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# 9.71 Functional MRI of High-Level Vision
Fall 2007

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# Lecture 9 9.71 Fall 2007

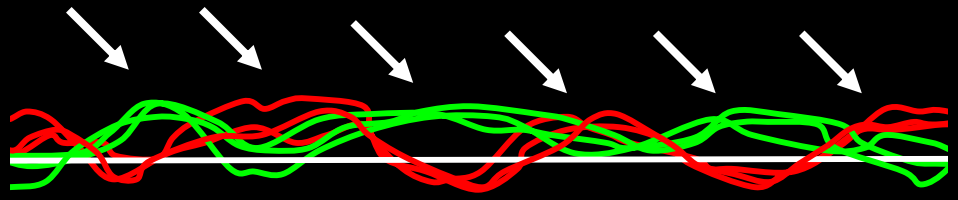
I. Midterm
II. Spatial Patterns of fMRI response: What information do they contain and what can they tell us about object representations?

Featuring work from my lab by:

*Becca Schwarzlose, Hans Op de Beeck, Leila Reddy, Mark Williams.*

# How spatially distributed are object representations in the cortex?

Imagine a profile of response across the cortex for two object classes A & B:



*distance across the cortex in neurons (microns) or voxels (mms)*

Caveat: voxels can tell us only about *spatially clustered* information.

Are objects coded neurally by a relatively small number of peak responses?

Or by the distributed profile of response across a larger number of neurons/voxels, most of which respond weakly to that object (Haxby)?

If the weak responses are fairly *consistent within an object class*, yet consistently *different between object classes*, then they contain information.

This question applies to micro level (neurons) and to macro level (voxels).

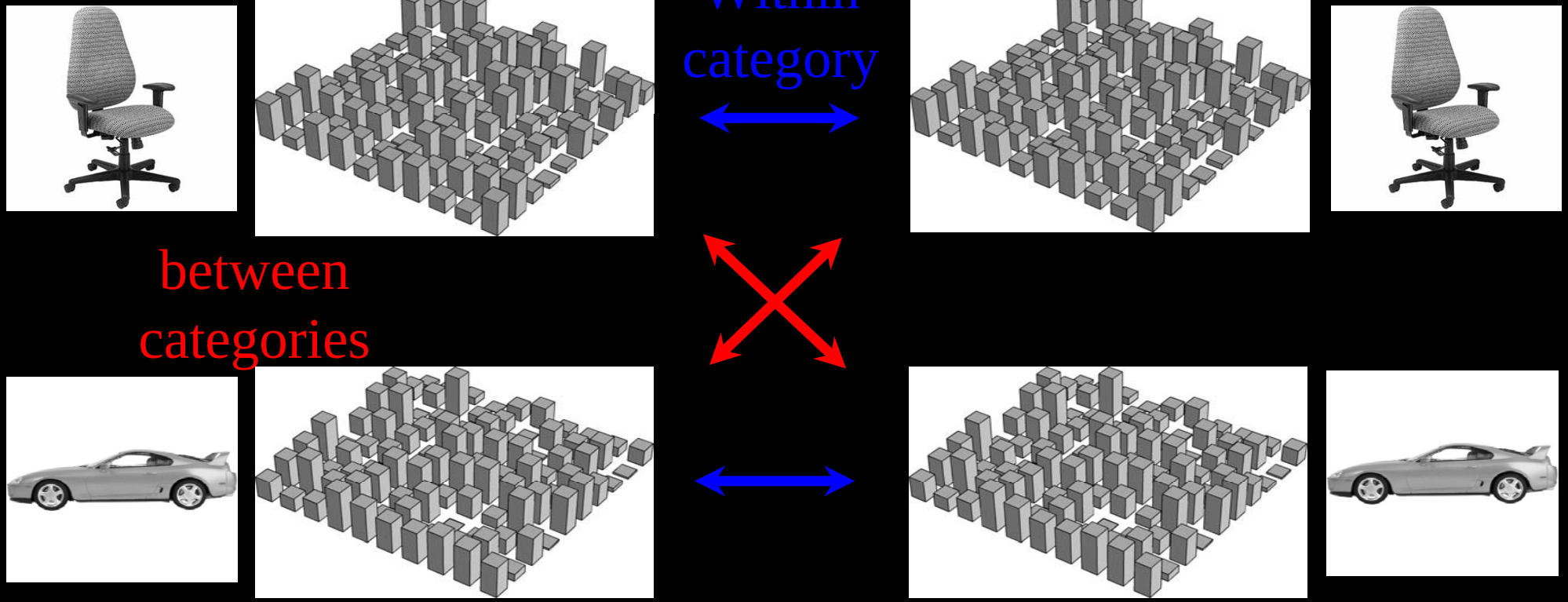
# Four Questions

A = faces
B = chairs
C = shoes

- What info is contained in the spatial profile of fMRI response across VVP?
- Does SPfR in FFA contain information about nonfaces? B vs. C ?
- Can SPfRs represent multiple objects presented simultaneously?
- Which of the information contained in SPfRs is *used/read out* in behavioral tasks?

# 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.




**Much fancier methods exist (e.g., SVMs).**

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

**Performance: for what % of pairs is r(w/in)>r(btwn)?**

# Haxby et al (2001): Distributed Representations of Objects

•Findings:

1. Overall performance is quite good, 96% of pairwise comparisons determined correctly.

2. So: can "read out" the code of what category of object the subject was viewing.

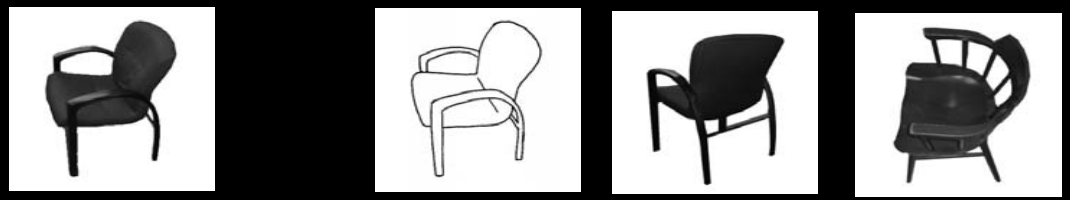
Will it generalize at all to new images of these categories?

# Spiridon & Kanwisher (2002)

We used a very similar technique to Haxby et al, but

But now looked for classification performance across changes in:

- Image format
- Viewpoint change.
- Exemplar change.



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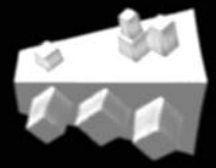
Performance was very good for all three, suggesting that low-level visual properties are not driving performance.

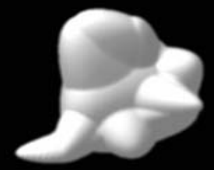
Spiridon, M. & Kanwisher, N. (2002) "How distributed is visual category information in human occipital-temporal cortex? An fMRI study. *Neuron* 35 (6) 1157-1165

# What does this Distributed Object Representation Reflect?

Does this object information reflect

- meaning?
- familiarity?
- shape?





We can't tell, these are all confounded.

If the same thing could be shown with novel shapes, that would suggest that shape is represented in the VVP, not just meaning.

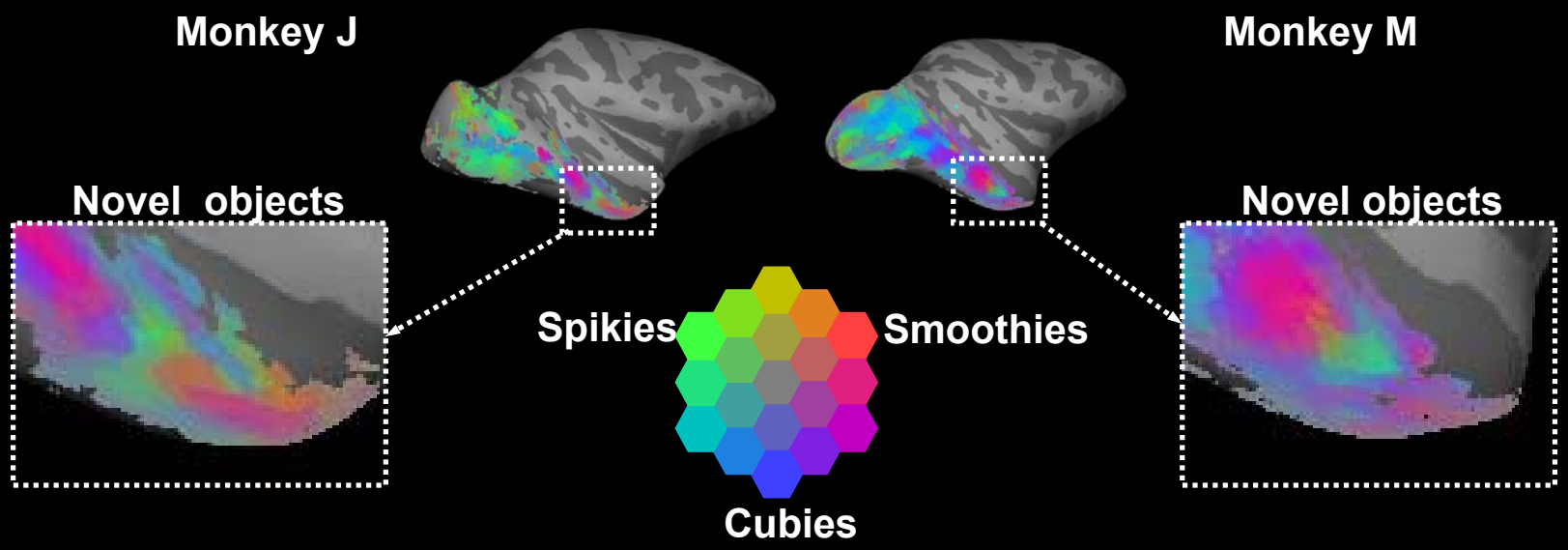
Images: Williams, M. A, N. Kanwisher et al. "Feedback of Visual Object Information to Foveal Retinotopic Cortex." *Nature Neuroscience* 11 (2008): 1439-1445.

Hans Op de Beeck, Jim DiCarlo, et al…..

Two monkeys scanned repeatedly while viewing these objects

# Conclusions: A Large-Scale Shape Map in Monkey IT Cortex

*Op de Beeck, Dicarlo, et al. (2008)*




- A robust topography of shape selectivity across IT, replicable across time, training, task, and stim. position.
- Systematically related to (but not reducible to) the face map.
- Shape map includes both global and local shape features.

See Op de Beeck, H. P., N. Kanwisher et al. "A Stable Topography of Selectivity for Unfamiliar Shape Classes in Monkey Inferior Temporal Cortex." *Cerebral Cortex* 18 no. 7 (2008): 1676 94.

# Object Categorization Performance from SPfRs in VVP

Does this object information reflect

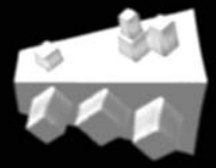
meaning?

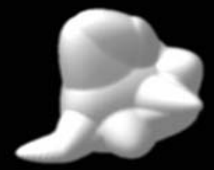
familiarity?

shape?

We can't tell, these are all confounded.

Not clear yet if human "object topography" is based on shape versus meaning.





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Hans Op de Beeck, Jim DiCarlo, et al…..

*Becca Schwarzlose*

Question: Is there location information in object- and category-selective regions?

Image removed due to copyright restrictions. See Fig. 2 in: Spiridon, M., B. Fischl, and N. Kanwisher. "Location and Spatial Profile of Category-Specific Regions in Human Extrastriate Cortex." *Human Brain Mapping* 27 (2006): 77-89.

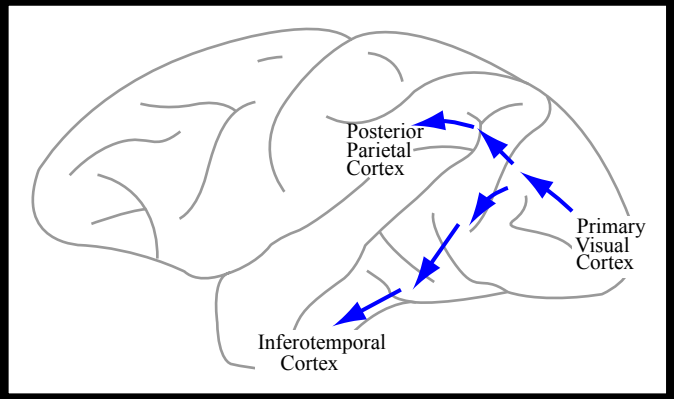



Figure by MIT OpenCourseWare.

- Monkey electrophysiology: more sensitivity to location in IT neurons than previously thought
  - » (Op de Beeck & Vogels, 2000;DiCarlo & Maunsell, 2003)

Vs.

- Retinotopic mapping with fMRI in humans shows retinotopic organization extending partway down the temporal lobe
  - » (Brewer, 2005; Heeger, 2006; Swisher, 2007)

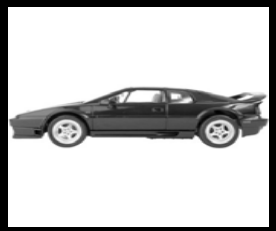
• Findings of eccentricity biases in some category-selective regions

•(Levy et al, 2001;Hasson et al, 2003)

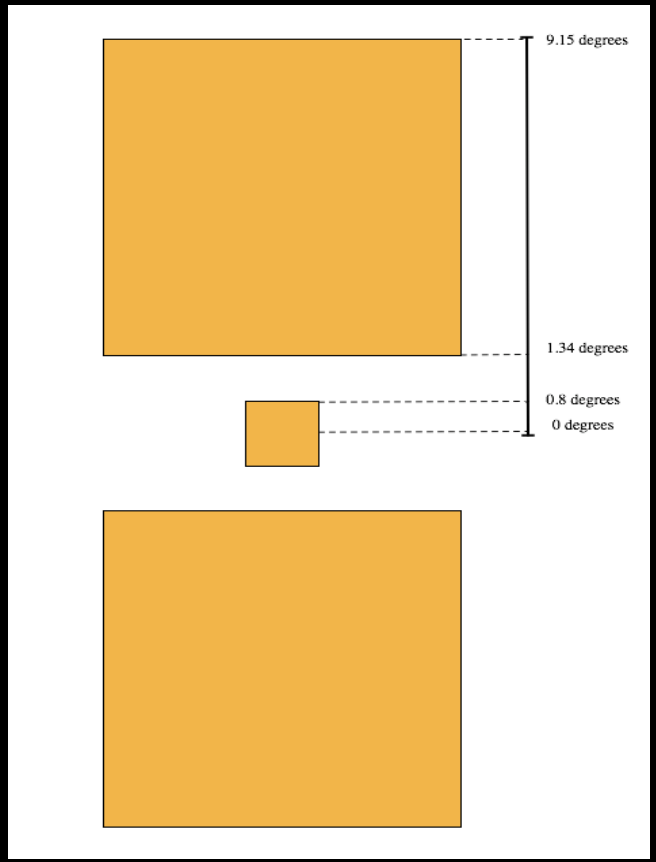
# Experimental Design

## LOCATION

## CATEGORY



X




Courtesy of Becca Schwarzlose. Used with permission.

