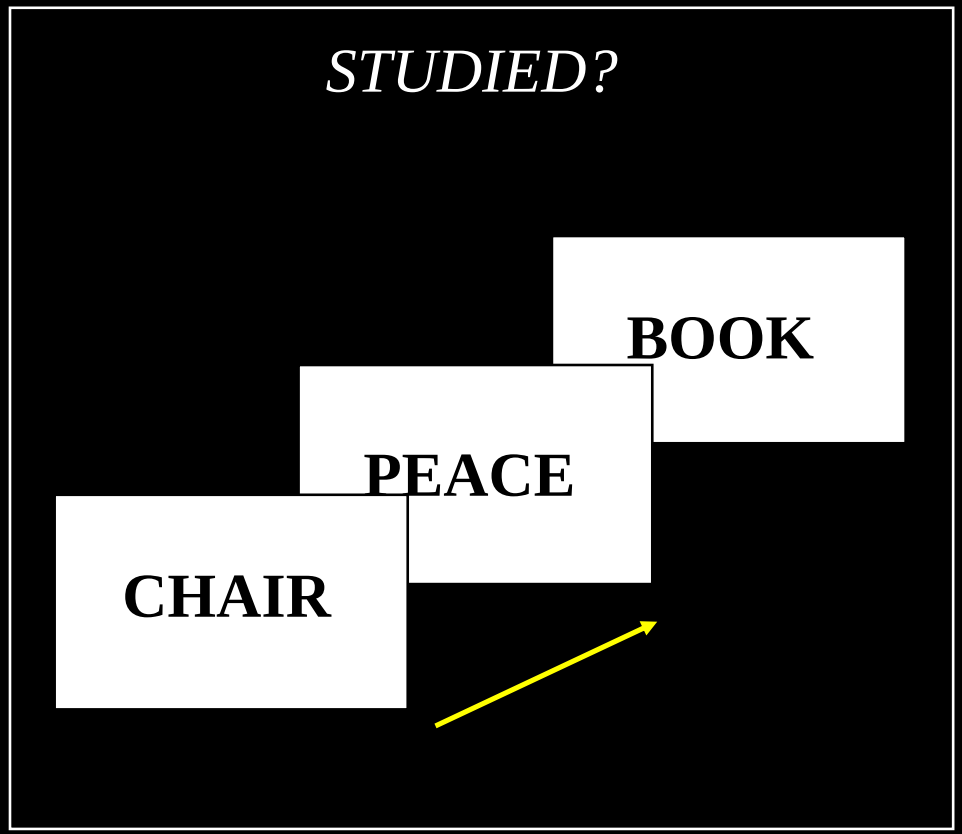
- Manipulate nothing; bin by behavior, e.g….

Wagner et al (1998)
Predicting Verbal Explicit Memory

fMRI Scanning during
Word Learning



Post-Scan Memory Test



Temporal Arrangement

How should these various conditions be distributed temporally within and across scans?

Some Tips:

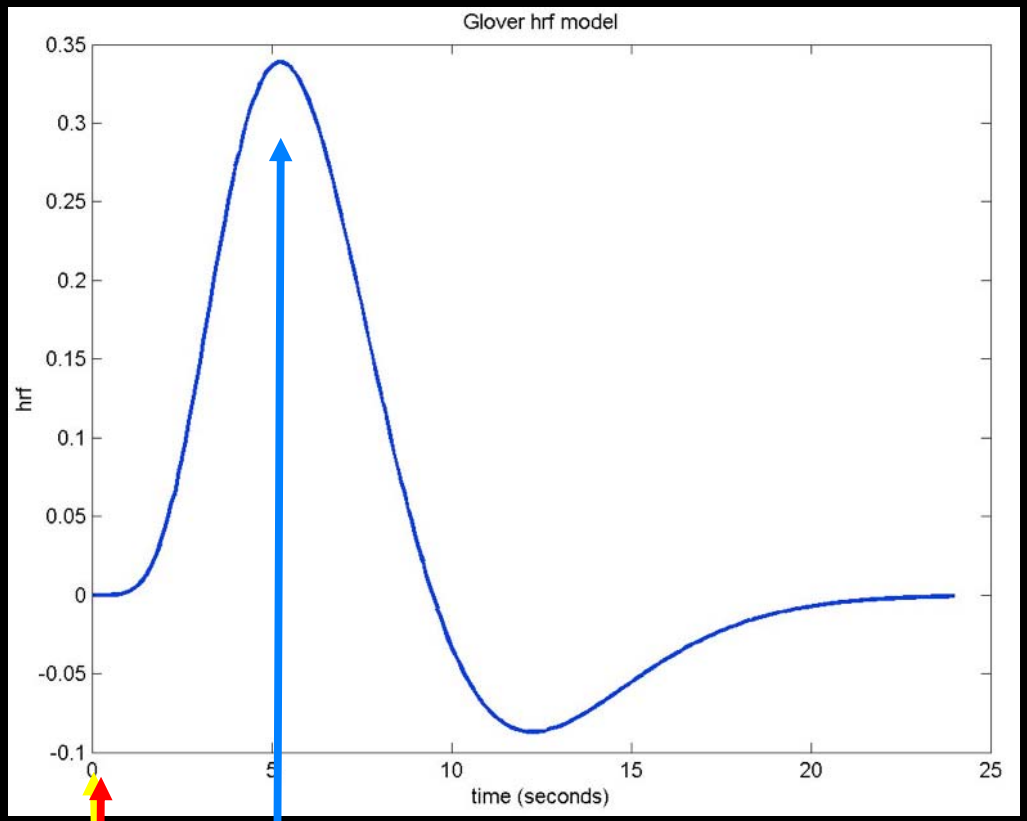
- Try to include all conditions within a subject and within a scan
- Avoid order confounds by counterbalancing within and across scans - subjects are more alert at beginning of scan.
- Tradeoffs concerning the length of each epoch:
  - difficulty of task switching
  - noise is generally low frequency so rapid alternation between conditions moves signal away from noise in freq space
  - importance of unpredictability
  - extreme ends of the spectrum: “blocked” vs “event-related”

Blocked vs. Event-related

Images removed due to copyright restrictions. Fig. 1A in Buckner, R. L. "Event-Related fMRI and the Hemodynamic Response." *Human Brain Mapping* 6, no. 5-6 (1998): 373-377.

