

9.13 The Human Brain Class 8

Navigation I

Today:

Quick review of Haxby & MVPA .

- I. What do we need to know to get around?
- II. The PPA, a region selectively responsive to scenes.
- III. The rest of the “scene network”: PPA, RSC, & OPA/TOS
- [IV. fMRI Adaptation and what it has told us about the scene network]

Wednesday (Navigation II):

- I. The hippocampal map and cells that code for location, borders, heading direction
- II. Reorientation

1. Haxby (2001) raised an important empirical challenge to functional specificity of FFA and PPA. What was his challenge?

Selective regions (like FFA) contain information about “nonpreferred” stimuli (e.g. cars vs shoes), so these regions do not care ONLY about preferred category!

2. What kinds of empirical data can provide counterevidence to Haxby’s challenge (say for the FFA)?

Prosopagnosia, electrical stim, TMS all can show causal role of region in processing preferred category only. So pattern information may not be used.

3. How can we use Haxby’s method to test whether the PPA can discriminate beach scenes from city scenes?

1. Functionally localize the PPA Scenes > Objects

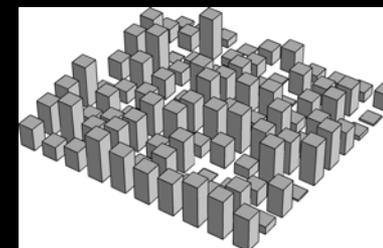
2. Collect the pattern of response across voxels in PPA while Ss view:

beach scenes. even runs (BE) →

beach scenes odd runs (BO)

city scenes even runs (CE)

city scenes odd runs (CO)



3. Now what do I predict if the PPA can discriminate beaches from cities?

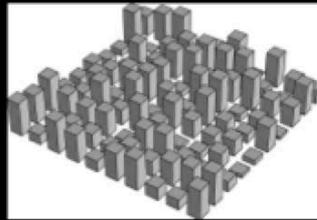
$r(\text{within category}) > r(\text{between category})$

$r(\text{BE, BO}) + r(\text{CE, CO}) > r(\text{BE, CO}) + r(\text{CE, BO})$

Multiple Voxel Pattern Analysis (MVPA)

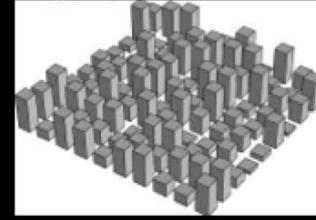
Is the pattern more similar **within a category**... than **between**

chairs even



Within category

r



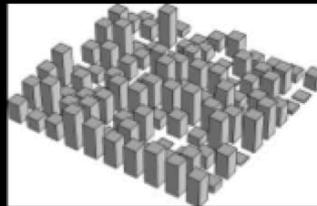
chairs odd



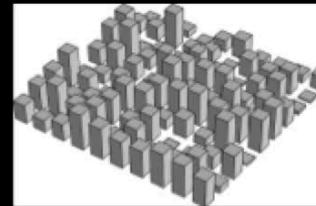
between categories



cars even



r



cars odd



If $r(\text{Within}) > r(\text{Between})$

the region contains info. distinguishing cars & chairs!

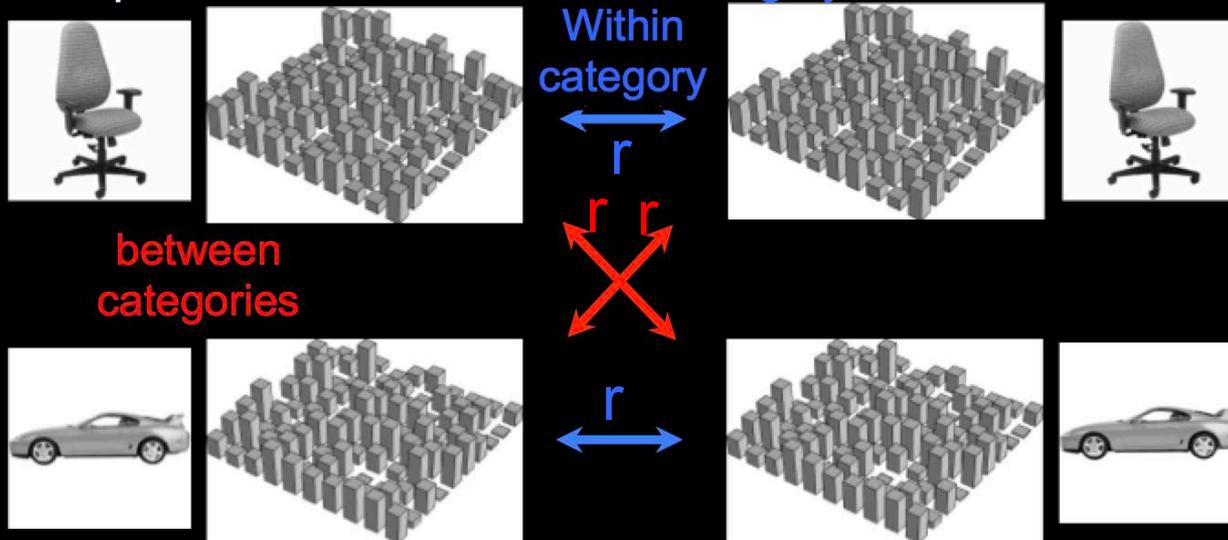
All we are doing here is asking if there are stably different patterns of response in the region for the two categories.