# Regions-of-Interest (ROIs) included:

| Faces | Scenes | Bodies | Objects |
|---|---|---|---|
| FFA | PPA | FBA | pFs |
| OFA | TOS | EBA | LO |

Courtesy of Becca Schwarzlose.
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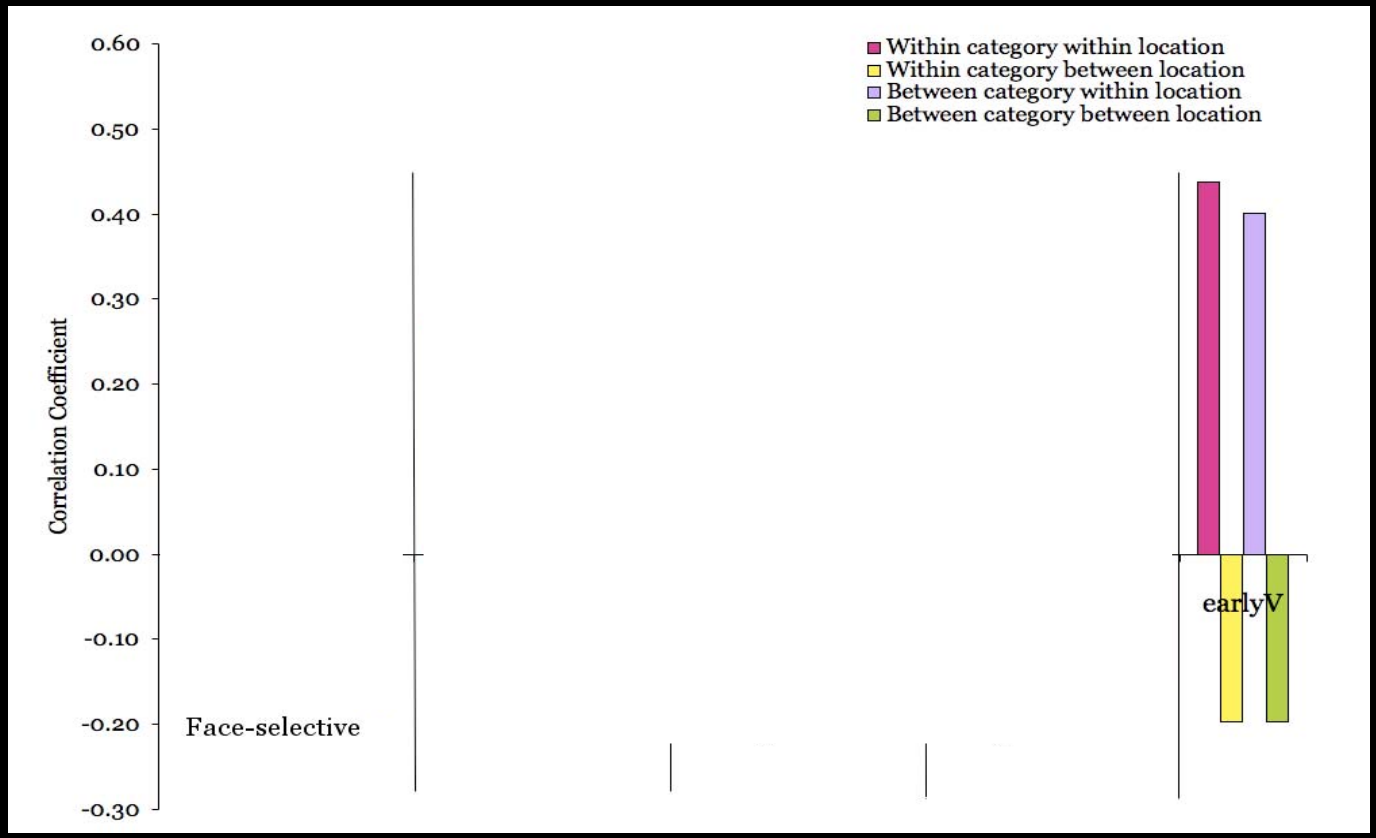
Image removed due to copyright restrictions. See Fig. 2 in:
Spiridon, M., B. Fischl, and N. Kanwisher. "Location and Spatial Profile of Category-Specific Regions in Human Extrastriate Cortex." *Human Brain Mapping* 27 (2006): 77-89.

Becca Schwarzlose

# Pattern Analysis Results: 2x2 ANOVA




- All ROIs contain category information except earlyV
- All ROIs contain location information except FBA

*Becca Schwarzlose*

The Distribution of Category and Location Information in Ventral Visual Cortex." MIT Ph.D. Thesis, 2008.

*Becca Schwarzlose*

Question: Is there location information in object- and category-selective regions?

*YES!*

Image removed due to copyright restrictions. See Fig. 2 in: Spiridon, M., B. Fischl, and N. Kanwisher. "Location and Spatial Profile of Category-Specific Regions in Human Extrastriate Cortex." *Human Brain Mapping* 27 (2006): 77-89.

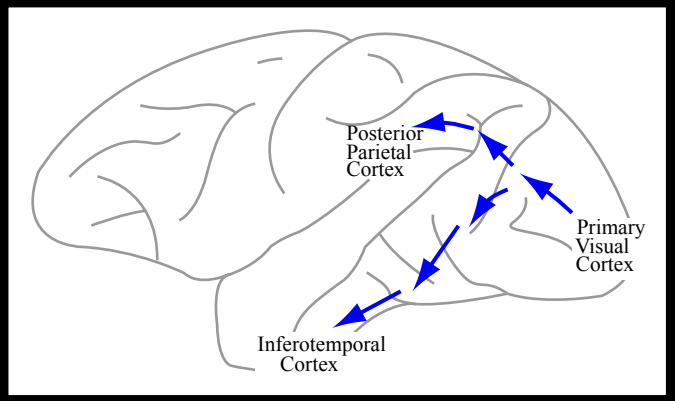



Figure by MIT OpenCourseWare.

Vs.

- Monkey electrophysiology: more sensitivity to location in IT neurons than previously thought
  - » (Op de Beeck & Vogels, 2000;DiCarlo & Maunsell, 2003)
- Retinotopic mapping with fMRI in humans shows retinotopic organization extending partway down the temporal lobe
  - » (Brewer, 2005; Heeger, 2006; Swisher, 2007)

• Findings of eccentricity biases in some category-selective regions

•(Levy et al, 2001;Hasson et al, 2003)

# Summary: Object Information contained in SPfRs

• Some ability to ‘read out” what the subject was viewing from the pattern of response across their cortex.

from 8 categories of objects (Haxby et al, 2001)
even across image changes (Spiridon & Kanwisher 2002)
even for novel shapes (Op de Beeck et al, in press)
some exemplar information (Tong/Kamitani VSS 2005)
some location information in VVP (Schwarzlose et al., sub)
not Joe versus Bob in the FFA (Kriegeskorte in press)
but maybe temporal pole?

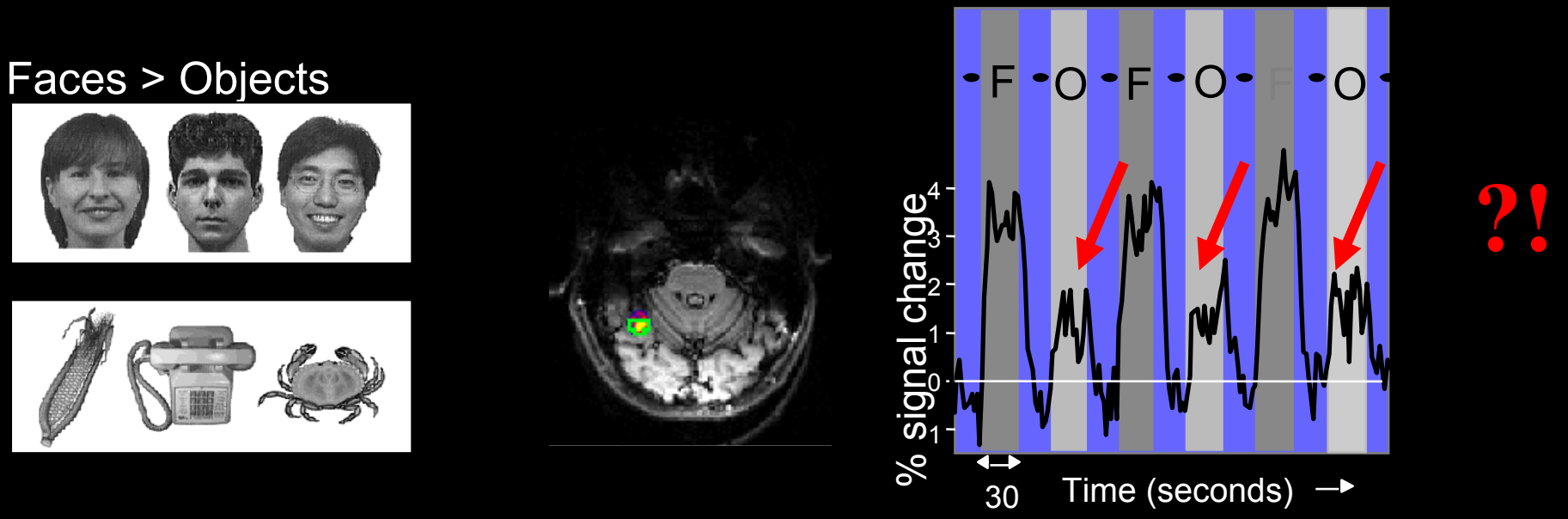
# Four Questions

- What info is contained in the spatial profile of fMRI response across VVP?
  Crude object category information is present in the SPfR across VVP
- Does SPfR in FFA contain information about nonfaces?

- Can SPfRs represent multiple objects presented simultaneously?

- Which of the information contained in SPfRs is *used/read out* in behavioral tasks?

# Nonpreferred Responses in the FFA

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- Do “nonpreferred” responses carry information about nonpreferred stimuli?
- A potential challenge to the domain specificity of 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 (in prep): yes (sort of) - stay tuned.

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!

# The Ultimate High Resolution: Single-Unit Neurophysiology

Tsao et al (2003) found three face-selective patches in monkeys using fMRI:

***Doris Tsao***

Image removed due to copyright restrictions.
Diagram of macaque brain surface, highlighting middle face patch and body response regions.
In Kanwisher, N. "What's in a Face?" *Science* 311 no. 5761 (2006): 617-618.
(http://web.mit.edu/bcs/nklab/media/pdfs/Kanwisher.science2006.perspec.pdf)

Tsao et al (2006) directed electrodes smack into the middle face patch and recorded from neurons that comprise it.

# Response of all 320 visually-responsive neurons in the faces patches of two monkeys to 96 different stimuli

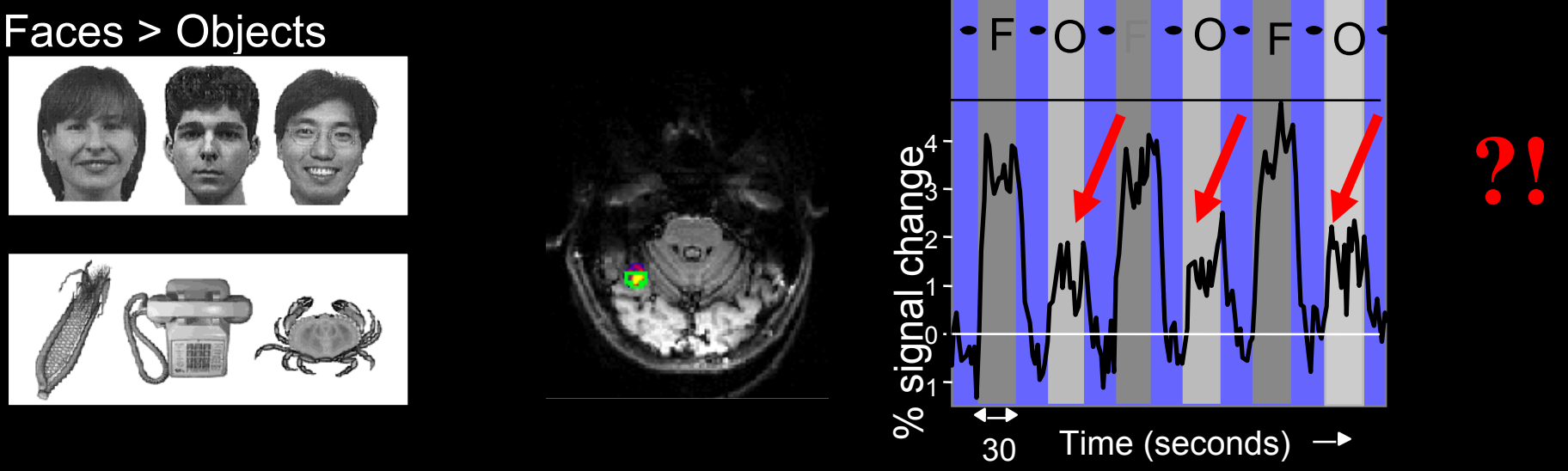
Image removed due to copyright restrictions.
Fig.2B in Tsao, Doris. "A Cortical Region Consisting Entirely of Face-Selective Cells."
*Science 311 no. 5761 (2006): 670-674. doi:10.1126/science.1119983.*

***The cells in this patch respond selectively, indeed virtually exclusively to faces.***

Tsao et al (2006), Science

# An Important Challenge

***Haxby and others***




Courtesy of Society for Neuroscience. Used with permission.

- At higher resolution, can you find information that discriminates between nonfaces?

  Face patches have very little discriminative information about nonfaces, at least in monkeys.

- Even if there were some information about nonfaces in the FFA, is this information *necessary* for perceiving those objects?

# Wada & Yamamoto (2001)

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.

Is profoundly prosopagnosic *but apparently normal at object recognition.*

Suggests: Information in the FFA is critical for face recognition *but not for object recognition.*

# Four Questions

- What info is contained in the spatial profile of fMRI response across VVP?

  Crude object category information is present in the SPfR across VVP

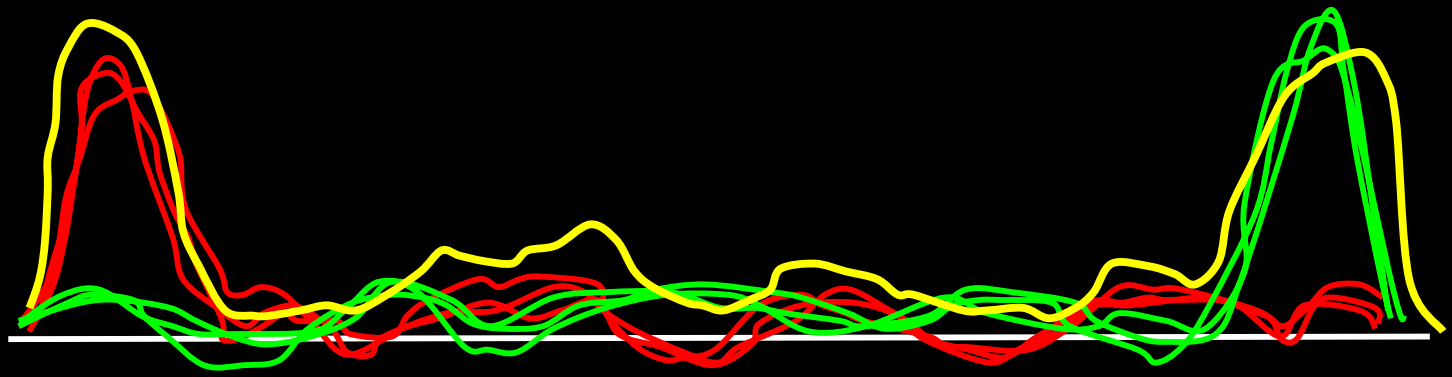
- Does SPfR in FFA contain information about nonfaces?

  Probably not (or not much).

- Can SPfRs represent multiple objects presented simultaneously?

  The problem of crosstalk in overlapping distributed representations

- Which of the information contained in SPfRs is *used/read out* in behavioral tasks?

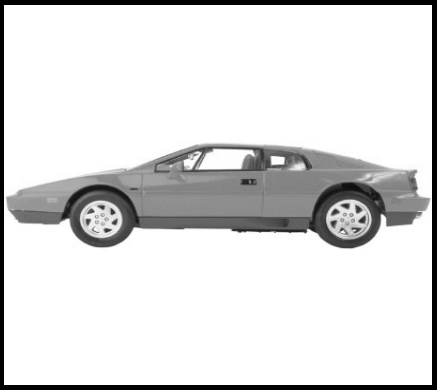


The Problem:

In prior classification experiments, subjects have viewed stimuli like this:

But natural images look more like this:

- multiple objects
- background texture
- “clutter”



General Question:

Are SPfR codes any use in natural viewing conditions, i.e. in clutter?

# Reddy & Kanwisher (2007)

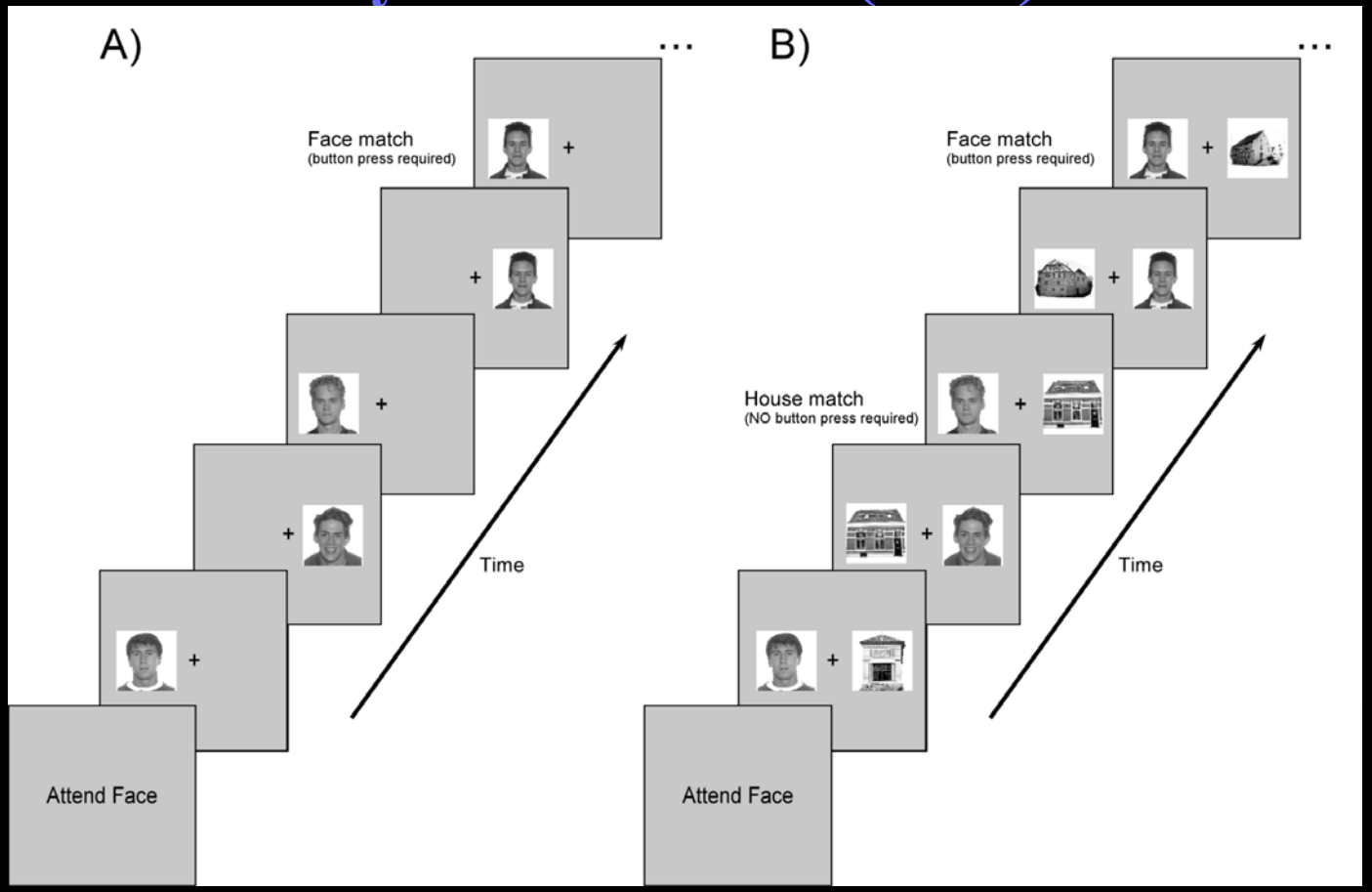
Specific Questions:

1.) Can information about object category be read out from the distributed profile of fMRI response even when two objects are present in the stimulus at once (“clutter”)?