Source: Buckner 1998

Recall the BOLD hemodynamic response function (HRF)



Visual stimulus on

Neurons fire

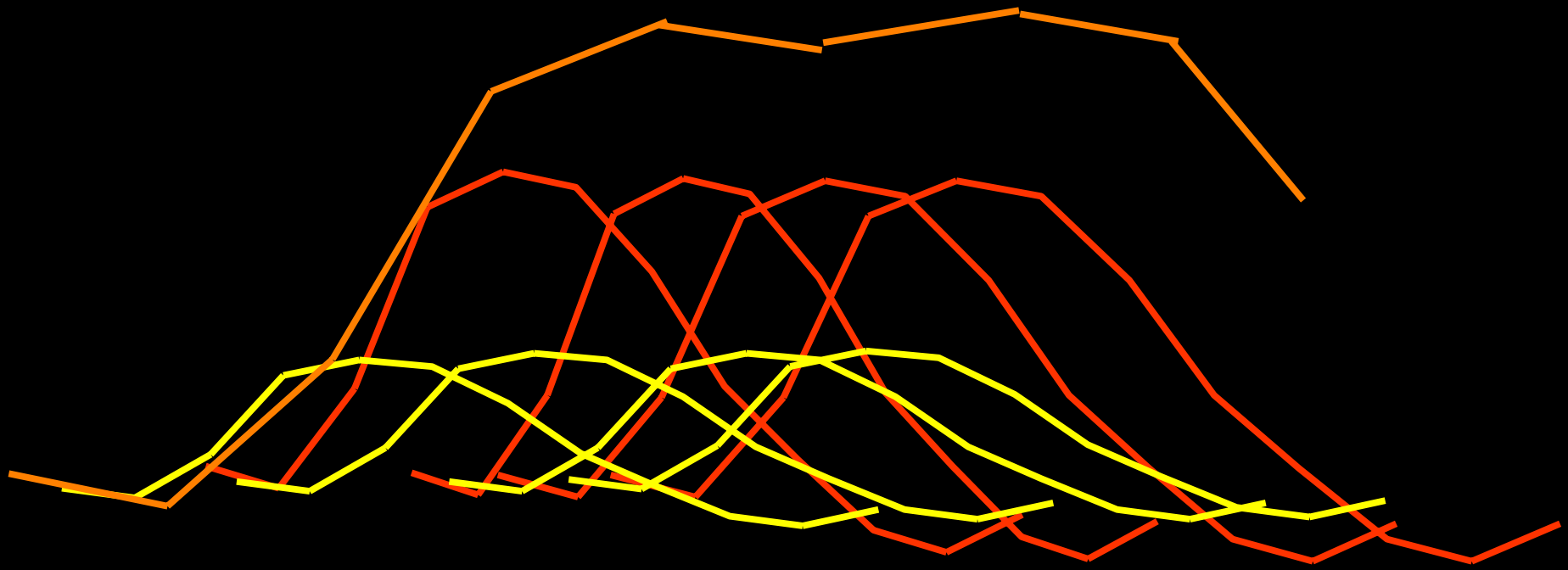
BOLD response

>>>> BOLD response is *SLOW*.

How do we analyze trials that occur in rapid succession?

Observed: the sum of all of these:

NOW: how do we recover the response to houses, and the response to faces?
The simplest way: just average…



modified by OCW
for privacy considerations.

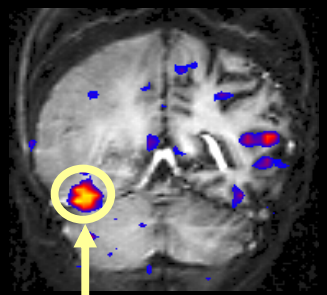
Event-related Design Logic

Collect all the face responses, align them, and average.

Then collect all the house responses, align them, and average.

Face photos modified by OCW
for privacy considerations.

FFA:



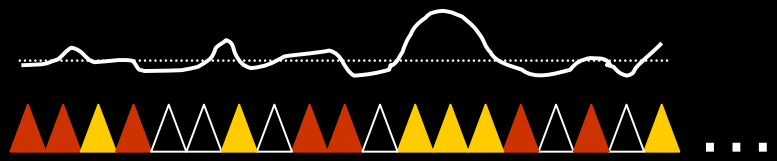
Courtesy of Paul Downing. Used with permission.

Courtesy of Society for Neuroscience. Used with permission.