If there are stably different patterns, then the region has information about, that is can discriminate (or “decode”) those two patterns.

$$r(\text{within category}) > r(\text{between category})$$
$$r(\text{BE, BO}) + r(\text{CE, CO}) > r(\text{BE, CO}) + r(\text{CE, BO})$$

If you feel shaky on MVPA

Is the pattern more similar **within a category**... than **between**



If $r(\text{Within}) > r(\text{Between})$

the region contains info. distinguishing cars & chairs!

1. Watch this video

<http://nancysbraintalks.mit.edu/video/multiple-voxel-pattern-analysis>

2. Reread Haxby et al (2001) and/or Bryan et al

3. Talk to me or a TA.

4. Shall we do an fMRI analysis problem set?

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Navigation I

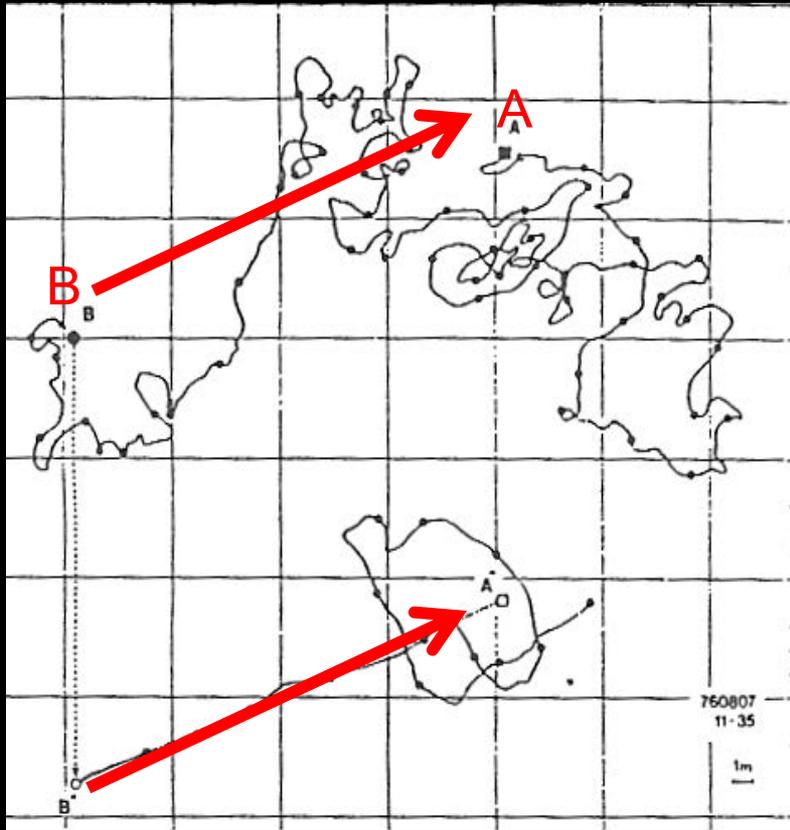
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Dead Reckoning in the Tunisian desert Ant



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- Ant wanders at random foraging for food (A to B), then goes straight home.
- If the ant is translated to a new location after finding food, he follows the *exactly correct vector* home (direction and extent).
- Searches for up to an hour for nest, centered on “correct” location.
- How does the ant know the correct vector home without landmarks?

Feats of Animal Navigation

Animals accomplish these extraordinary feats of navigation because they have to, to find:

food

mates

shelter

MIT students too need to be able to find

What is Navigation anyway, and what does it entail?

Two fundamental problems of navigation:

I. Where am I?

II. How do I get from here (A) to there (B)?

For example, if you see this.....



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You immediately know:
where you are, &
where to go if

it starts raining,
you are hungry,
same deal here.....