2) How is the ability to read out the code for an object affected by attention?

3) Does the answer to these questions depend on the category of the stimulus?

# Reddy & Kanwisher (2007)




*Current Biology* 17 no. 23 (2007): 2067-2072. doi:10.1016/j.cub.2007.10.043.

Courtesy Elsevier, Inc., http://www.sciencedirect.com. Used with permission.

Subjects perform 1-back on stimuli of one category in a block.

- Isolated/Attended/Unattended
- Faces & houses versus Shoes & cars
- Look at classification performance in FFA/PPA/"OR"

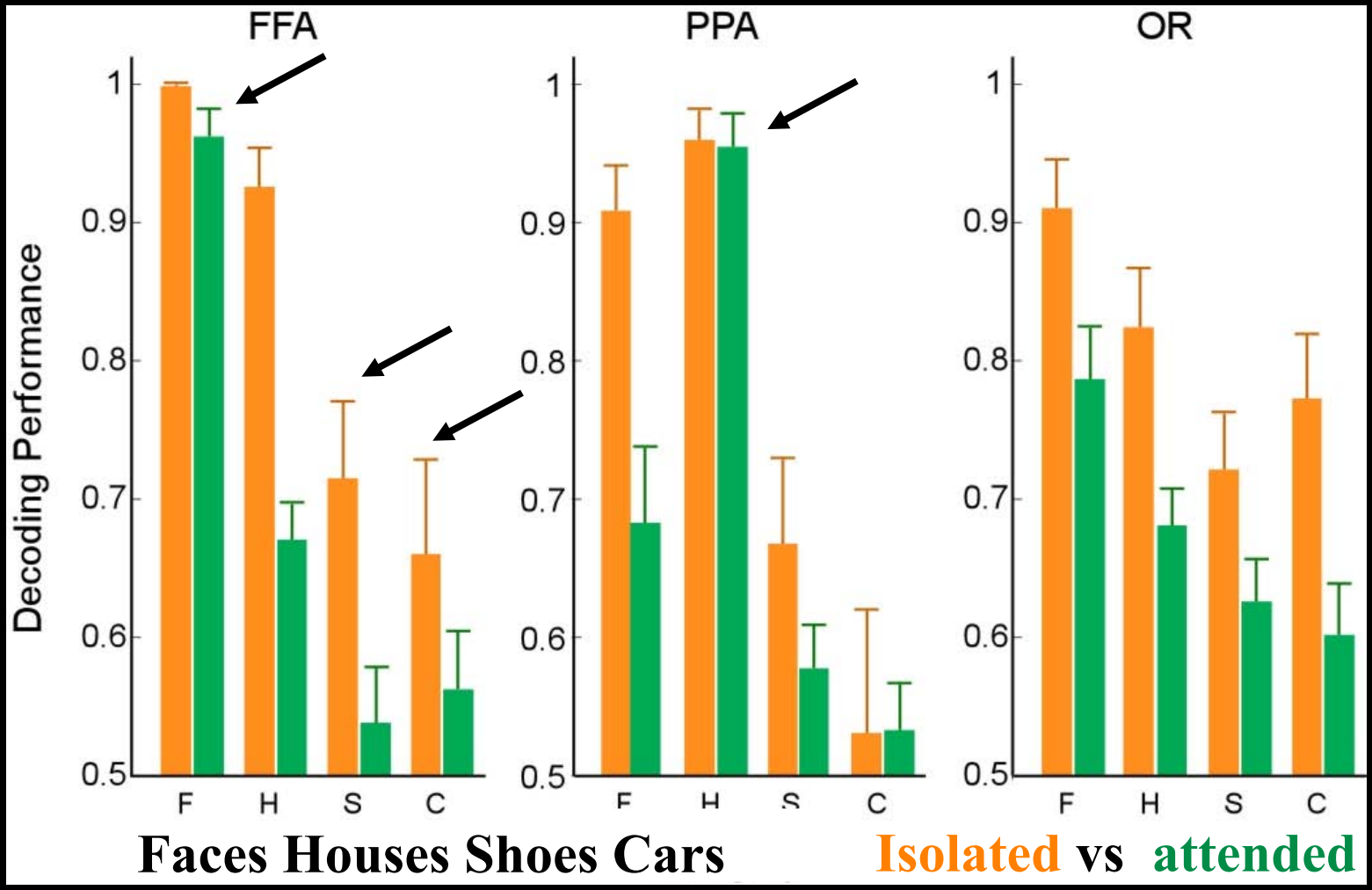
# Results 1: Is there a "Clutter Cost"?

1. Performance is higher for isolated than attended, = "clutter cost".

[2. Performance is higher for faces and houses than shoes and cars.]

What re FFA/PPA?

3. There is no "clutter cost" for faces in the FFA or for houses in the PPA.




[4. Above-chance performance for shoes & cars in FFA (even when face & houses are excluded).]

What happens when attention is diverted?

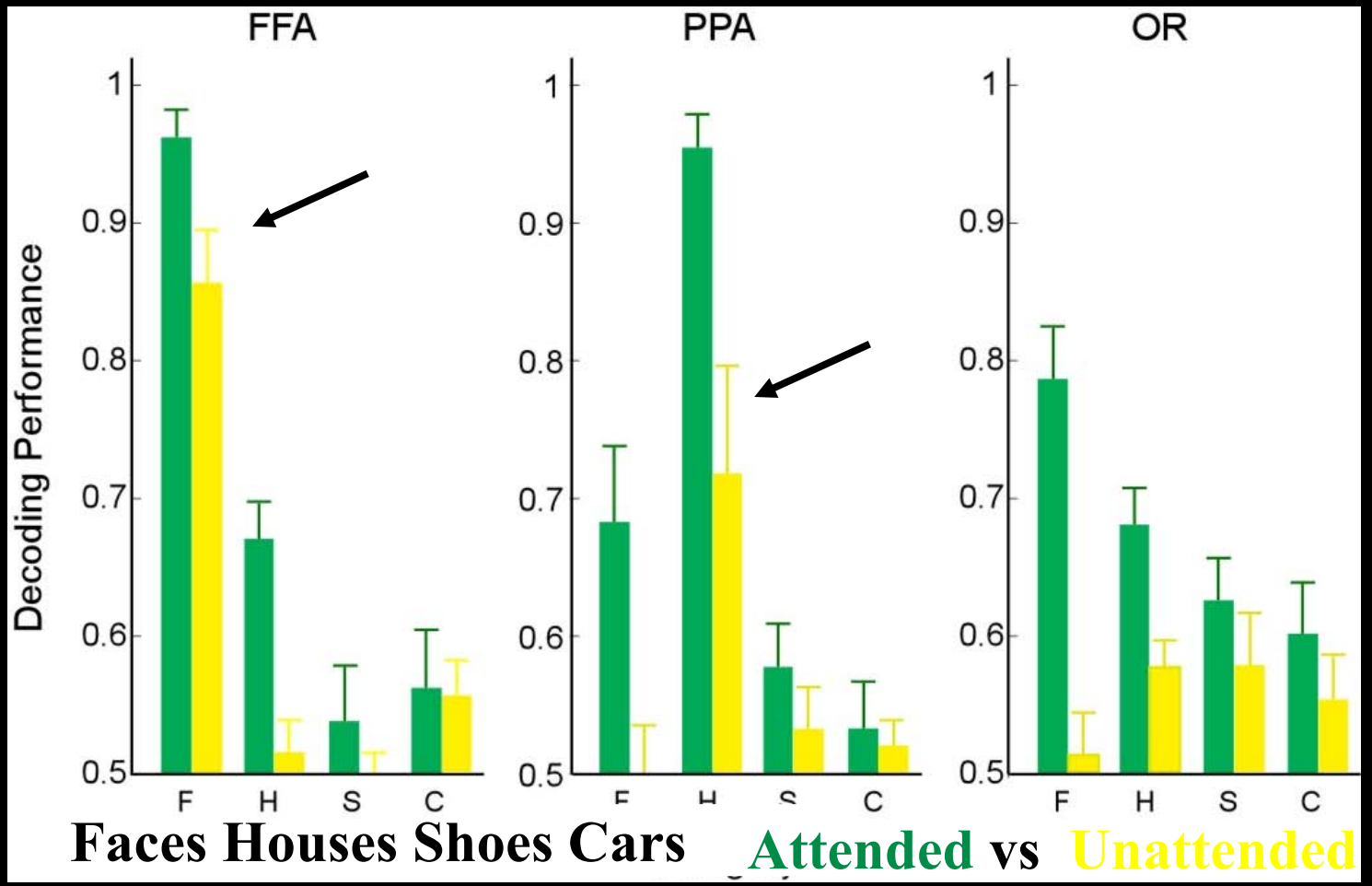
*Reddy & Kanwisher (2007)*

# Results 2: Is there an Effect of Attention?

1. Performance is not above chance for any category in OR when unattended.

But what re FFA/PPA?

2. Some "sparing" from costs of diverted attention for faces in the FFA and houses in the PPA.

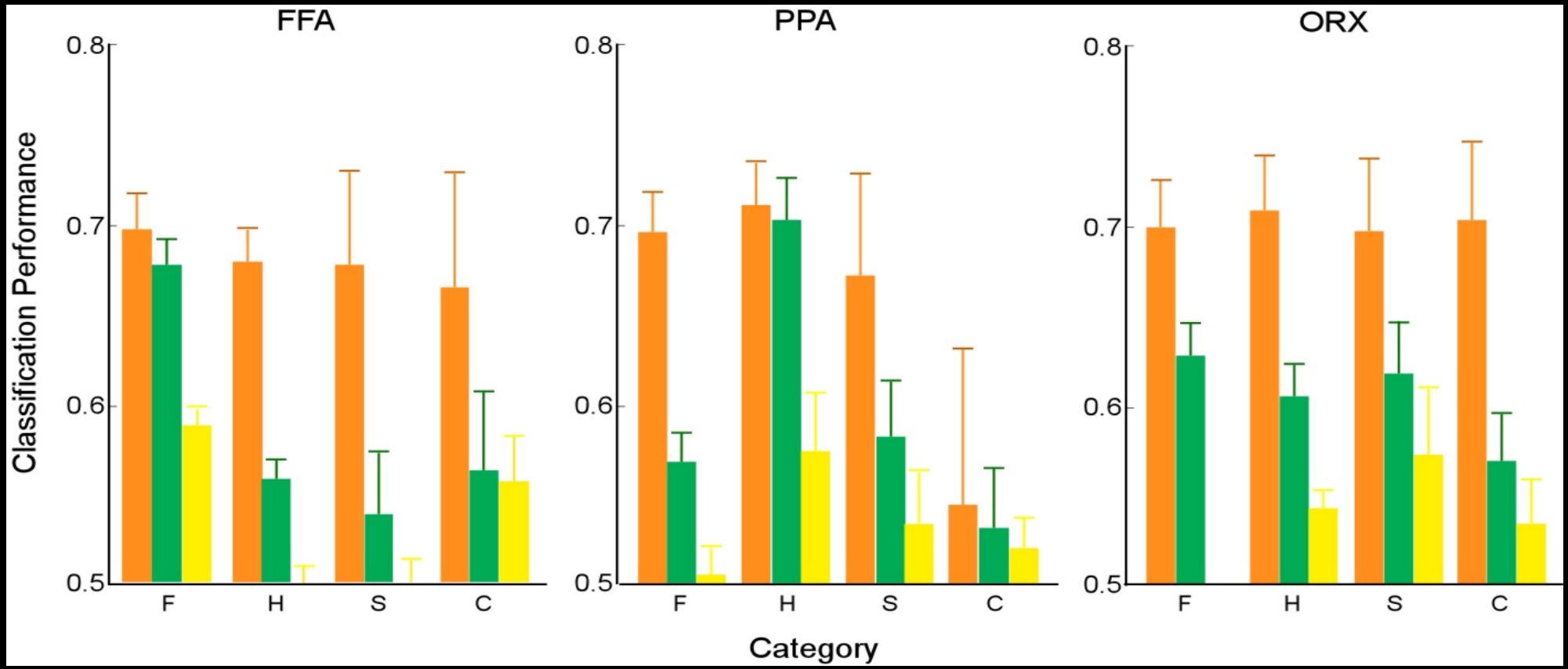



*BUT:*

*Is this sparing for faces and houses in clutter and diverted attention just due to the fact that performance is higher for these categories to begin with?*

*Reddy & Kanwisher (2007)*

# Performance in all conditions when performance in the isolated condition is equalized by throwing out voxels




*Current Biology* 17 no. 23 (2007): supplemental resources. doi:10.1016/j.cub.2007.10.043.

- Qualitatively same pattern of results obtained when isolated performance is equalized.

Courtesy Elsevier, Inc., http://www.sciencedirect.com. Used with permission.

*Reddy & Kanwisher (2007)*

# Reddy & Kanwisher (2007)

Specific Questions:

1.) Can information about object category be read out from the distributed profile of fMRI response even when two objects are present in the stimulus at once ("clutter")?

A substantial clutter cost, challenging utility of SPfRs as object representations

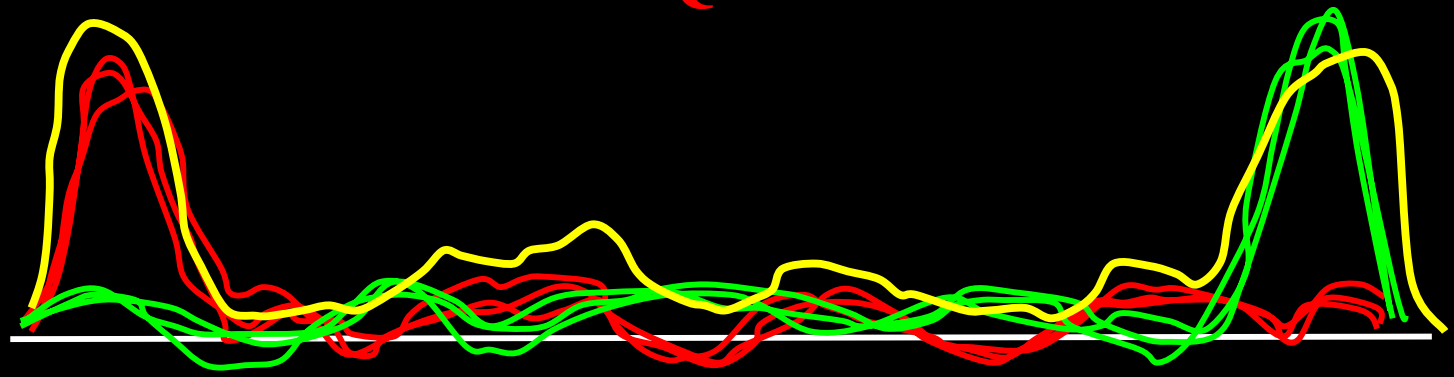
2) How is the ability to read out the code for an object affected by attention?

A substantial cost of diverting attention, with very little object info present for unattended objects

3) Does the answer to these questions depend on the category of the stimulus?

Yes! Selective sparing of faces & houses in clutter and (somewhat) in diverted attention

# Four Questions



- What info is contained in the spatial profile of fMRI response across VVP?
  Crude object category information is present in the SPfR across VVP
- Does SPfR in FFA contain information about nonfaces?
  Probably not (or not much).
- Can SPfRs represent multiple objects presented simultaneously?
  Limited utility of distributed cortical fMRI codes in "clutter"
  BUT: category selectivity confers robustness to clutter & diverted attention
- Which of the information contained in SPfRs is *used/read out* in behavioral tasks?

# Are SPfRs used/read out?

Haxby argues that the whole spatial profile of response across centimeters of ventral visual pathway constitutes the representation of an object.
And indeed there is some object info spread across here.