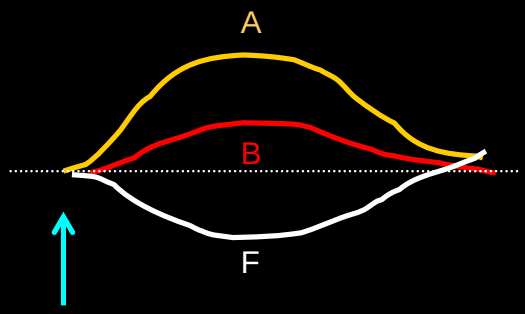
Slide adapted from Paul Downing

Analysis of Single Trials w/ Counterbalanced Order

Raw data

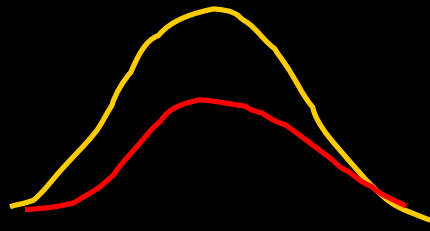


Event-related average



Event-related average
with control period factored out

A signal change = (A – F)/F



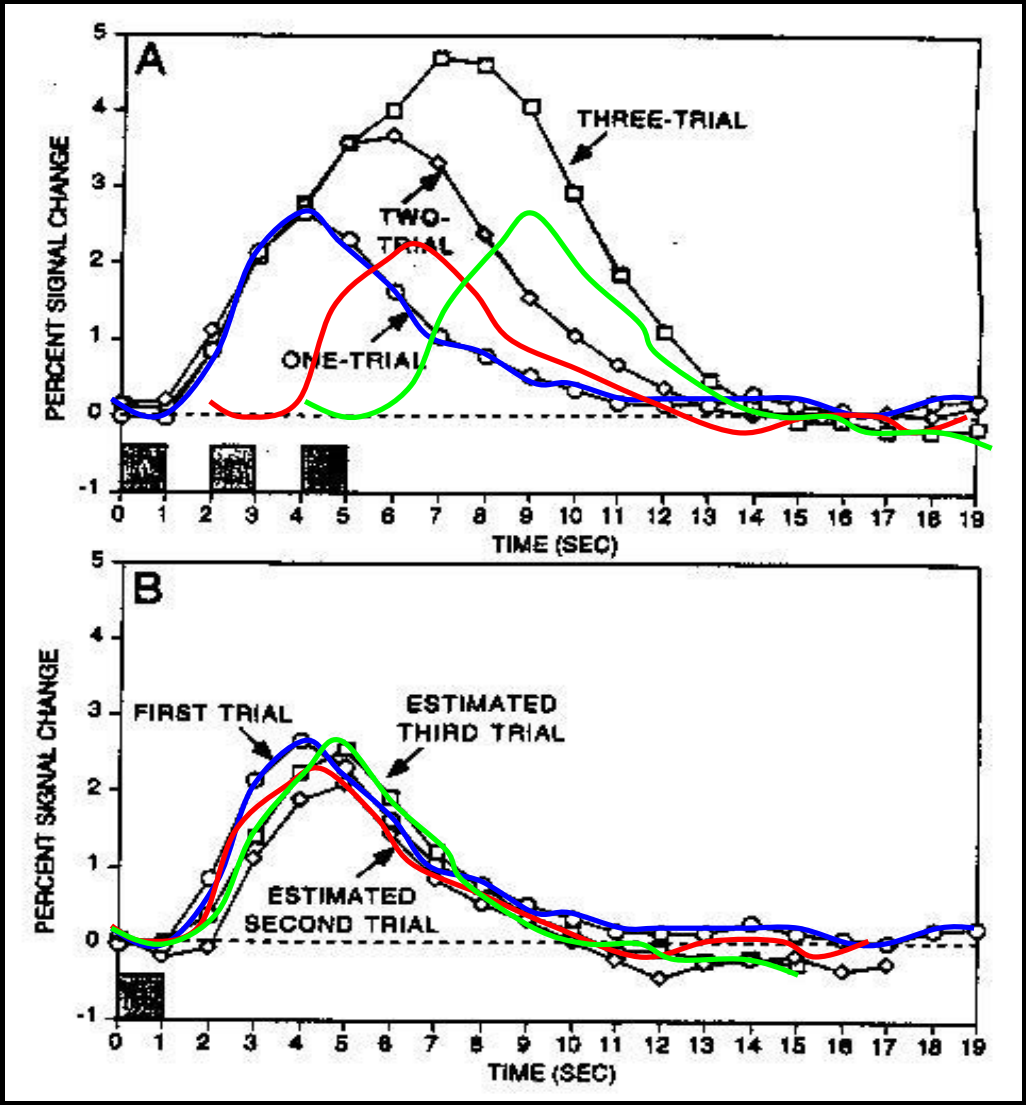
B signal change = (B – F)/F

Note that this will only work if MRI signals from different trias sum linearly. Do they?

Adapted from Jody Culham's fMRI for Dummies web site
http://psychology.uwo.ca/fmri4newbies/

Dale & Buckner, 1997

Linearity of BOLD response



Linearity:
"Do things add up?"

red = 2 - 1

green = 3 - 2

Sync each trial response to start of trial

Not quite linear but good enough

Soon et al (2003): things are less linear in more anterior regions.

Slide from Jody Culham

Courtesy of http://psychology.uwo.ca/culhamlab/

Advantages of Event-Related

Flexibility and randomization

- eliminate predictability of block designs
- reduce practice effects
- reduce attentional confounds

Post hoc sorting

- (e.g., correct vs. incorrect, aware vs. unaware, remembered vs. forgotten items, fast vs. slow RTs)

Rare or unpredictable events can be measured

- e.g., P300

Can look at different phases of the response within a trial (if it is long enough to resolve these)

- Sample versus delay in a working memory tasks
- attentional cue versus response in an attention task

Source: Buckner & Braver, 1999 via Culham

Outline for Today

Lecture 2A: Introduction to the Ventral Visual Pathway

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including FFA, PPA, EBA, LOC

II. Controversies about the VVP & Unanswered Questions

Lecture 2B: Experimental Design & Data Analysis

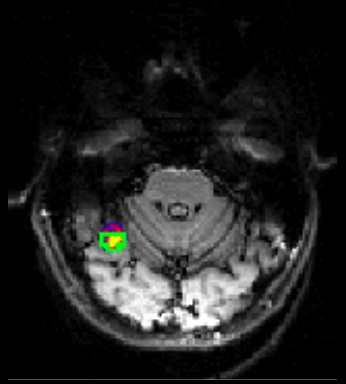
I. Basic Kinds of Experimental Designs

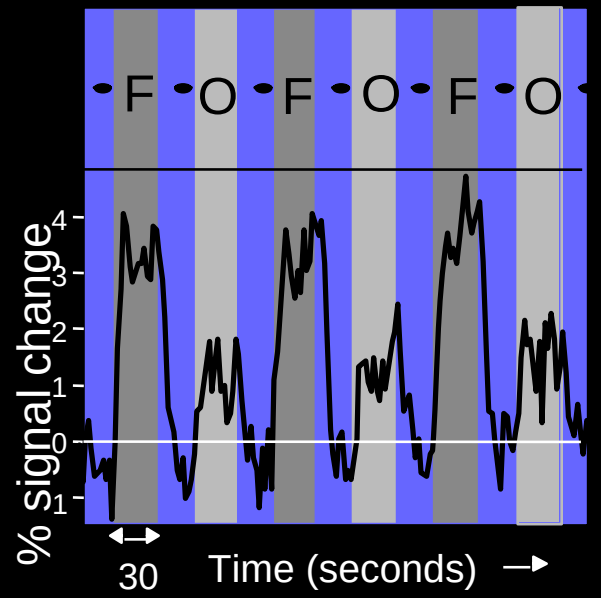
II. Basic Data Analysis Methods

III. Five Common Problems with fMRI Experiments

Example of Raw Data & The “Eyeball Test”

Faces > Objects





Do we need stats here? Why?