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These judgments rely on specific knowledge of this place. But even if you are in a place you have never been in before.... 10



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Even in unfamiliar places, can tell:
What kind of place is this?
Where can we go here?

The Fundamental Problems of Navigation

I. Where am I?

- Recognize a *specific* familiar location
e.g. this is *my* living room
- Even if unfamiliar: What *kind* of place is this?
a living room, a city street, a mountain, a desert
- Geometry of current loc't'n
e.g. I am next to long wall of rectangular room
how would I get out of here?

II. How do I get from here (A) to there (B)?

- If you can see or hear B, go toward it (“beaconing”).
E.g. head toward lighthouse/foghorn, or landmark.
like this.....

The Fundamental Problems of Navigation

I. Where am I?

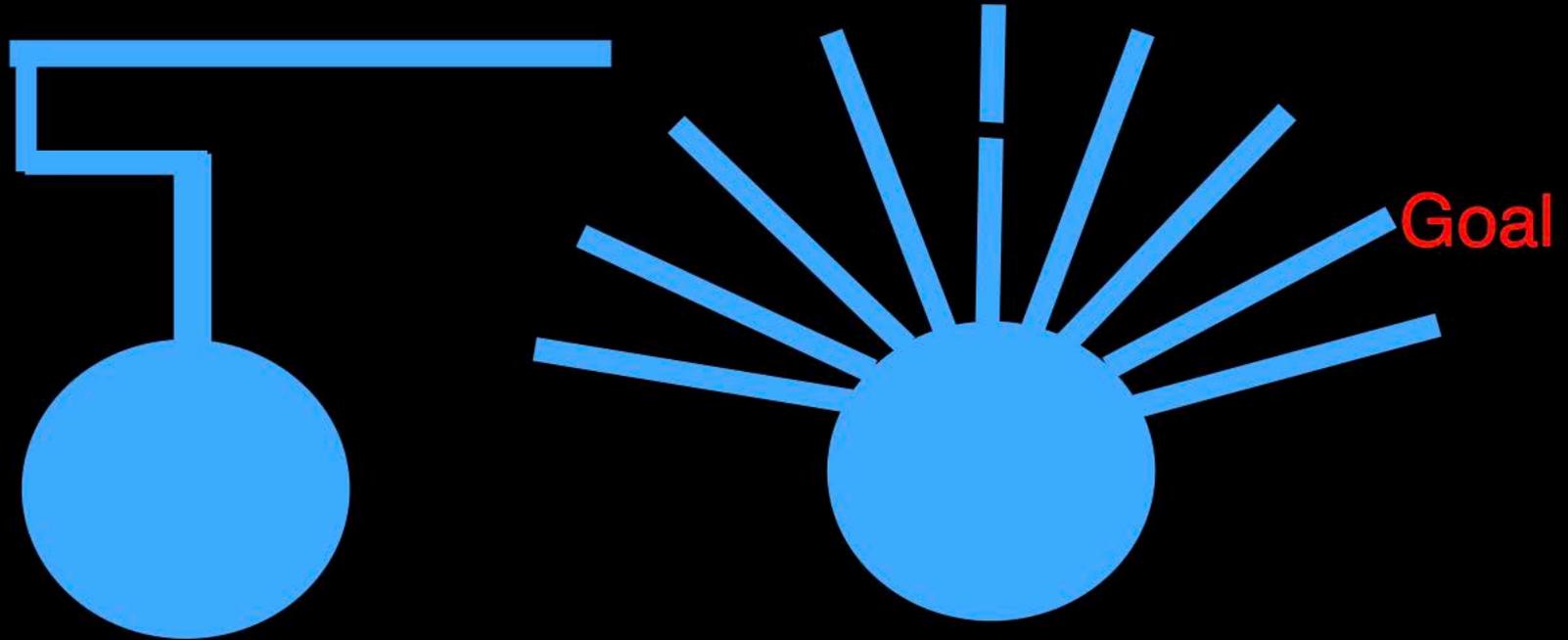
- Recognize a familiar location
e.g. this is my living room
- Even if unfamiliar: What *kind* of place is this?
a living room, a city street, a mountain, a desert
- Geometry of current loc't'n
e.g. I am next to long wall of rectangular room