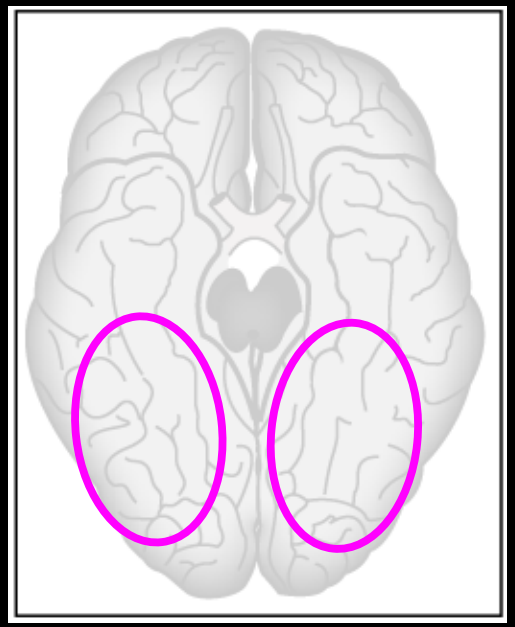


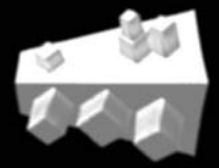
Figure by MIT OpenCourseWare. After Allison, 1994.

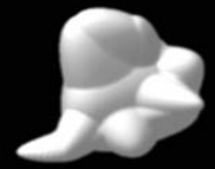
But:
Just because some information is *present* in the SPfR in a given ROI does not mean that that SPfR is *part of the representation*.

What we need to know:
Is that SPfR used/read out behaviorally?

*How could we tell?*

# Williams et al (submitted)
# Overall Logic





Brief masked stimuli, shape categorization task

some errors, but above chance

bin fMRI data by behavioral performance

Key prediction:

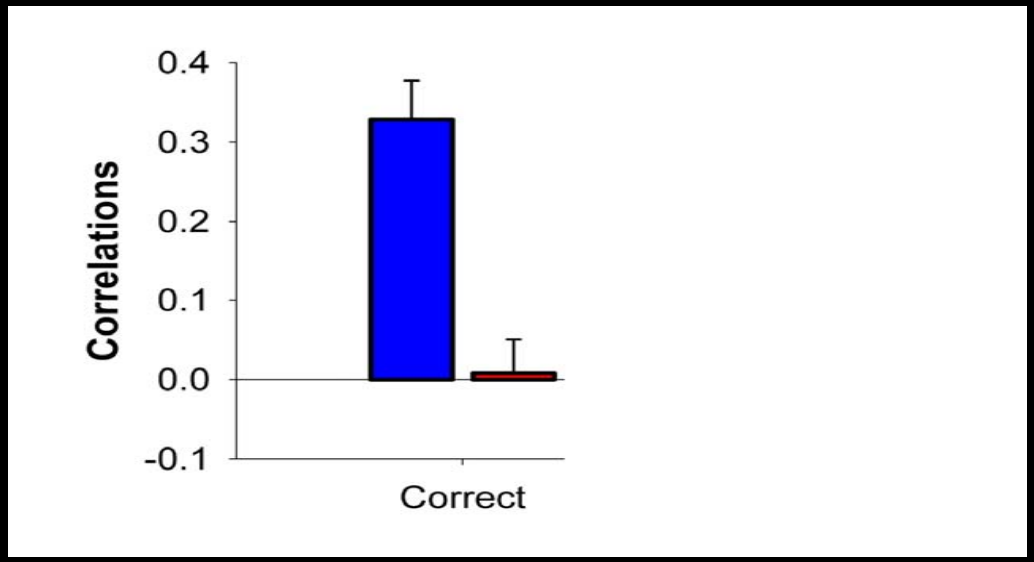
Any pattern information that is used in task performance should be stronger on correct than incorrect trials, i.e.:

[r(w/in) - r(betwn)] on correct trials > [r(w/in) - r(betwn)] on incorrect trials

Images: Williams, M. A, N. Kanwisher et al. Feedback of visual object information to foveal retinotopic cortex." *Nature Neuroscience* 11 (2008): 1439-1445.

# Williams et al, Results

## Retinotopic Cortex

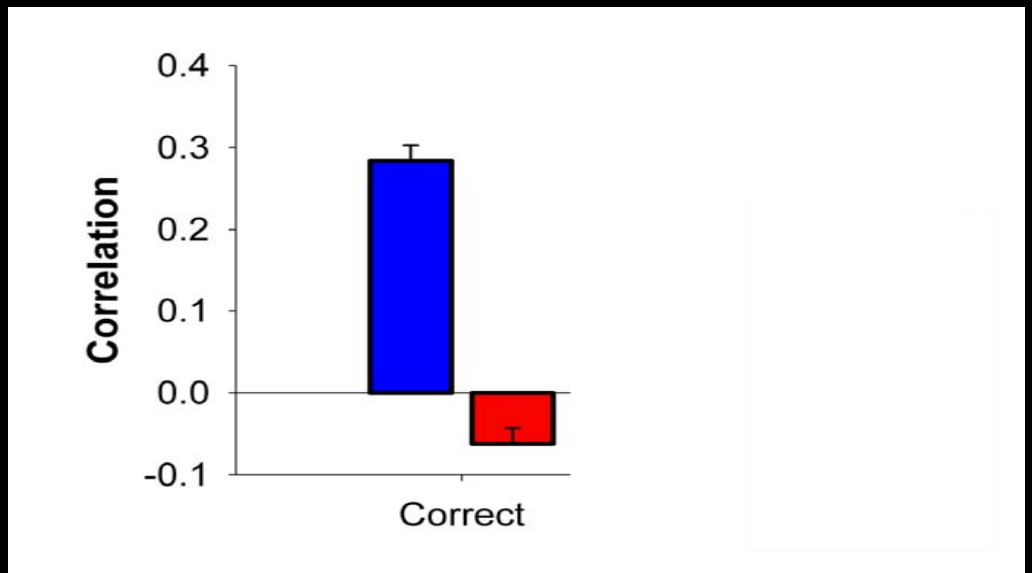



Within-category

Between-category

**Information is present in retinotopic cortex, but not related to behavior.**

## Lateral Occipital Complex (LOC)



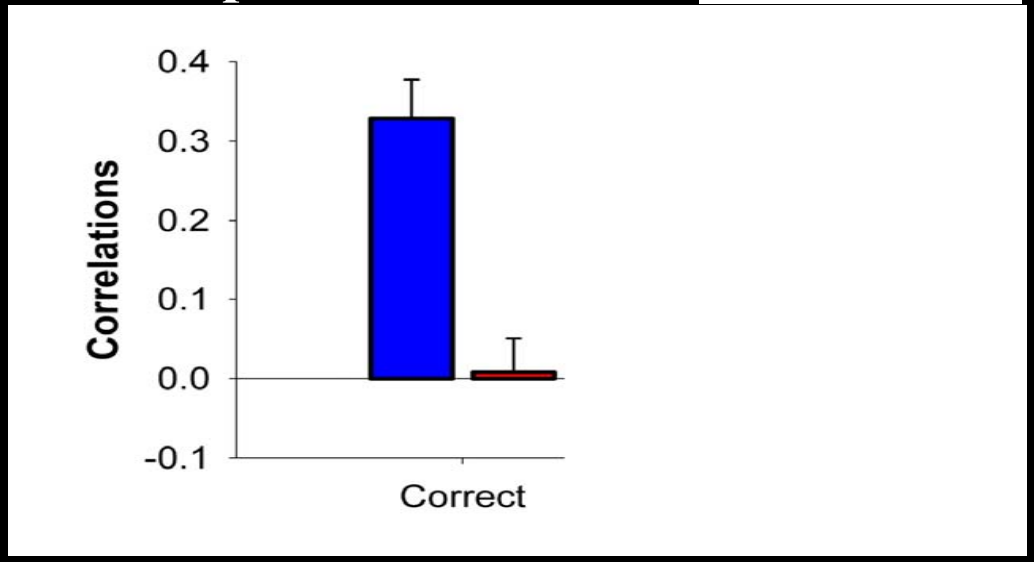

**Information is present in LOC on correct trials, not on incorrect trials>>>>**

**This information is apparently read out in performance.** **Other areas?**

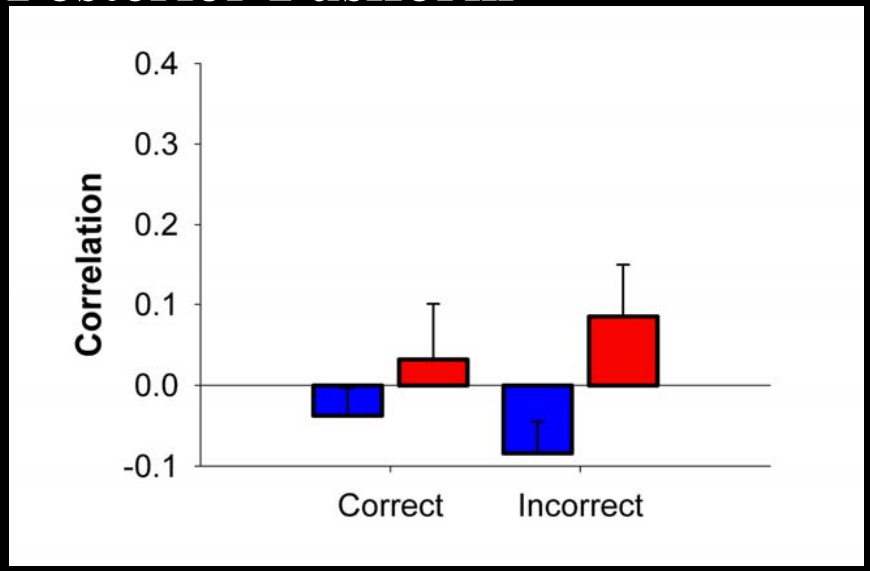
Williams, M. A, S. Dang, and N. Kanwisher. Only some spatial patterns of fMRI response are read out in task performance." *Nature Neuroscience* 10 (2007): 685-686.

# Williams et al, Results

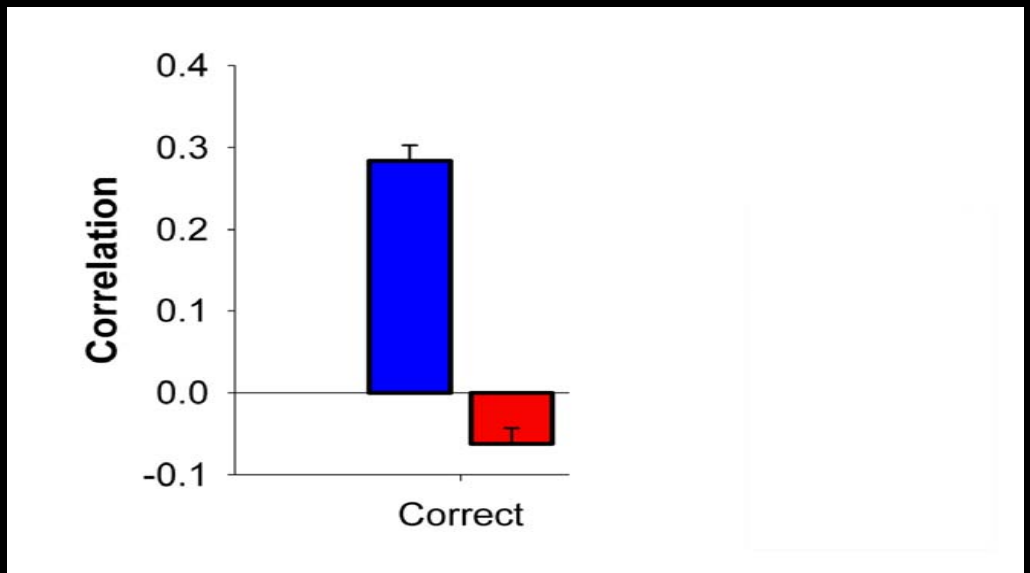
## Retinotopic Cortex




## Posterior Fusiform

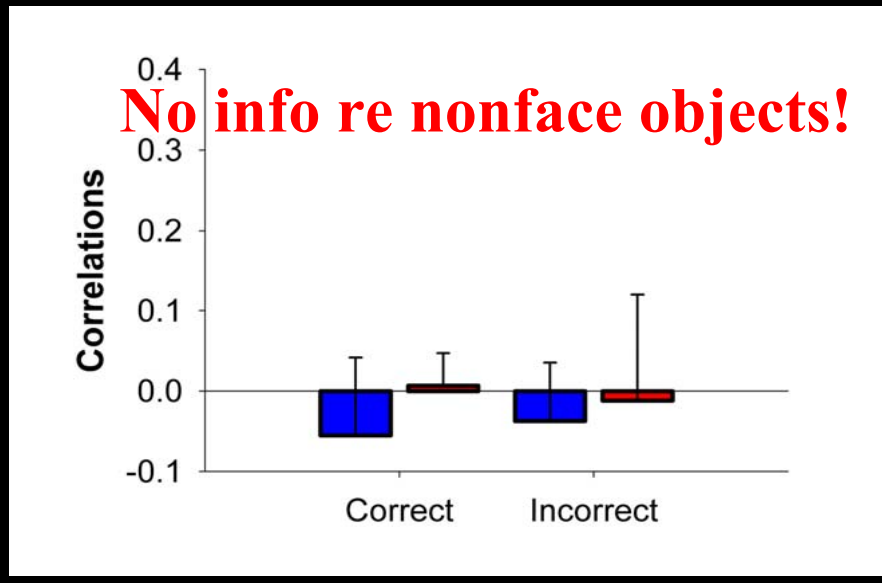



## Lateral Occipital Complex (LOC)



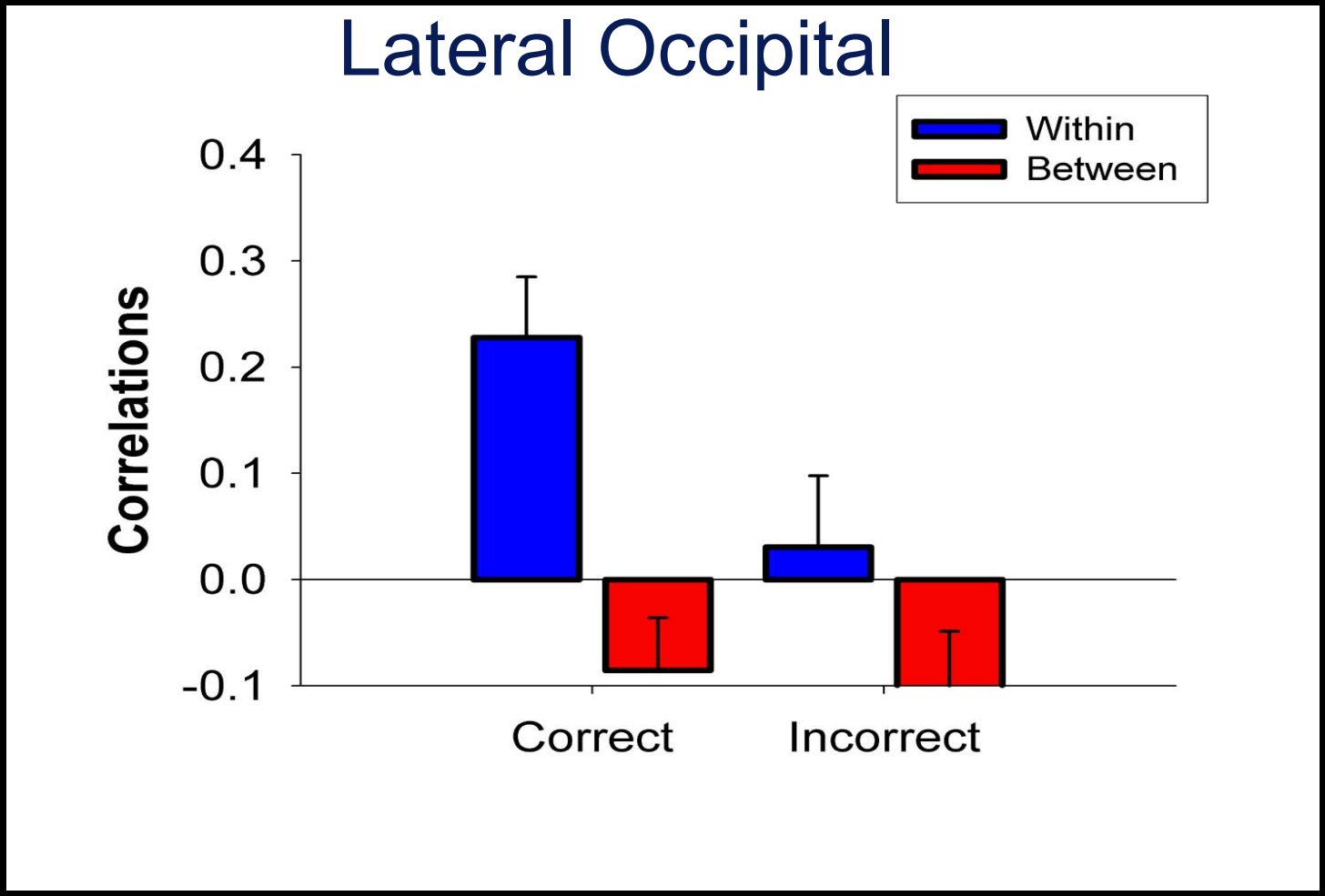

## FFA

**No info re nonface objects!**



Could weaker category information in incorrect trials be due to the smaller number of trials? **No**