Why do we need stats?

- Eyeballing raw time courses isn't a viable option. We'd have to do it 49,152 times and it would require a lot of subjective decisions about whether activation was real. Plus, somewhere in there we are bound to find a nice result (so beware of "voxel sniffing").

- This is why we need statistics

- Statistics:
  - » tell us where to look for activation that is related to our paradigm
  - » help us decide how likely it is that activation is "real"

Source: Jody Culham's fMRI for Dummies web site
http://psychology.uwo.ca/fmri4newbies/

Formal Statistics

- Formal statistics are just doing what your eyeball test of significance did
  - » Estimate how likely it is that the signal is real given how noisy the data is
- confidence: how likely is it that the results could occur purely due to chance?
- "p value" = probability value
  - » If "p = .03", that means there is a 3% chance that these results could be found even if the data were noise.
- By convention, if the probability that a result could be due to chance is less than 5% ($p < .05$), we say that result is statistically significant
- Significance depends on
  - » signal (differences between conditions)
  - » noise (other variability)
  - » sample size (more time points are more convincing)

Source: Jody Culham's fMRI for Dummies web site
•*http://psychology.uwo.ca/fmri4newbies/*

A Big Challenge in NeuroImaging

Suppose you run your statistics on each of the 49,152 voxels you scanned

You find 200 voxels that reach the $p<.05$ significance level.

Should you be impressed?

Lots of fancy math has been proposed for how you “correct for multiple comparisons”.

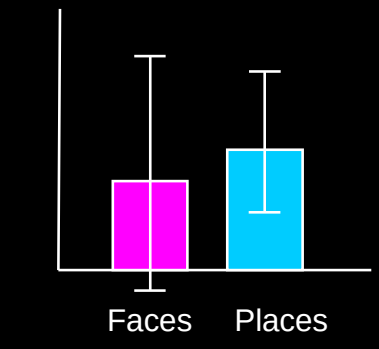
You can avoid this whole problem if your hypothesis refers to a specific place in the brain that you specify in advance (though not all intersting hypotheses are of this form).

A Common Statistical Error

Common flawed logic:

Run1: A – baseline
Run2: B – baseline

"A – 0 was significant, B – 0 was not, ∴ Area X is activated by A more than B"



Error bars = 95% confidence limits

If you do this, you can get a situation where A is significantly > 0 but B is not, yet the difference between A and B is not significant

Bottom line: If you want to compare A vs. B, compare A vs. B!

You can find this error in some fancy journals….

Owen et al (2006), *Science*, 313, p. 1402.

Tennis > rest
And
Navigation > rest

Are these patterns of activation different from each other?

Image removed due to copyright restrictions.
Fig. 1 in "Detecting Awareness in the Vegetative State." Adrian M. Owen, Martin R. Coleman, Melanie Boly, Matthew H. Davis, Steven Laureys, John D. Pickard. *Science*, 8 SEPTEMBER 2006, VOL 313.

1. These statistics don't tell us!
(What would we have to do?)
What else is fishy here?

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II. Basic Data Analysis Methods

III. Five Common Challenges with fMRI Experiments

Problem 1: What counts as the "same place" in the brain?

I. Individual Subject versus Group Analyses

We can ask whether the "same place" in the brain is activated by two different tasks if we look within individual subjects. Here same place means *exact same voxel/s in the exact same subject*. But then how to we generalize to other subjects?

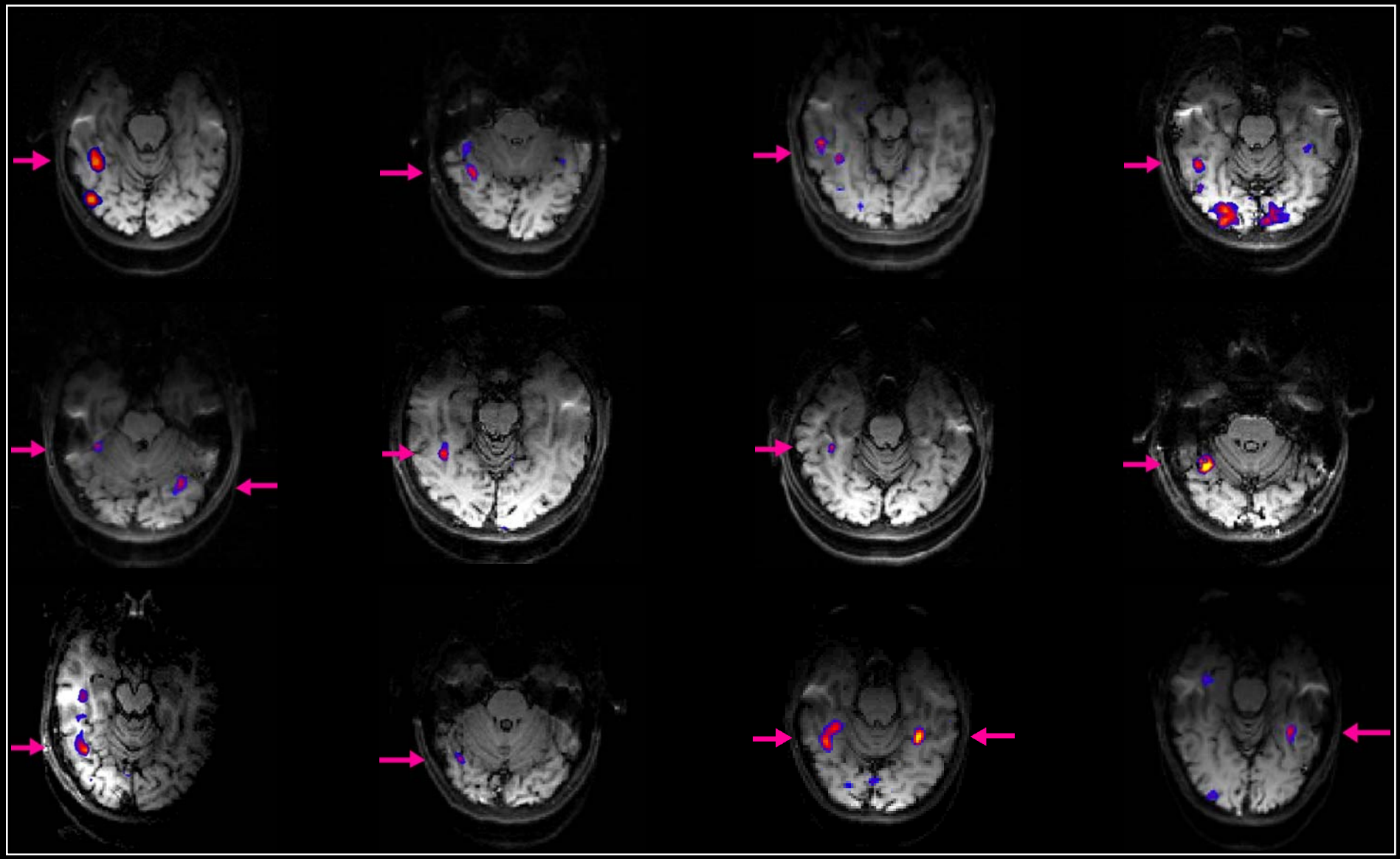
- We want to be able to make a general claim about all (or most) people, not just a claim about Joe Shmo's brain.