II. How do I get from here (A) to there (B)?

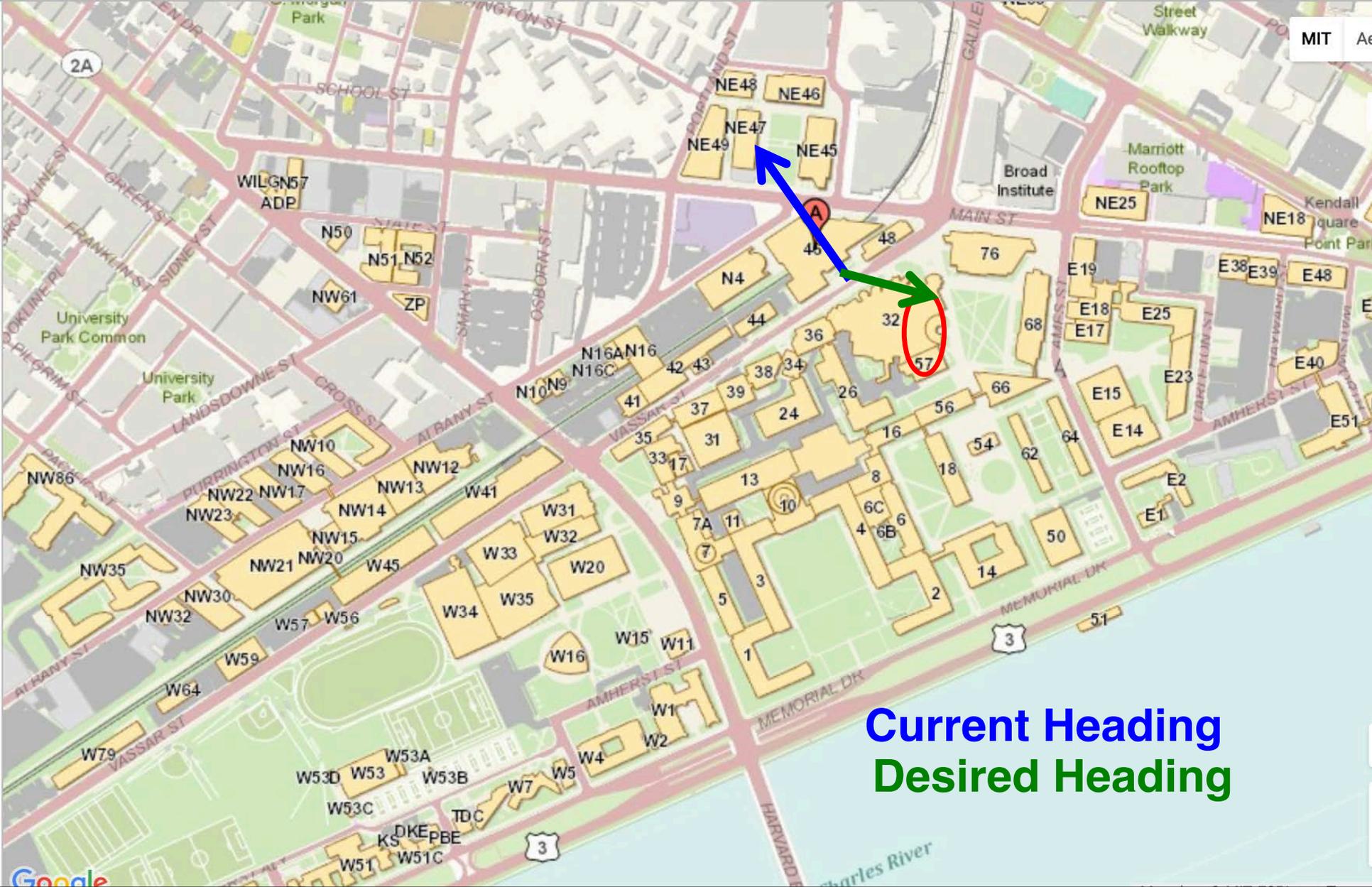
- If you can see or hear B, go toward it (“beaconing”).
E.g. head toward lighthouse/foghorn, or landmark.
Requires no “mental map”.
But if you cannot see or hear B,.....
- Need a mental map of your world
an idea first articulated way back...

Evidence for “Cognitive Maps”

- Tolman, Ritchie, & Kalish (1946)



- Rat trained on maze at left, then run on maze at right. When original route is blocked, rat chose path heading toward **goal**.
- Rats must have some kind of map in their head.
And so do you.....



Current Heading
Desired Heading

The Fundamental Problems of Navigation

I. Where am I?

- Recognize a familiar location

e.g. this is my living room

- Even if unfamiliar: What *kind* of place is this?

a living room, a city street, a mountain, a desert

- Geometry of current loc't'n

e.g. I am next to long wall of rectangular room

This is what we need to do to navigate around in our world.

What is the neural basis of all this?

II. How do I get from here (A) to there (B)?

- If you can see or hear B, go toward it (“beaconing”).

E.g. head toward lighthouse/foghorn, or landmark.