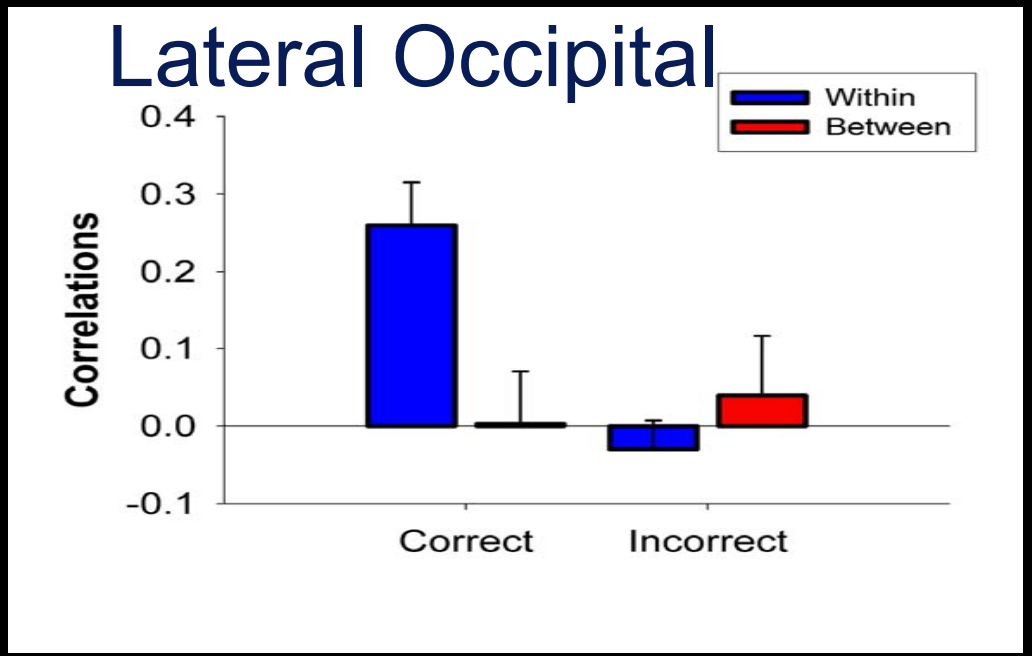
Equalised trial numbers

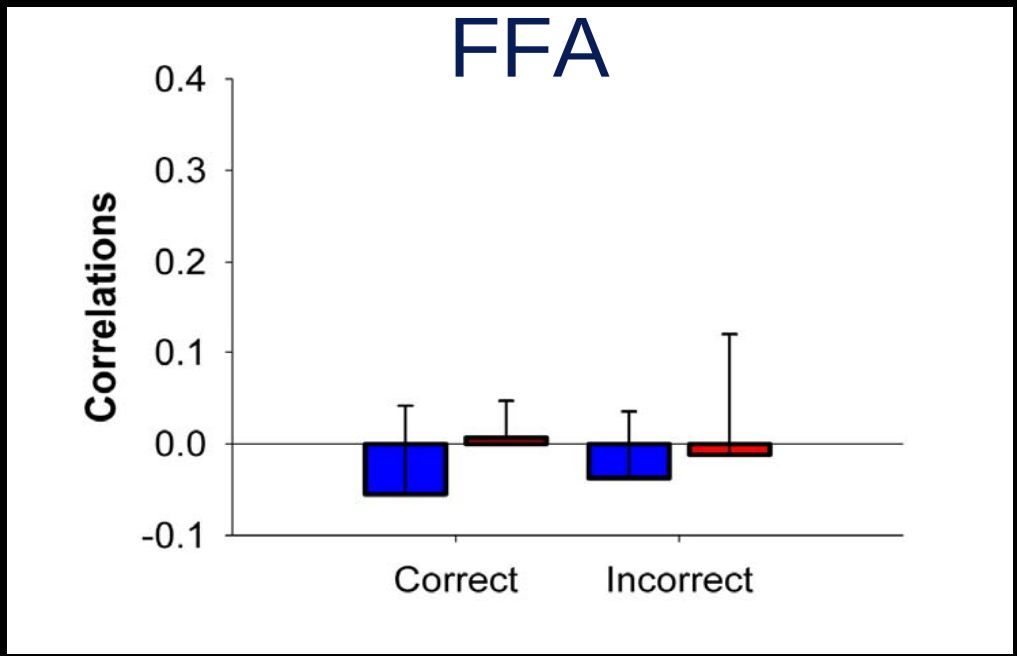


Is the greater category information in LO than FFA due to a larger number of voxels?

No

Equalised voxel numbers.



# Four Questions

- What information is contained in the spatial pattern of fMRI response?

  Crude object category information is present in the SPfR across VVP

- Does SPfR in FFA contain information about nonfaces?

  Probably not (or not much).

- Can SPfR across cortex represent multiple objects presented simultaneously?

  limits on utility of distributed cortical fMRI codes in "clutter"
  category selectivity confers robustness to clutter & diverted attention

- Which of the information contained in SPfRs is *used/read out*?

  Not all information present in SPfRs is part of the representation, i.e. is read out in task performance.

  Now we have a way to tell which SPfRs are read out in which tasks.
  Does readout change with expertise? Task?

# How Distributed are Object Codes in the Cortex?

Haxby argues that the whole spatial profile of response across centimeters of ventral visual pathway constitutes the representation of an object.

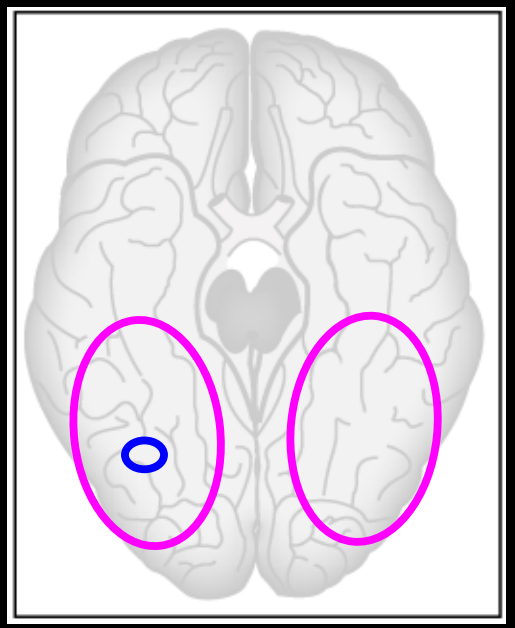


Figure by MIT OpenCourseWare. After Allison, 1994.

Our data suggest that:

- information about some object categories is indeed somewhat spread out in the cortex, BUT

- some categories (e.g., faces) are represented in much more focal regions of cortex (*why?!*)

- distributed object representations may be of limited utility because they are vulnerable to clutter

- and only part of the distributed representation is “used”

# Caveats/Open Questions/Challenges

fMRI Classification methods are exciting because they give us a way to look at information in the brain. But:

- Voxels are not natural kinds. No one knows how readout of neural codes works, but it is a good bet that what is read out is spikes not blood flow changes.

- We are looking at the cortex at a very coarse scale. Failure to detect pattern information with fMRI does not mean it is not there!

- So far ability to see finer-grained discriminative information is disappointing.

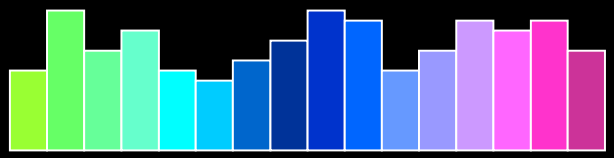
- On the other hand, SPfR analyses do afford a much wider field of view than available in physiology studies….

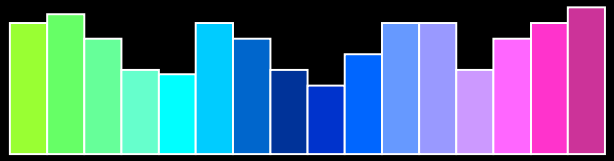
# Distributed Representations to Classify Visual Objects

- Haxby et al. (2001): Activity patterns in ventral temporal cortex can reliably predict if subject is viewing images of faces, houses, cats, bottles, scissors, shoes, chairs, scrambled stimuli

Pattern of Activity on Runs 1-4

Pattern of Activity on Runs 5-8

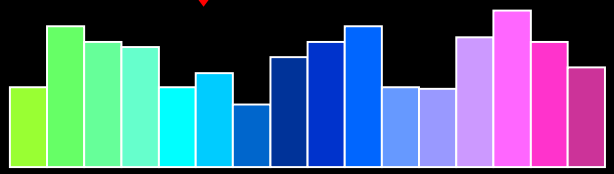


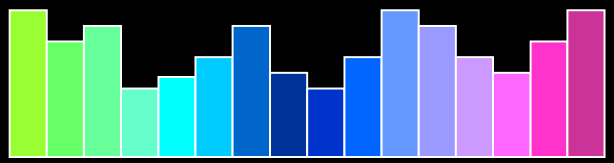


R≈.25-.75

R≈0

R≈.25-.75





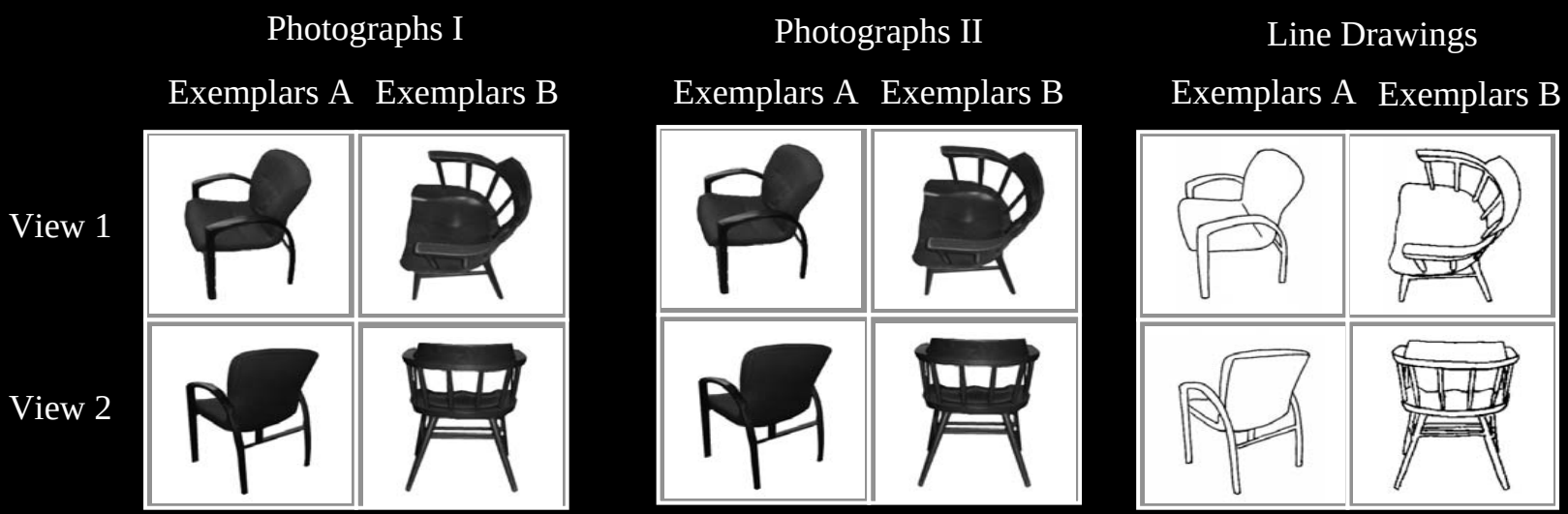
# Summary of Orientation Experiments

- Ensemble activity patterns in early human visual areas contain highly reliable information about stimulus orientation
- Brain states, evoked by unambiguous stimuli, can be used to reliably predict mental states
- Multi-voxel pattern analysis may allow for extraction of feature information that varies at much more fine-scale resolutions (i.e. cortical columns)
- This approach may be useful for cortical feature tuning, mind reading, possibilities for human neuroprosthesis, and the neural underpinnings of mental states

# Spiridon & Kanwisher - Design

Scan each of 6 subjects on the same 8 categories used by Haxby et al;

- Twelve different kinds of blocks for each category created by orthogonally crossing exemplar x viewpoint x format:

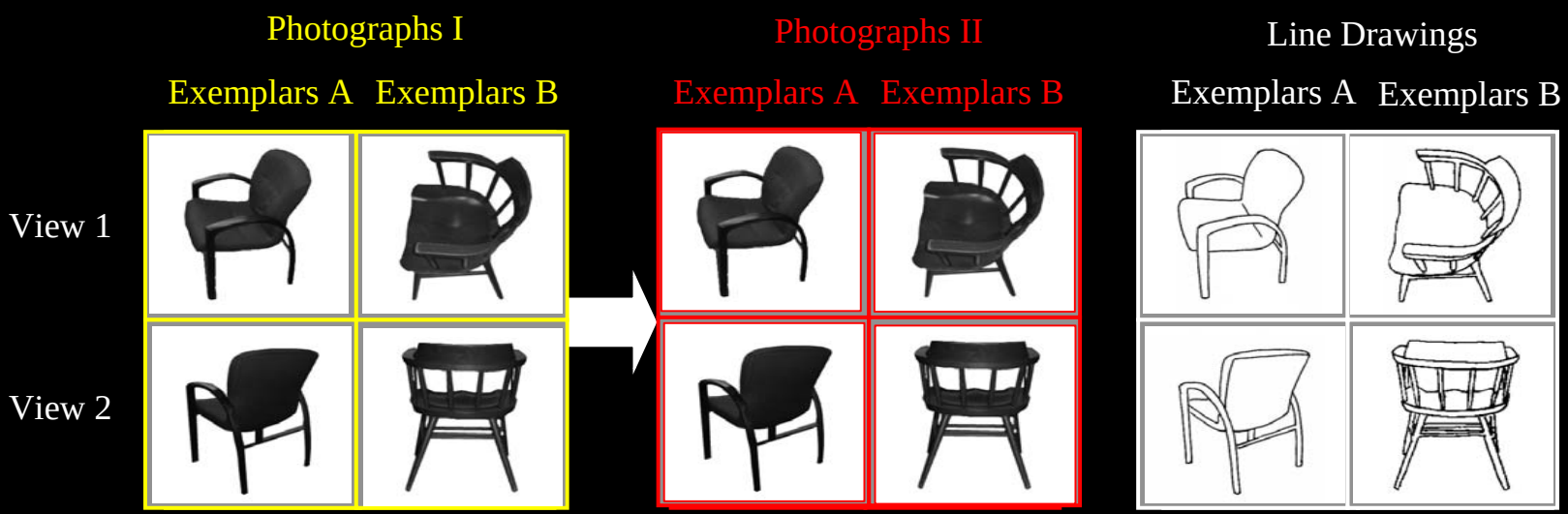



8 runs 8 runs 8 runs

Courtesy Elsevier, Inc., http://www.sciencedirect.com. Used with permission.

Spiridon, M. & Kanwisher, N. (2002) "How distributed is visual category information in human occipital-temporal cortex? An fMRI study. *Neuron* 35 (6) 1157-1165

# Spiridon & Kanwisher - Design




Courtesy Elsevier, Inc., http://www.sciencedirect.com. Used with permission.

To test replicability of Haxby et al result (across identical photographs), Use activation from yellow blocks as original basis images to be used as the "key" in categorizing the activation from red "test" data.