- But people's brains are as different in shape from one person to the next as their faces are.

- So: What is the "same place" in two different brains?
  (Is the freckle on Joe's nose in the *same place* as the freckle on Bob's face?)

- Approach 1: use gyri/sulci to indicate brain locations….

For example is this face > object activation
in the "same place" in these 12 subjects?

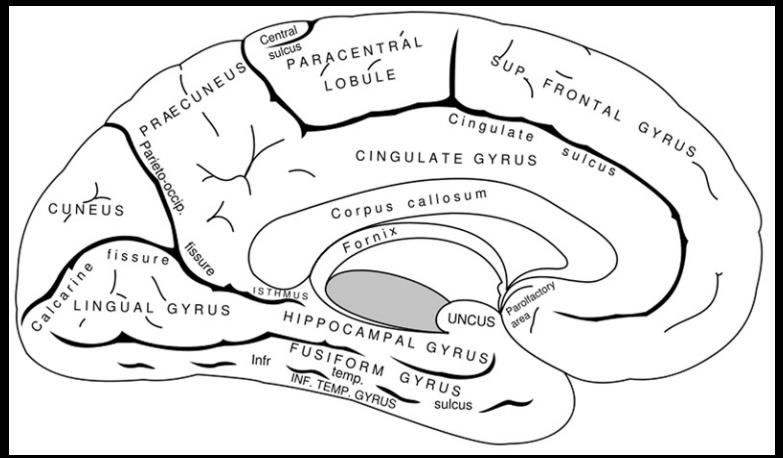


Fusiform Gyrus

Consider this (published) argument:

1. Kanwisher says there is a face-selective region in the fusiform gyrus.
2. But we found a region that responds strongly to non-face stimuli in the fusiform gyrus.
3. Kanwisher is wrong about that face-selective region: it isnt face-selective.

Is this a good argument? Why/why not?



Courtesy of wikipedia.
http://en.wikipedia.org/wiki/File:Gray727.svg

What counts as the "same place" in different brains?

Approach 2: Register all subjects to a "common space"

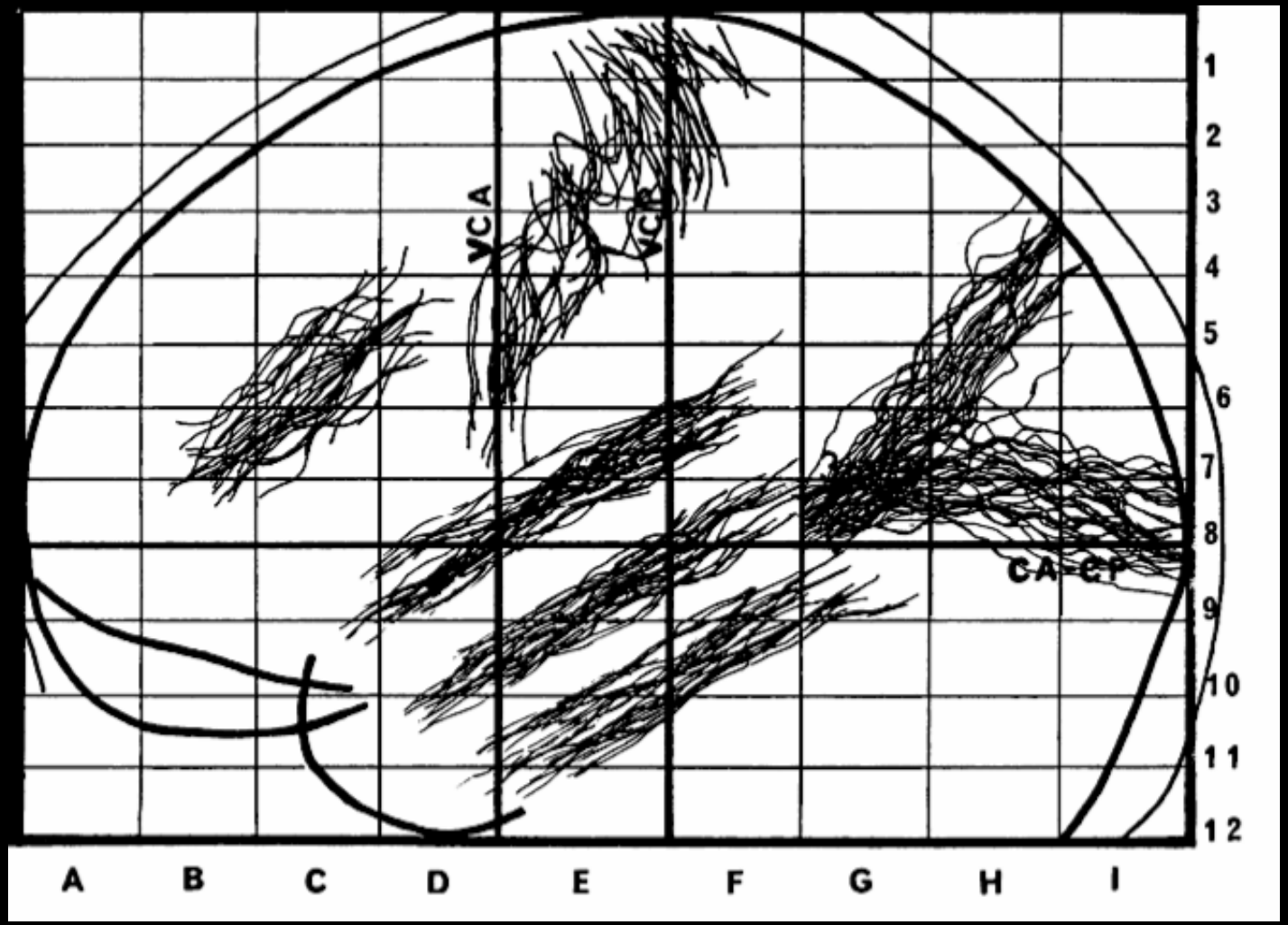
For example: Talairach space: an alignment method with several degrees of freedom - linear transformations (stretch, twist) for best fit.