- Need a mental map of your world.....

Where am I in that map, and where is B

- Also need to know current heading w/ respect to that map

to determine necessary heading to get to B

- What routes are possible from here?

“navigational affordances” like doors and halls, getting around barriers

- Regaining bearings when lost (“reorientation”).

Lecture 8: Navigation I

Today: What is navigation?

I. What do we need to know and do to get around?

II. The PPA, a region selectively responsive to scenes.

III. The rest of the “scene network”: PPA, RSC, & OPA

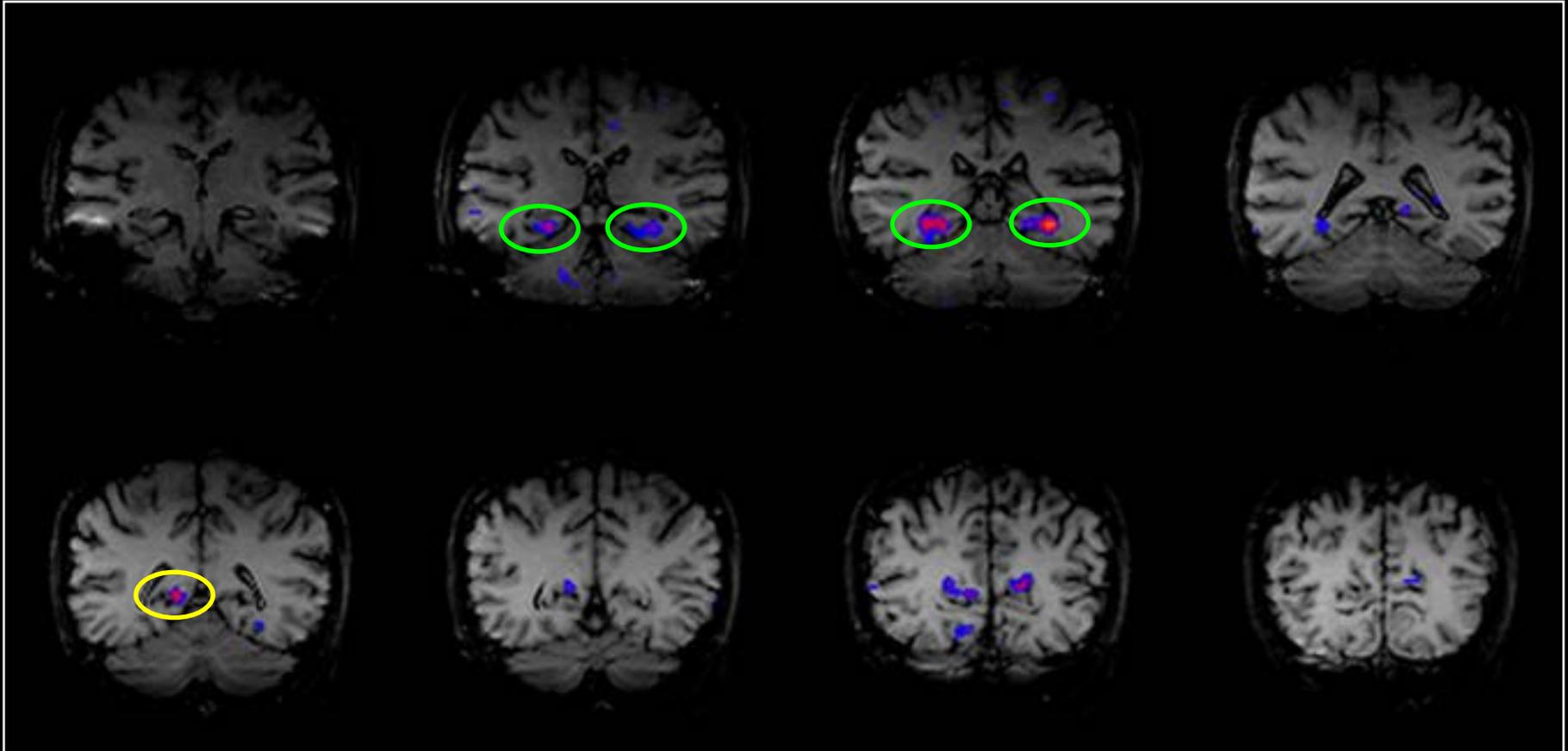
[IV. fMRI Adaptation and what it has told us about the scene network]

Wednesday:

I. The hippocampal map and cells that code for location, borders, heading direction

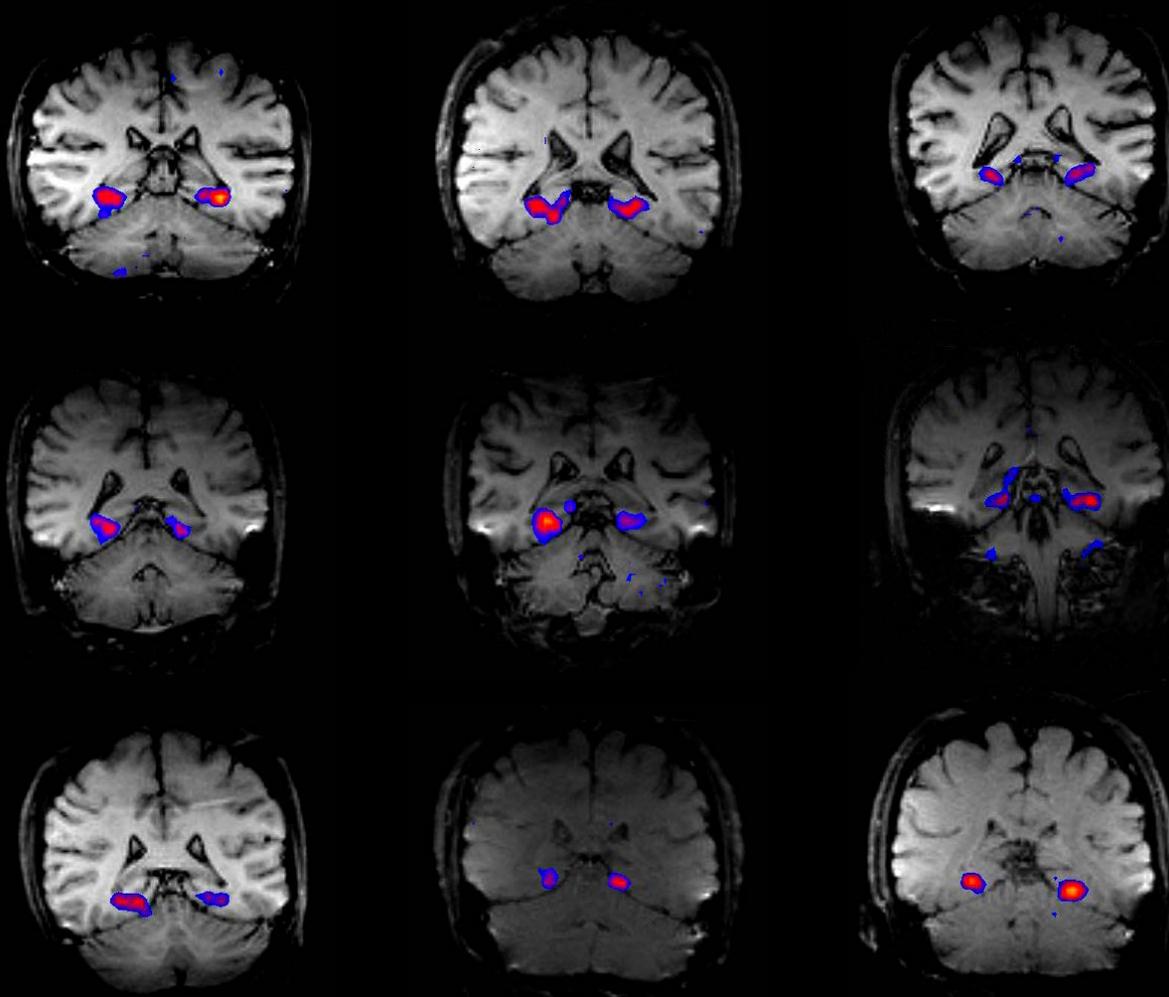
II. Reorientation

Scenes > Objects in 1 subject



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PPA in all 9 subjects Scenes > Objects



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“Parahippocampal Place Area” (PPA) 20

Why does the PPA respond more to scenes than to objects?

Is this a minimal pair?



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- high-level visual/semantic complexity
- multiplicity/relative position of objects
- spatial layout

How would we figure out which of these things are driving the response of PPA?

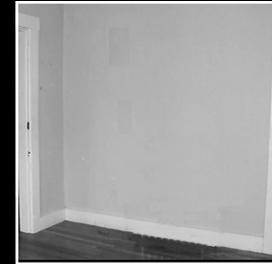
Scene



Furniture



Empty Rooms



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Predictions of PPA Response:

- visual/semantic complexity
- multiplicity of objects

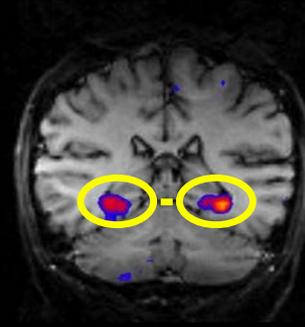
- spatial layout

} Furniture > Empty Rooms

Furniture < Empty Rooms

Functional Region of Interest Analysis

- Using one set of “localizer” scans to define PPA (scenes > objects).