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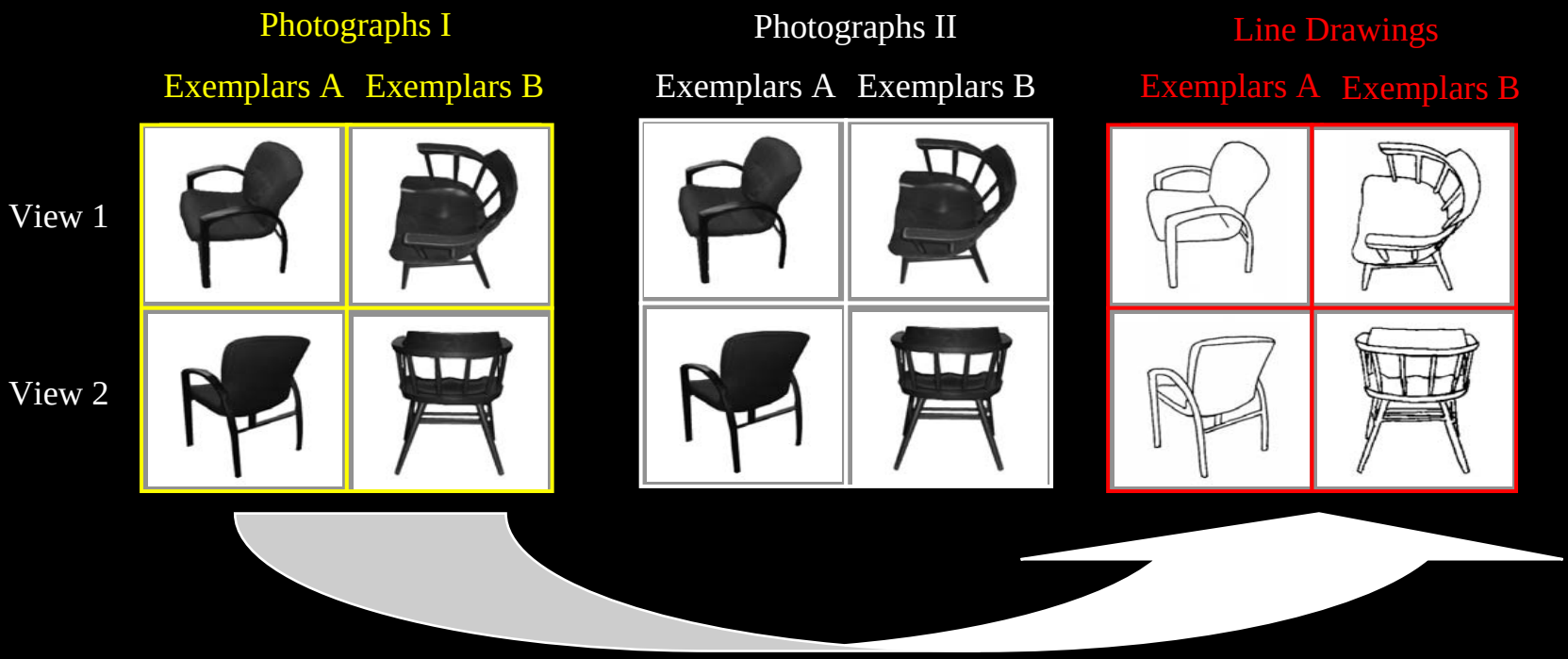


Courtesy Elsevier, Inc., http://www.sciencedirect.com. Used with permission.

To test generalization across **format** (photo > line drawing),
Use activation from yellow blocks as original basis images to be used as the "key" in categorizing the activation from red "test" data.

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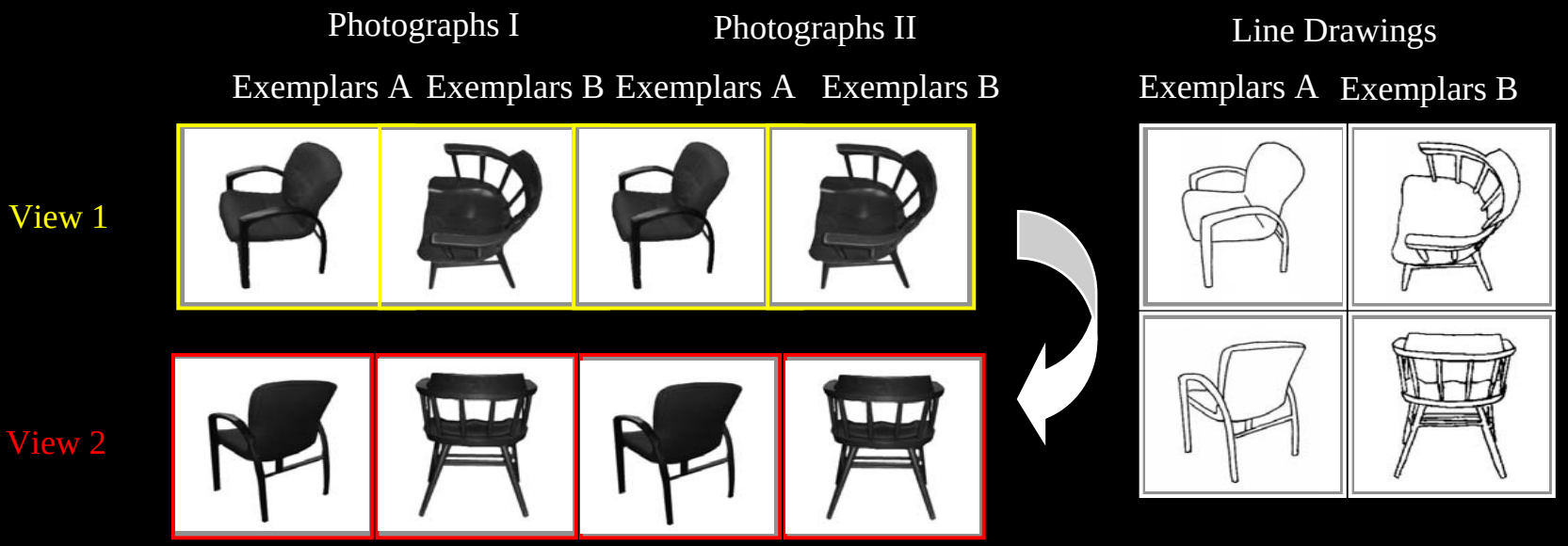


Courtesy Elsevier, Inc., http://www.sciencedirect.com. Used with permission.

To test generalization across **viewpoint**,
Use activation from yellow blocks as original basis images to be used as the "key" in categorizing the activation from red "test" data.

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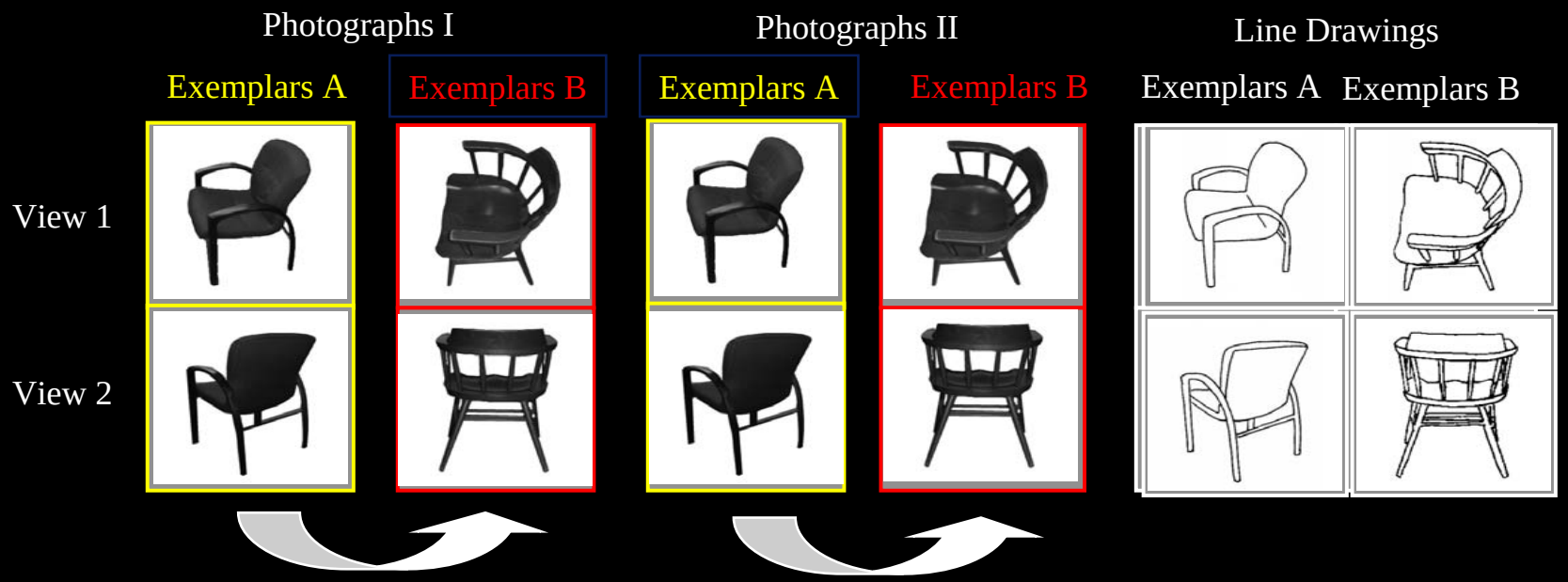



Courtesy Elsevier, Inc., http://www.sciencedirect.com. Used with permission.

To test generalization across **exemplars**,
Use activation from yellow blocks as original basis images to be used as the "key" in categorizing the activation from red "test" data.

# Hypothesis: IT cortex contains a large-scale map of shape.

## Predictions:

i) Continuous and spatially varying shape selectivity will be found spanning much of IT cortex, at a large grain.

ii) This "shape map" will be stable across
time, training, task, and stimulus position

## Background:

Tanaka/Tanifuji/others - columnar organization of IT in macaques
scale: several mms >> what about larger scale?

Human fMRI - category-selective regions, and patterns, but
virtually all of this work is on familiar, meaningful objects
to unconfound shape from meaning and memory>>
use novel objects!

# Testing for Shape Maps with Novel Objects

***Op de Beeck, Vanduffel, Deutsch, Kanwisher, & DiCarlo***

## Two Monkeys scanned while viewing 3 novel object classes:

**Smoothies** **Spikies** **Cubies**

Stimuli: 5x5 degrees
TR = 3 sec
Block length: 45 sec

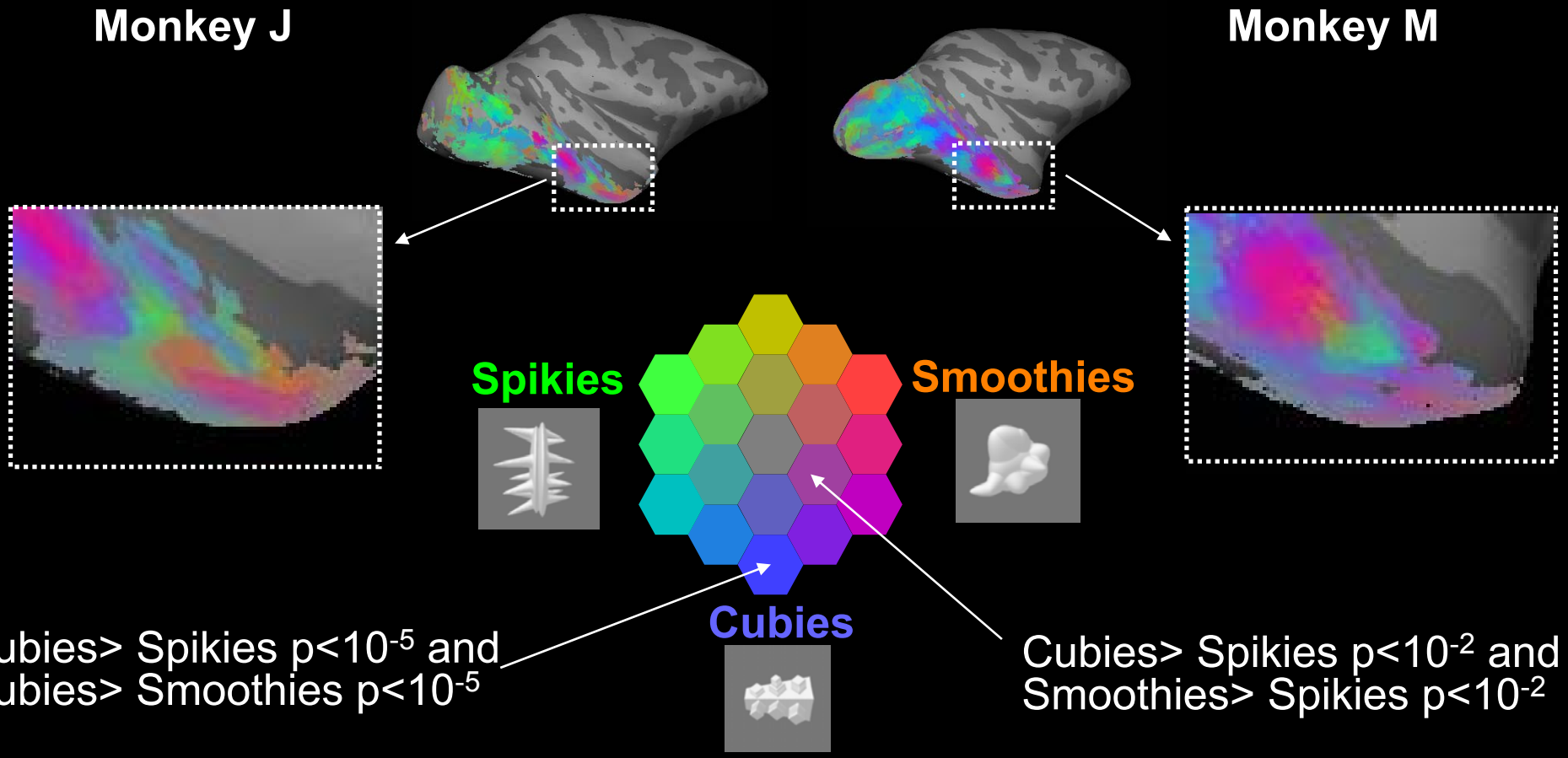
Image removed due to copyright restrictions.
See Fig. 2 in Op de Beeck, H. P., N. Kanwisher et al. "A Stable Topography of Selectivity for Unfamiliar Shape Classes in Monkey Inferior Temporal Cortex." *Cerebral Cortex* 18 no. 7 (2008): 1676-94.
[http://web.mit.edu/bcs/nklab/media/pdfs/OpdeBeeck_etal_2007.pdf]

Blocked design; monkeys perform orthogonal color task.
1.25 mm isotropic functional resolution; MION
To look for "shape maps", compute

3 pair-wise t-tests on each visually responsive voxel in IT, & display it like this…..

# Shape Maps in IT Cortex?

## *>>>Are they stable across time, training, task, and stimulus position?*




**Higher saturation indicates higher selectivity.**

See Op de Beeck, H. P., N. Kanwisher et al. "A Stable Topography of Selectivity for Unfamiliar Shape Classes in Monkey Inferior Temporal Cortex." *Cerebral Cortex* 18 no. 7 (2008): 1676 94.

# Scanning Sequence

**Monkeys were scanned while viewing novel objects in four phases (several scanning sessions each):**

Phase 1 Scans. Color task - detect rare color changes between successive stimuli.

>>Three months of training on one object category on successive same-different shape judgement. 130,000 stimulus presentations.

Phase 2 Scans. Color task: *transfer over time & training (& meaning change)?*

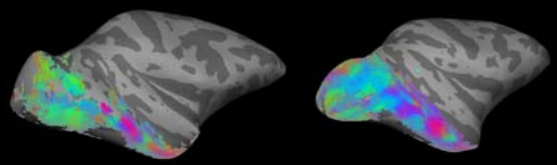
Phase 3 Scans. Shape discrimination task: *transfor over task*?

Phase 4 Scans. Position change: *transfer over stimulus position?*

Monkey J - stimuli @ 8.4 degrees eccentricity, nonoverlapping (fixation task).

Monkey M - stimulus-class-specific jitter to remove differences in retinotopic envelope; color task.

**Monkey J**
**(trained on Spikies)**



**Monkey M**
**(trained on Smoothies)**

**Shape maps look similar across time, & training.**

Image removed due to copyright restrictions.
See Fig. 6 in Op de Beeck, H. P., N. Kanwisher et al. "A Stable Topography of Selectivity for Unfamiliar Shape Classes in Monkey Inferior Temporal Cortex." *Cerebral Cortex* 18 no. 7 (2008): 1676-94.
(http://web.mit.edu/bcs/nklab/media/pdfs/OpdeBeeck_etal_2007.pdf)

**To quantify the replicability of these maps within an animal, we calculated the correlation across the color maps between experiments.**

**Shape maps are about as replicable across experiments as they can be given the variability in the data!**

**Correlations across position are zero in V1.**

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Predictions:

√ i) Continuous and spatially varying shape selectivity will be found spanning much of IT cortex.