Then run statistics across subjects on voxels in this common space.

Problems:

- Even "hard" anatomical loci (e.g. major sulci) do not coregister to the same place across subjects…..

Variability in Sulcal Locations Across Individuals in Talairach (1967) Space



Source: R. Woods, Correlation of Brain Structure and Function. Chapter in *Brain Mapping*

What counts as the "same place" in different brains?

Approach 2: Register all subjects to a "common space"

For example: Talairach space: an alignment method with several degrees of freedom - linear transformations (stretch, twist) for best fit.

Then run statistics across subjects on voxels in this common space.

Problems:

- Even "hard" anatomical loci (e.g. major sulci) do not coregister to the same place across subjects.
- Even with respect to "hard" anatomical landmarks, some functionally-defined regions may vary anatomically across subjects.
- To get around this data are typically blurred ("smoothed") within each subject before analysis.
- The smoothing and the imperfect registration drastically lowers resolution.

Interpreting Group-Averaged Data

Approach 2: Register all subjects to a “common space”
Then run statistics across subjects on voxels in this common space.

Inferences:

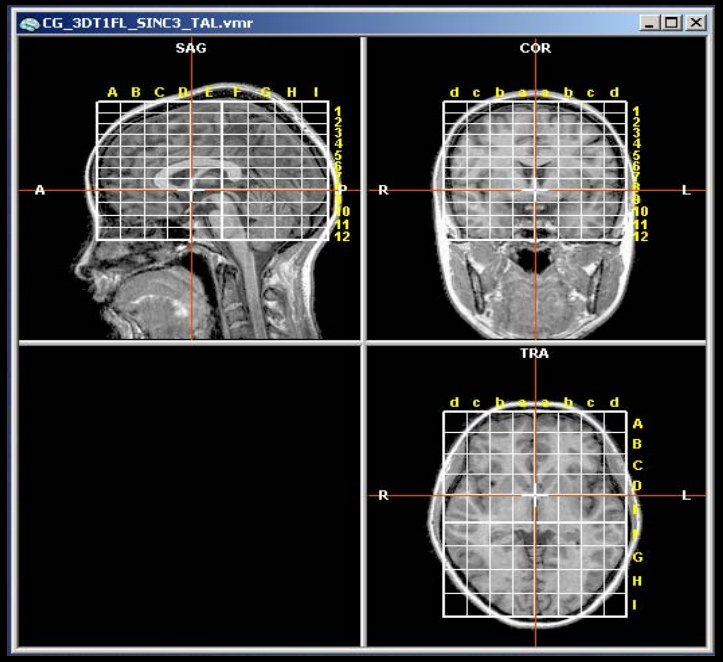
- If an activation is significant across subjects in the group data that implies that the region is consistent enough (or large enough) that it lands in an overlapping location across many of the subjects.

- BUT: failing to find an activation in the group data could just mean the region in question is anatomically variable and does not get well aligned across subjects.

- Similar or overlapping group activations for two different comparisons do not necessarily imply that the same voxels are activated in each individual. Why?

Common Use of Whole Brain Group Stats

1. You don't necessarily need a priori hypotheses (though sometimes you can use less conservative stats if you have them)
2. Average all of your data together in Talairach space
3. Compare two (or more) conditions using precise statistical procedures and assumptions. Anything that passes at a carefully determined threshold is considered real.
4. Make a "laundry list" of these areas and publish it.



When will this aproach be useful/interesting?

Alternative: ROI approach….

Adapted from Jody Culham's fMRI for Dummies web site

•http://psychology.uwo.ca/fmri4newbies/

What counts as the “same place” in different brains?

Approach 3: use individually-defined “regions of interest” (ROI).

1. Localize ROI individually in each subject anatomically (e.g., hippocampus; calcarine sulcus) or w/ functional “localizer” scan, e.g. face area = faces > objects.

2. Run new scans in the same subject and session. Quantify the response of previously-defined region to new conditions.

- deals with anatomical variability across Ss
- removes requirement to correct for multiple comparisons

Though widely used, this method is considered controversial by some….

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NeuroImage 30 (2006) 1077 – 1087

Comments and Controversies

A critique of functional localisers

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Received 4 May 2005; revised 19 July 2005; accepted 15 August 2005

Introduction

The use of functional localisers to constrain the analysis of fMRI data is becoming popular in neuroimaging. This approach entails a separate experiment to localise areas in the brain that serve to guide, constrain or interpret results from a main experiment. The need and motivation for functional localisers are often not stated explicitly and is sometimes unclear. Nevertheless, several colleagues have encountered reviewers who thought that omission of a functional localiser did not conform to good or standard practice. The purpose of this commentary is to provide a reference for people who do not want to use functional localisers and have to defend themselves against the contrary attitudes of reviewers (see Appendix A for some verbatim comments).