- Then measure response in PPA to new conditions:

Scenes



Furniture



Empty Rooms



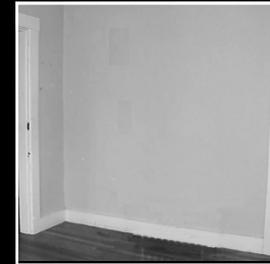
Scene



Furniture



Empty Rooms



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PSC 1.3

0.5

1.2

[p<0.01]

Predictions:

- ~~● visual/semantic complexity~~
- ~~● multiplicity of objects~~

} Furniture > Empty Rooms

- spatial layout

Furniture < Empty Rooms

Experiment 3

Question: Is the PPA involved in the recognition of a particular scene, or in processes specific to familiar scenes?

To Test: Examine PPA response to MIT versus Tufts scenes in MIT versus Tufts students – can thus **counterbalance** for specific stimuli.

Result: 1.9 PSC familiar vs. 1.8 PSC unfamiliar, n.s.

Conclusion: The PPA does not do anything that requires knowing the specific place (e.g. planning a route to a distant location in a familiar environment).

Summary of Exps. 1-3

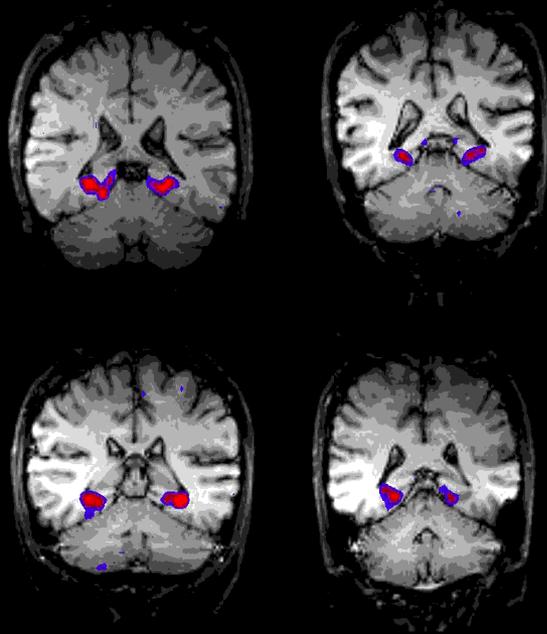
Exp. 1 There is region of parahippocampal cortex that responds more to scenes than objects.

Exp. 2 When all the objects are removed from the scenes, the response is unchanged.

Exp. 3 The PPA responds similarly to familiar & unfamiliar scenes.

The PPA analyzes the **shape** of the local environment.

Parahippocampal Place Area



The shape/geometry of space around you.

And now for the pushback....

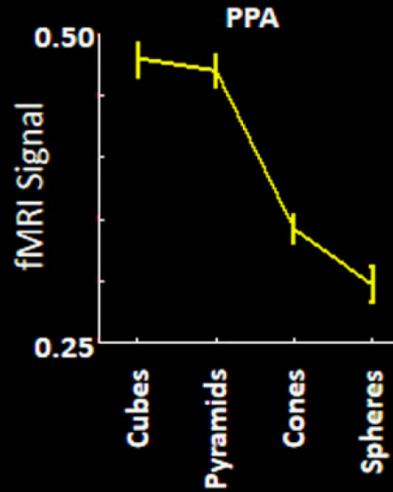
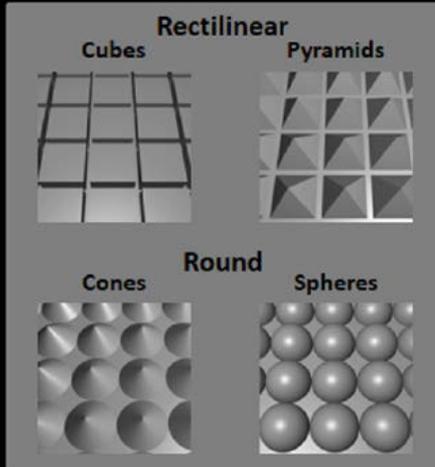
Outdoor Fam 1.9	Outdoor Unfam 1.8	Indoor Furn 1.3	Indoor Unfurn 1.2	Landscape 1.2
F. Landmark 1.5	U. Landmarks 1.1	House 1.0	Frac. Rooms 1.2	Lego Scene 1.1
Text. Gradients 0.5	Maps 0.3	Scr. Scenes 0.5	Displ. Rooms 0.8	Lego Objects 0.6
		Objects 0.4	Drop Shadow 0.5	Faces 0.0