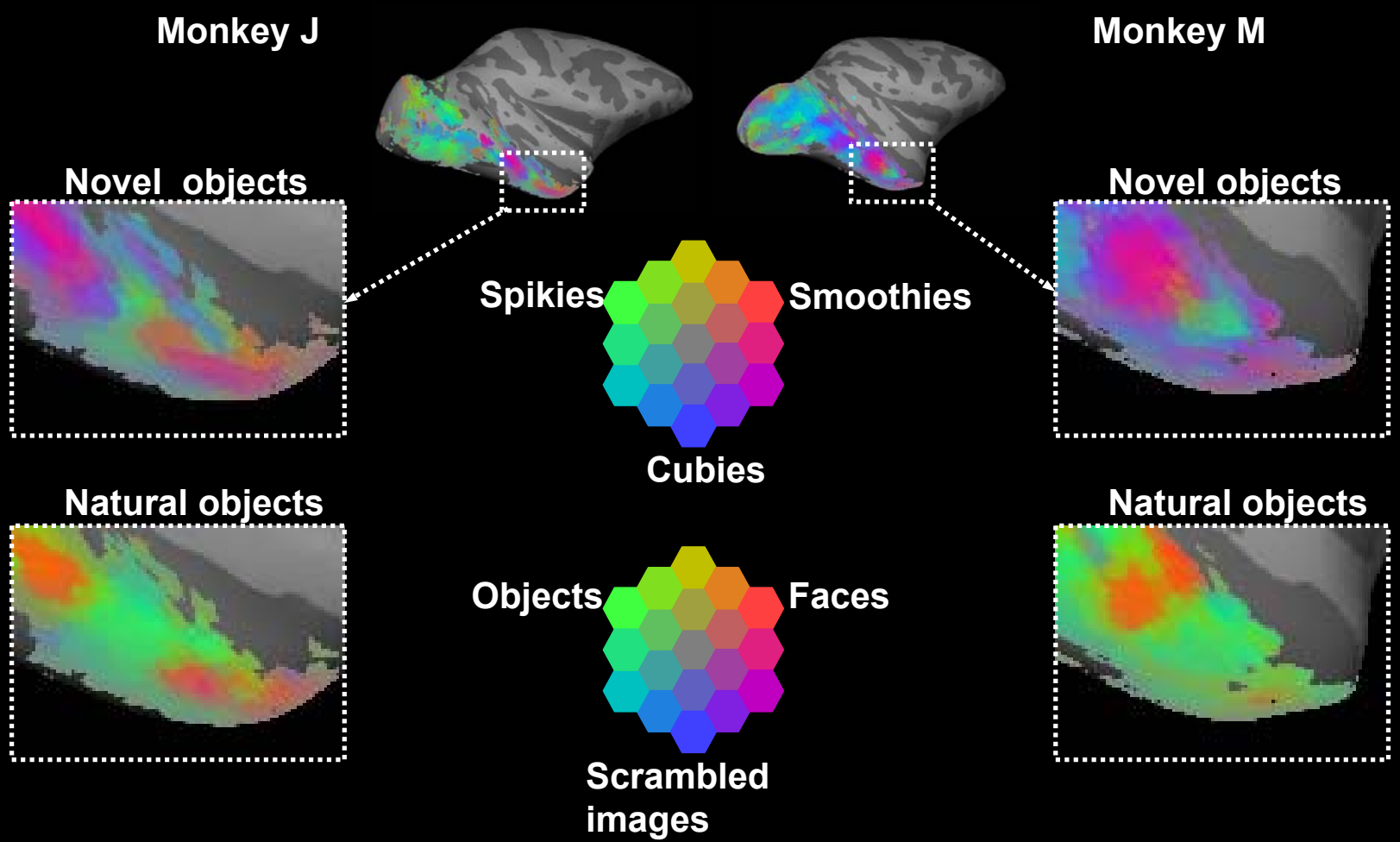
ii) This "shape map" will be stable across

√ time, √ training, √ task, and √ position

Many more questions…..

1. Is the "shape map" systematically related to the face patches?
2. Is it reducible to the face map?
3. Does the "shape map" reflect selectivity for global or local features?

# Comparison of Novel Object Map and Face Map



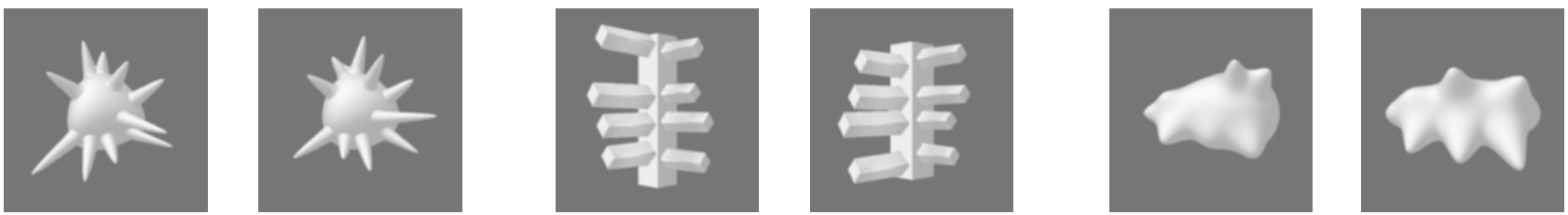

- Novel object map bears a clear relationship to face map.
- But is not reducible to it: correlations in object selectivity maps (r=0.52, p<.001) are almost as strong when all face-selective voxels are omitted (r=.47) .

See Op de Beeck, H. P., N. Kanwisher et al. "A Stable Topography of Selectivity for Unfamiliar Shape Classes in Monkey Inferior Temporal Cortex." *Cerebral Cortex* 18 no. 7 (2008): 1676 94.

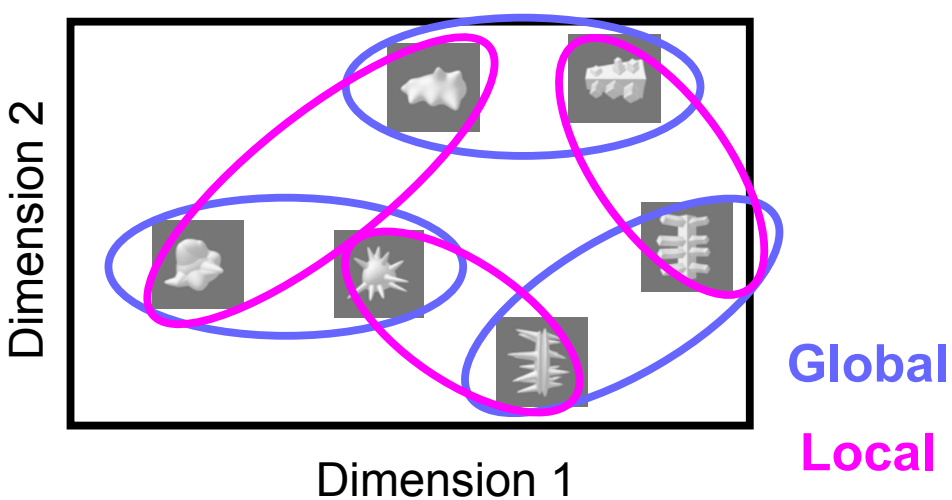
# “Shape Map”: Global or Local Features?

**Test on new stimulus set where local and global feature are exchanged:**

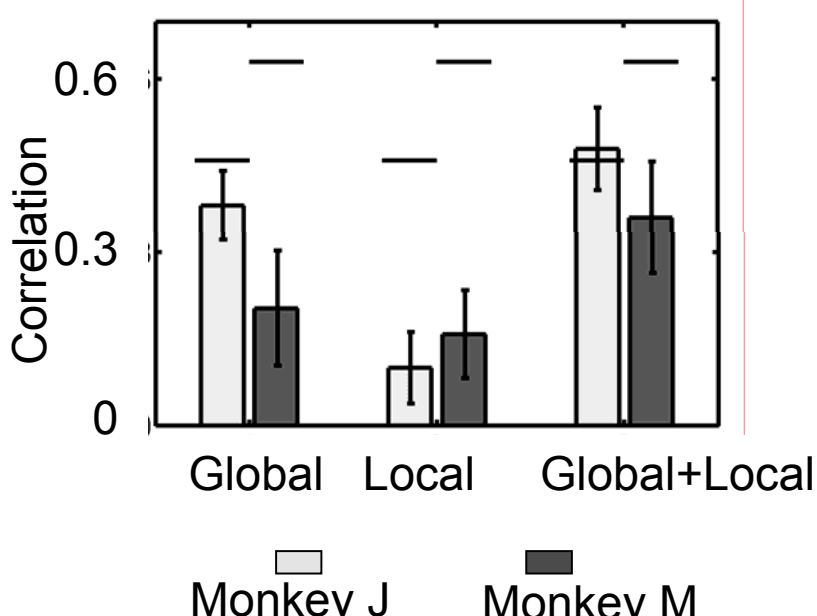
Spiky smoothies | Cuby spikies | Smoothy cubies



**Perceived similarity between six classes based on same-different confusion matrix.**




**Correlation btwn selectivity maps for objects sharing glob, loc, or both.**




See Op de Beeck, H. P., N. Kanwisher et al. “A Stable Topography of Selectivity for Unfamiliar Shape Classes in Monkey Inferior Temporal Cortex.” *Cerebral Cortex* 18 no. 7 (2008): 1676-94.

# Hypothesis: IT cortex contains a large-scale map of shape.

## Predictions:

√ i) Spatially varying selectivity will be for novel objects spanning much of IT cortex.

ii) This "shape map" will be stable across

√ time, √ training, √ task, and √ position

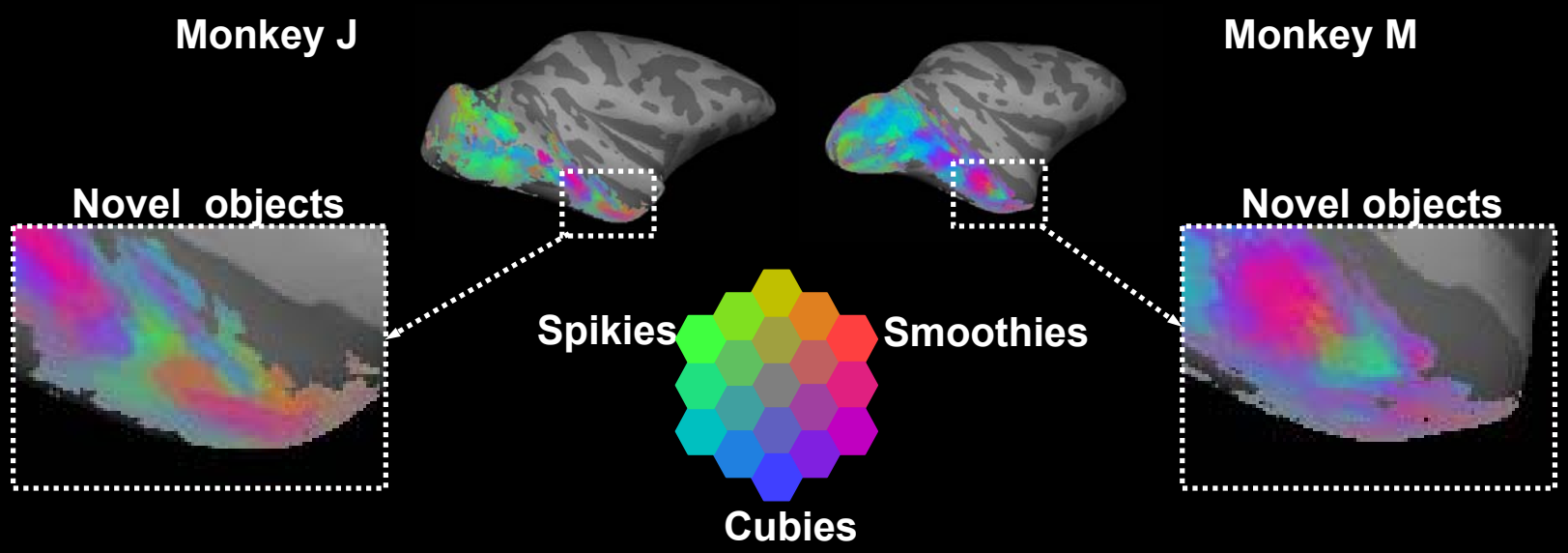
## Many More Questions:

YES 1. Is it systematically related to the face patches?

NO 2. Is it reducible to the face map?

BOTH 3. Does the "shape map" reflect selectivity for global or local features?

# Conclusions: A Large-Scale Shape Map in Monkey IT Cortex




- A robust topography of shape selectivity across IT, replicable across time, training, task, and stim. position.
- Systematically related to (but not reducible to) the face map.
- Shape map includes both global and local shape features.

Courtesy of the American Physiological Association. Used with permission.

See Op de Beeck, H. P., N. Kanwisher et al. "A Stable Topography of Selectivity for Unfamiliar Shape Classes in Monkey Inferior Temporal Cortex." *Cerebral Cortex* 18 no. 7 (2008): 1676 94.

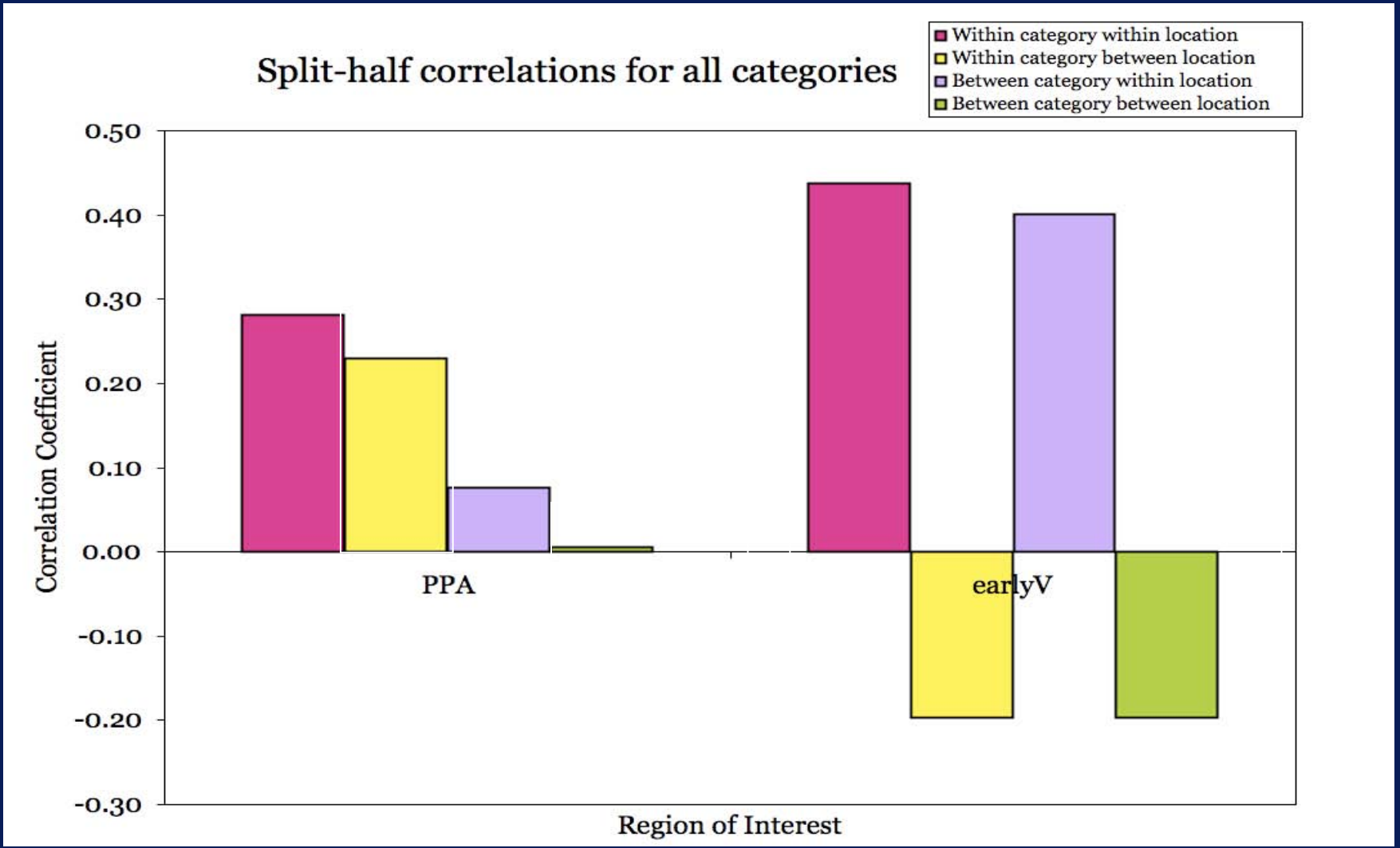
# Questions

- What is this map a map of?
- What is the dimensionality of this map?
  - so far: 3-dim projection of presumably much bigger space
- How consistent is the shape map across individuals? Species?
- How does the shape map arise in development?
  - Face patches first?
  - Shape map first?
  - Do both arise together and somehow constrain each other?
- How are the properties of this shape map related to perception?
- Why do things cluster in the cortex in the first place?
- Which parts of the map are used/ read out during task performance?

An even smaller speck of data on this last point…..

Courtesy of the American Physiological Association. Used with permission.

# Correlations across all object categories



# Talk Outline

1) Is there location information in object- and category-selective regions?

- Means: Yes
- Pattern: Yes

2) Are category and location information independent or do they interact?

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1) Is there location information in object- and category-selective regions?