See reply by Saxe, Brett, & Kanwisher (2006)

Comparing the two approaches

Region of Interest (ROI) Analyses

- Is useful to the extent that the ROI is a real "thing", that we are "carving nature at its joints".
- Gives you more statistical power because you do not have to correct for the number of comparisons
- Hypothesis-driven
- ROI is not smeared due to intersubject averaging
- Easy to analyze and interpret
- Neglects other areas which may play a fundamental role (though can use multiple ROIs)
- Popular in North America

Whole Brain Analysis

- Requires no prior hypotheses about areas involved
- Includes entire brain
- Often neglects individual differences
- Can lose spatial resolution with intersubject averaging
- Can produce meaningless "laundry lists of areas" that are difficult to interpret
- You have to be fairly stats-savvy
- Popular in Europe

NOTE: Though different experimenters tend to prefer one method over the other, they are NOT mutually exclusive. You can check ROIs you predicted and then check the data for other areas.

Adapted from: Jody Culham's web site

Courtesy of Jody Culham

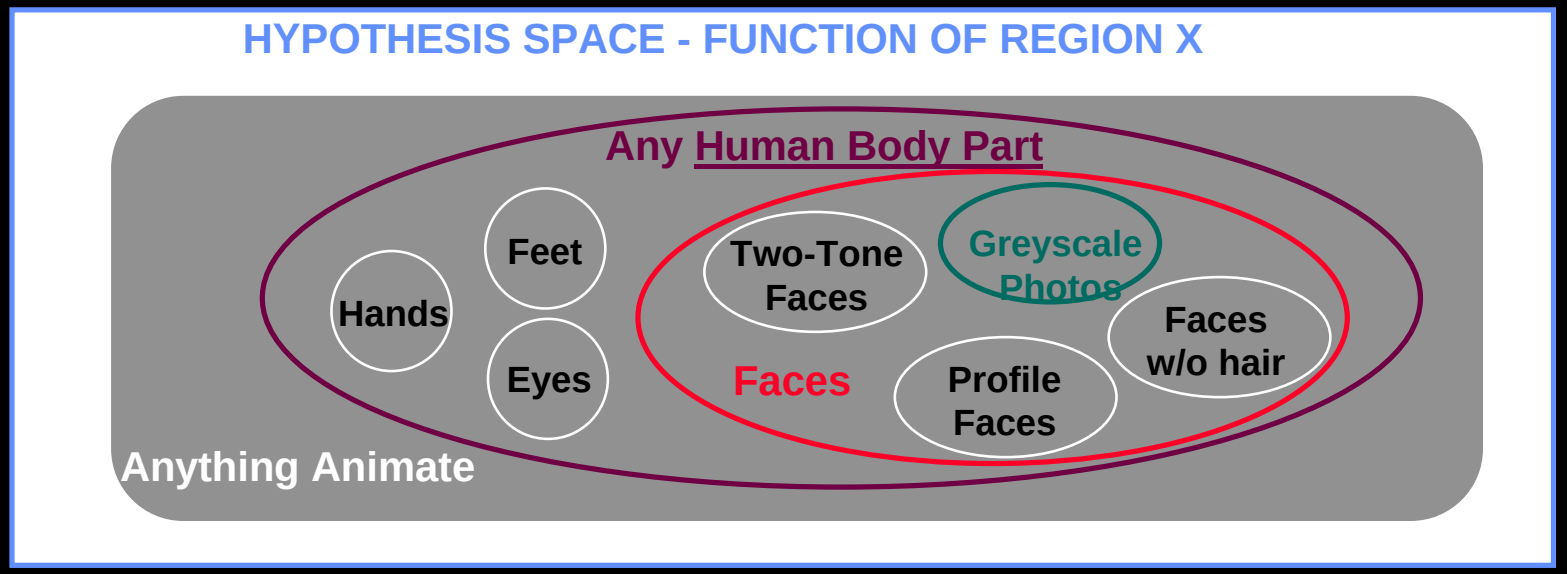
Problem 2: Infering Function at the Right Level of Generality/Specificity

Hypothesis: Region X is involved in process Y.

Evidence: Region X is activated when subjects do an instance of process Y.

Problem: Without running several further conditions, we can't tell whether region X might instead be involved in something either more specific or more general than process Y.

Example:

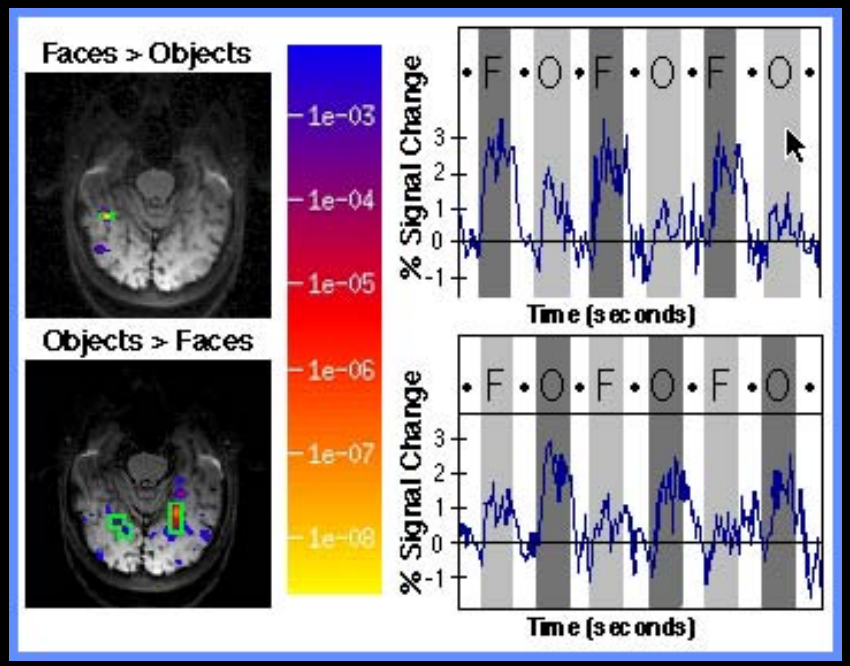


Problem 3: Attentional Confounds

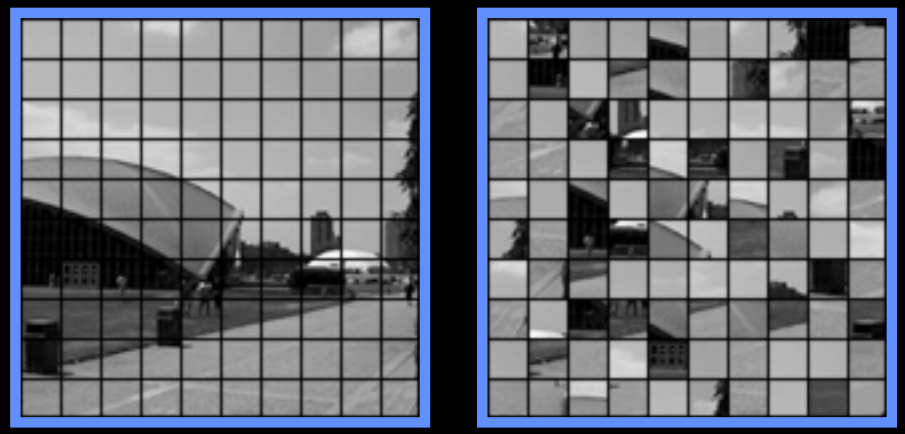
→ **A given region might respond more strongly in condition A than condition B simply because A is more interesting/attention–capturing than B.**

Solutions:

I. Double dissociations



II. Test conditions with opposite attentional predictions



A **B**

Predictions from Attention alone:

passive viewing: A > B

1–back task: B > A

If A > B in both, then result is probably not due to an attentional confound.

Problem 4: Statistical Significance vs. Theoretical Significance

→ **P levels alone are not sufficient.**

For example, the FFA may respond significantly more to pineapples than watermelons, but the response to pineapples might nonetheless be much lower than the response to faces.

Solutions:

- Quantify effect size, e.g. with percent signal change.
- Provide "benchmark" conditions within the same scan to give these magnitudes meaning.

	Objects	Watermel.	Pineapp.	Faces
NO BIG DEAL	0.6	O.7	0.9	2.0
TROUBLE	0.6	O.7	1.8	2.0

Problem 5: Activity vs. Necessity

→ **Just because a given region is active during a given process doesn't mean that region is *necessary* for that process.**

fMRI has no way to test necessity, though we can get a little closer to a causal connection if we find a correlation between fMRI signal and performance.

<u>Solutions (?): Use other methods!</u>

- TMS
- Patient Studies
- Animal Lesion or Microstimulation Studies

Problem 6: Time Course

→ **Visual recognition happens within about 200 ms, which means that its component processing steps take tends of milliseconds. Yet the temporal resolution of fMRI is much lower than this.**

<u>Solutions (?): Use other methods for studying temporal information</u>

- ERPs & MEG
- Single unit recordings

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[Lecture 2C: Critiquing fMRI Experiments: Some Tips

Discussion of Lie Detection]

Tips on How to Critically Evaluate fMRI Studies

1. First, figure out what question the researcher is asking and what answer they are giving to that question.

Ask yourself: Is this an interesting question? Does it have clear theoretical implications and if so what are they? Do you care about the result? Should anyone? Why? Are you *surprised* by the result? Situate the question in a broader theoretical context. If there is no such broader context, be worried.

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2. The most critical aspect of the design of the experiment is: what is getting compared to what?

Make a list of all the mental functions that you think go on during the critical test condition. Then make a list of all the mental functions that are going on in the control condition, then see how many go on only (or more) in the test condition than the control condition.

Are the test and control conditions “minimal pairs”?

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3. Classic problems in analyses/inferences/conclusions to be wary of:

A. “Brain area X was activated by task Y.”

i. Ask: task Y *compared to what*? Everything is a comparison, and many comparisons are uninformative/trivial.

ii. What else activates brain area X?

iii. How strongly activated was that region? Not all ‘activations” are the same - *Effect sizes matter!* If one condition produces a massive response compared to a given baseline, and another condition produces a very small but significant activation, the two “activations” are not the same.

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B. “Because Region X responded significantly more strongly in Task A than control, but didn't respond significantly more strongly in Task B than control, it is selectively activated by Task A.”

A difference in significances is not necessarily a significant difference.

If you want to claim that the region responds more to A than B, then *compare A to B*. Statistics are not transitive.

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C. Claims of this form: "We found activation in the medial prefrontal cortex for tasks involving reasoning about other minds, consistent with numerous prior studies."

Brains are as different across individuals as faces are, so what counts as the "same place" in the brain is not well defined across different brains.

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D. "The results of the present study demonstrate that Task A is carried out in a distributed network of cortical areas."

What has been learned here?

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4. Some of the many ways to cheat:

A. Showing data from the “best voxel”.

With tens of thousands of voxels to chose from in an overall nosiy data set, some of them will look pretty good.

B. Showing activation maps that “look similar” or “look different”.

There are many ways to chose particular slices, thresholds, etc to make activations look similar or different. If the claim is that they are similar or different, this should be tested statistically *on the exact same voxels*. Just showing similar-looking activations (especially in group data or across subjects) without statistically testing whether the *same voxels* are activated, is very weak. Beware of sneaky choice of slices; look at the anatomical images to see if it really is the same slices.

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5. Some signs of a well done study:

A. The researchers show some raw data, e.g. nonfitted time courses or at least percent signal increases from fixation (or “beta weights”) in independently-defined regions of interest.

B. The critical result is replicated at least once.

C. More than one control condition is used, or the control condition is a “minimal pair”.

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6. Some important general caveats about fMRI research:

A. Typical imaging parametrs include about *several hundred thousand neurons per voxel*! Most studies smooth their data and average across subjects which increases this number dramatically. It is a great miracle that we see anything at all with this method.

B. Temporal resolution of fMRI is lousy – at best a few 100 ms. Most of cognition happens in tens of milliseconds, not hundreds. So component steps cant usually be resolved.

C. fMRI activations do not imply necessity!