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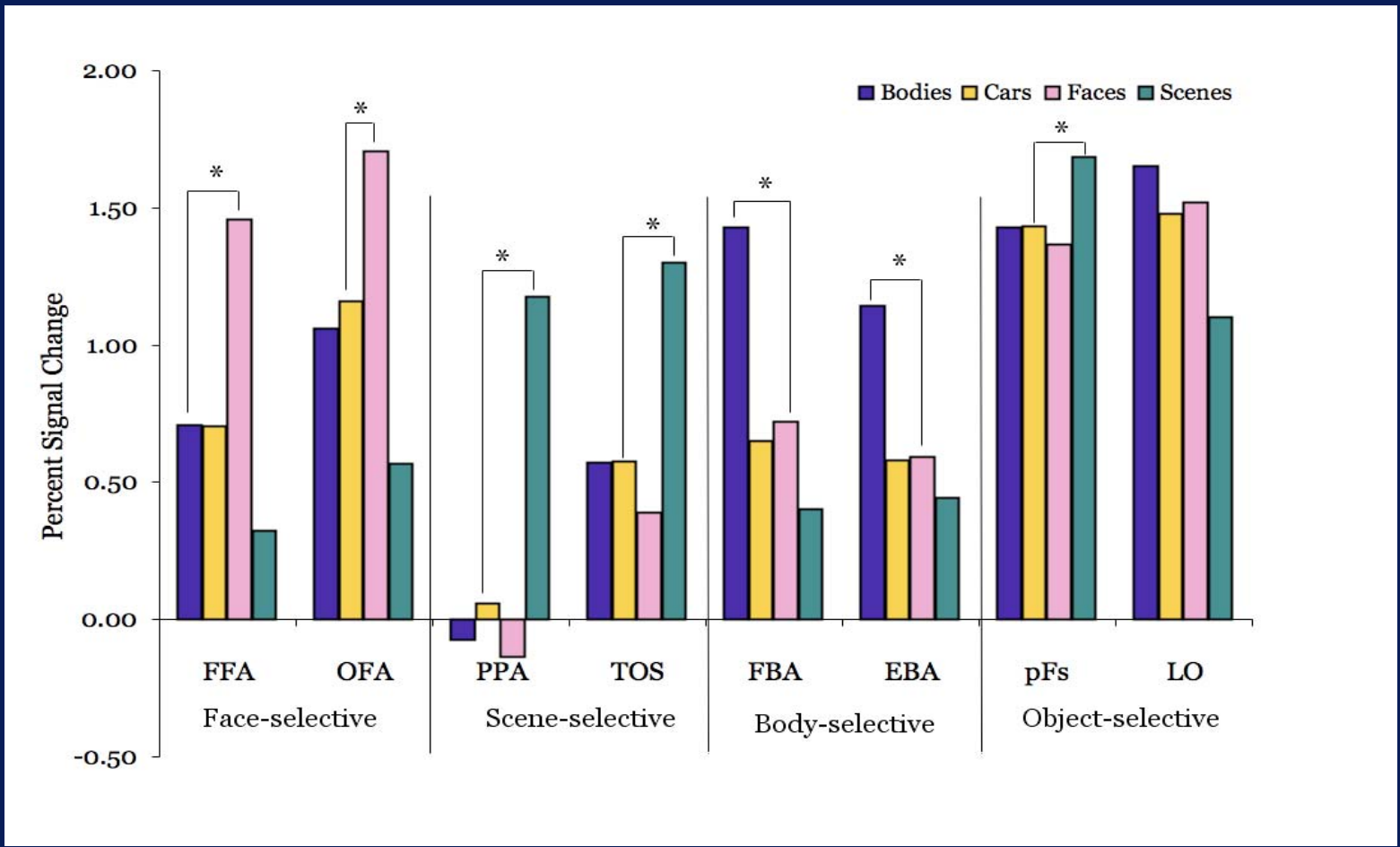
4 Categories x 3 Locations x 8 ROIs

Two methods:

- Mean response magnitude
- Pattern classification analyses

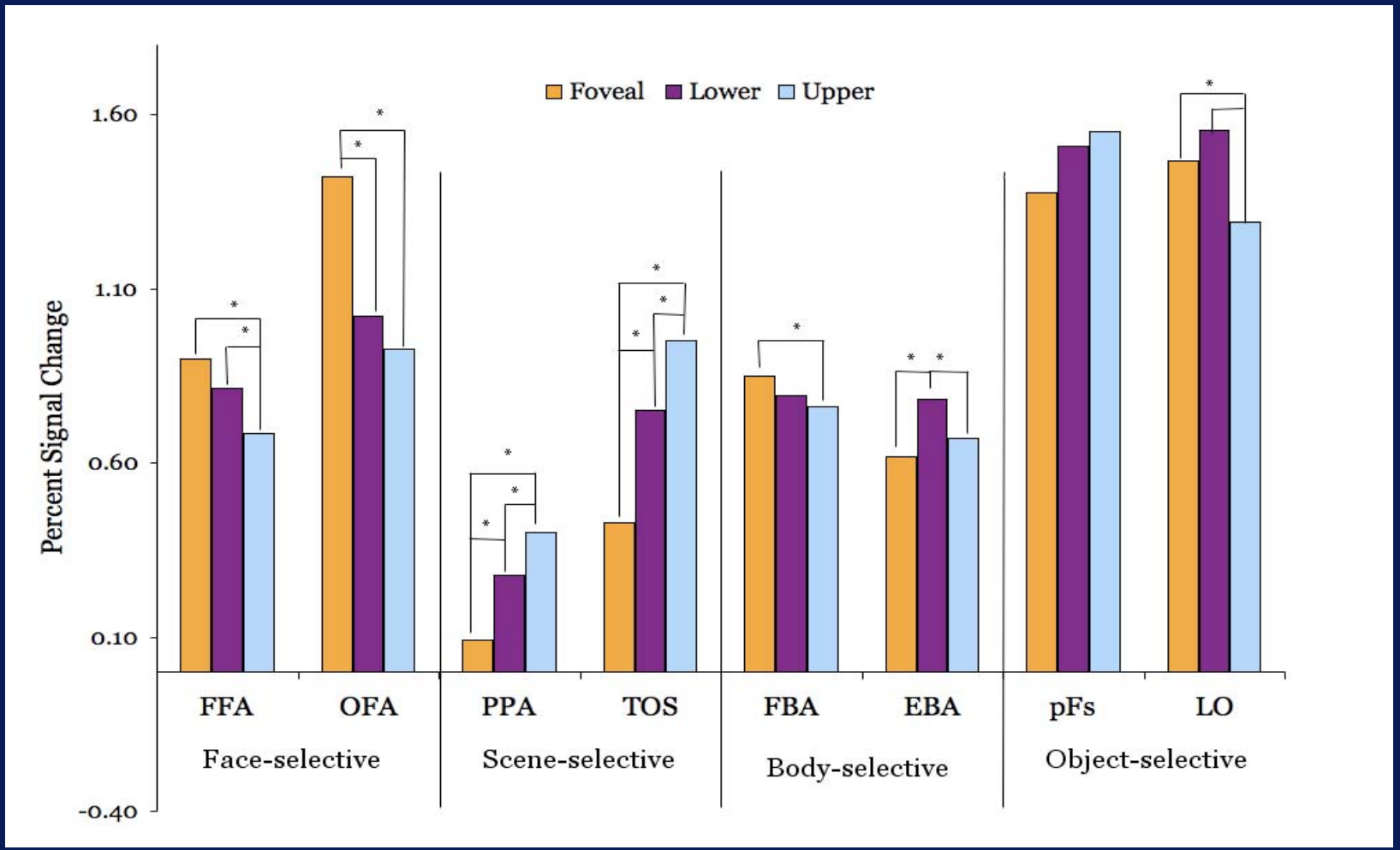
# Category Biases Across Locations




Schwarzlose, R. A. The Distribution of Category and Location Information in Ventral Visual Cortex." MIT Ph.D. Thesis, 2008

But what about location biases?

# Location Biases Across Categories




Schwarzlose, R. A. The Distribution of Category and Location Information in Ventral Visual Cortex." MIT Ph.D. Thesis, 2008

# Talk Outline

1) Is there location information in object- and category-selective regions?

- Means: Yes

2) Are category and location information independent or do they interact?

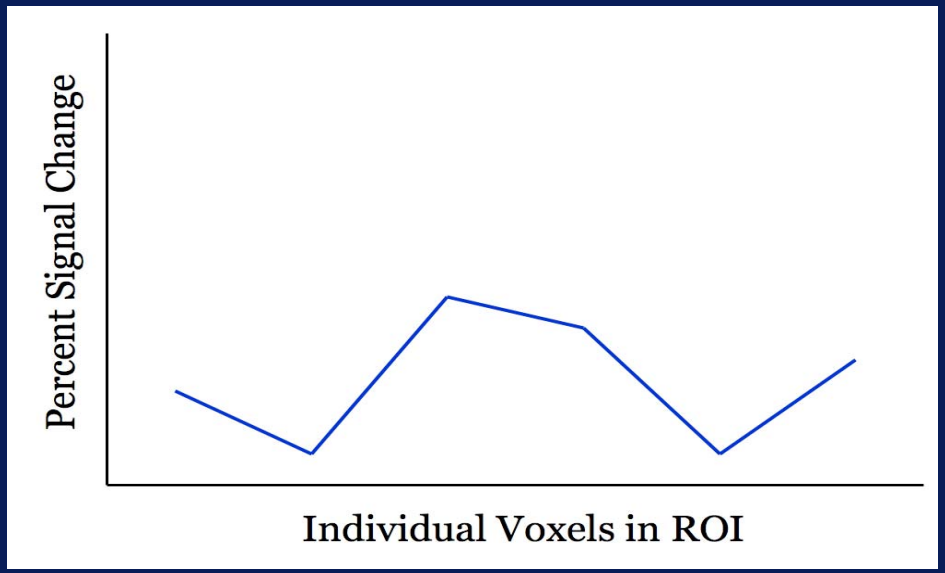
# An Orthogonal Measure of Location Information:

Pattern Classification Analyses

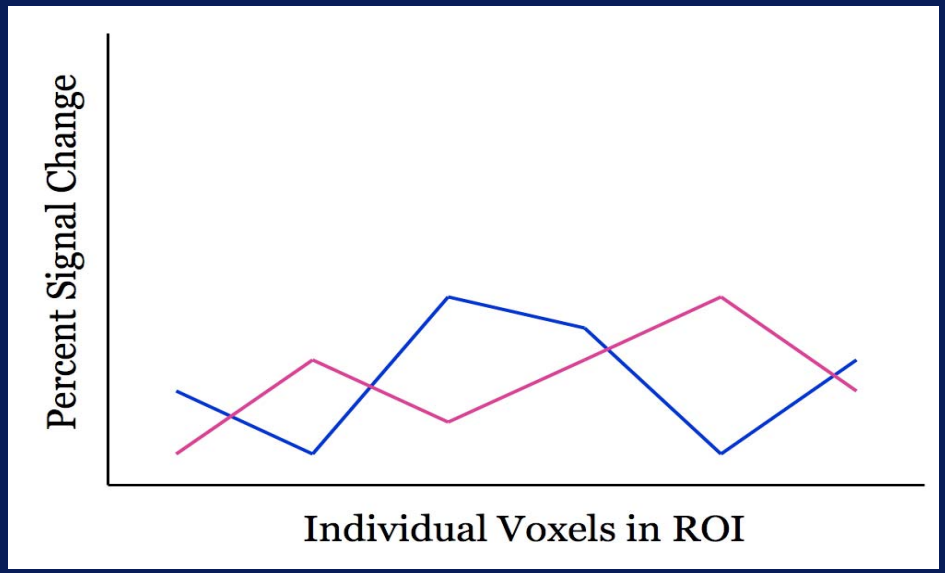
(voxel-based “population code”)

# Orthogonal Measures of Information

Different Mean,
Same Pattern



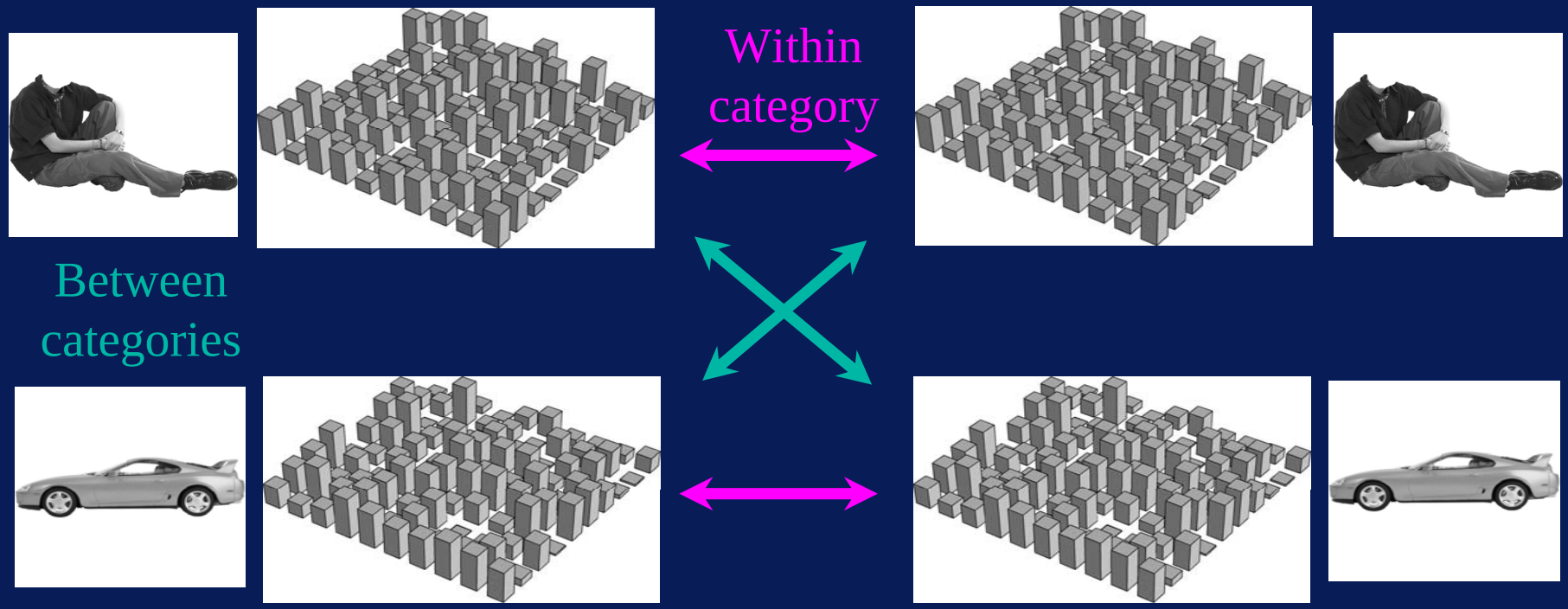

Different Pattern,
Same Mean

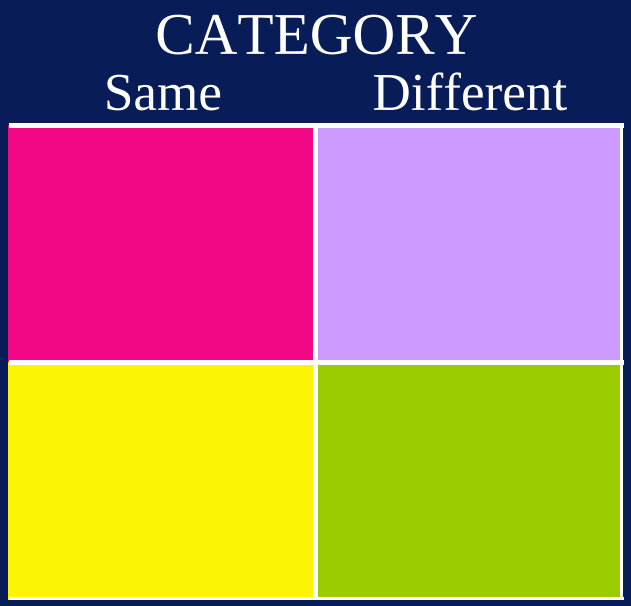
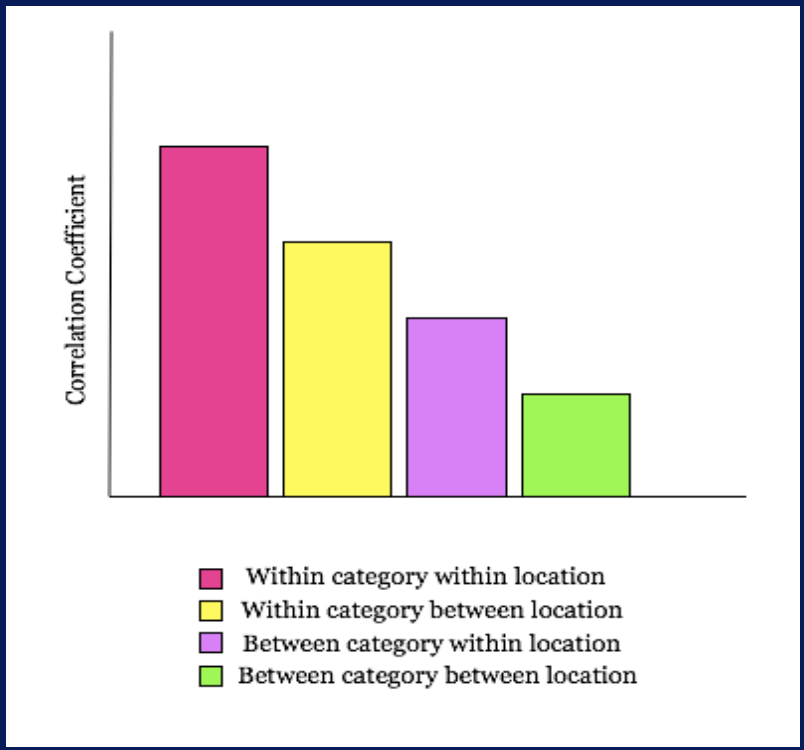


# Correlation-based classification analysis

(Haxby et al., 2001)

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




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

# Format of Pattern Classification Results