Thinking Outside the Box: Rectilinear Shapes Selectively Activate Scene-Selective Cortex

Shahin Nasr,¹ Cesar E. Echavarria,¹ and Roger B.H. Tootell^{1,2,3}

¹Athinioula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Charlestown, Massachusetts 02129, ²Department of Radiology, Harvard Medical School, Boston, Massachusetts 02115, and ³Department of Health Sciences and Technology, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

Nasr et al. 2014



So, the PPA likes rectilinear > curvilinear shapes.

Scenes in general are more rectilinear than objects and faces.

So, is the apparent scene selectivity of the PPA just due to a _____ of scenes with rectilinearity?

No!

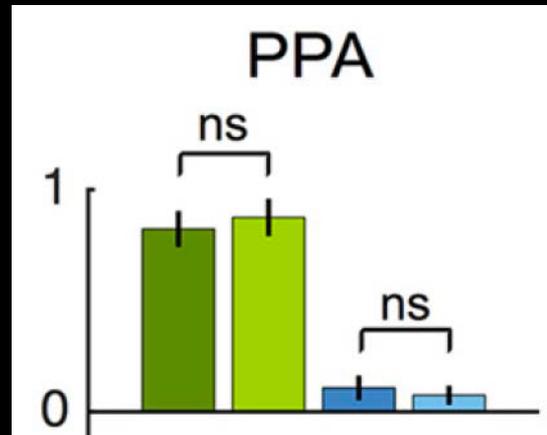
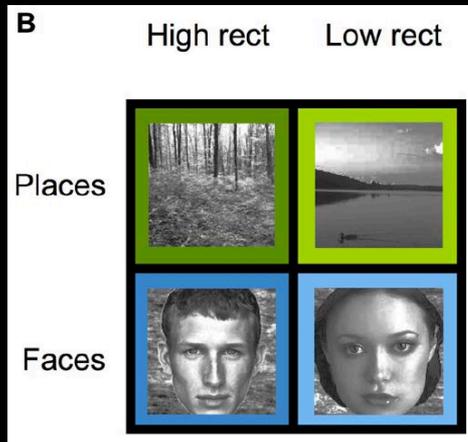
(Main effect?
Interaction?)

Nonetheless, might the PPA hold *information about*

rectilinear/curvilinearity?

How would we find out?

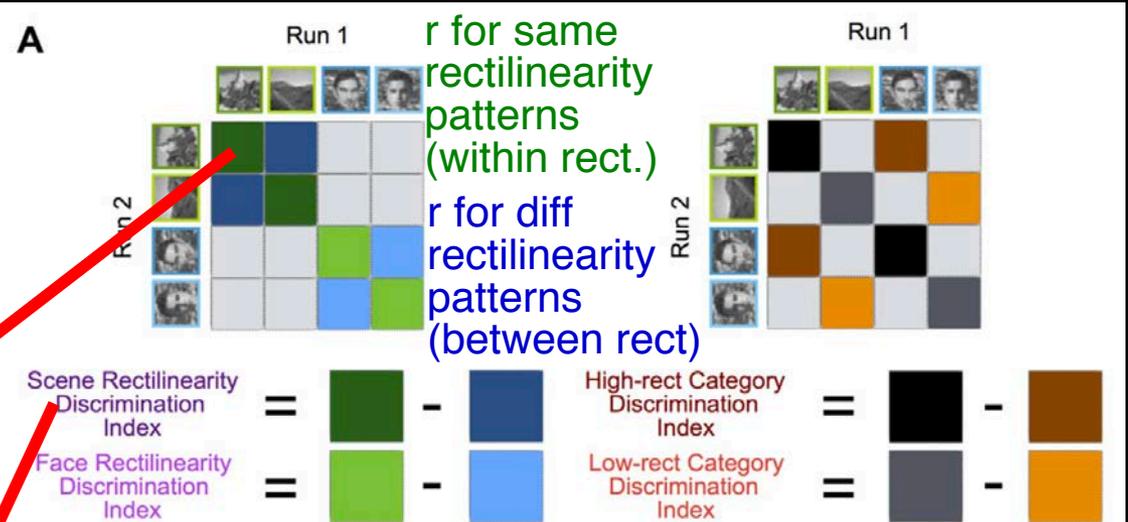
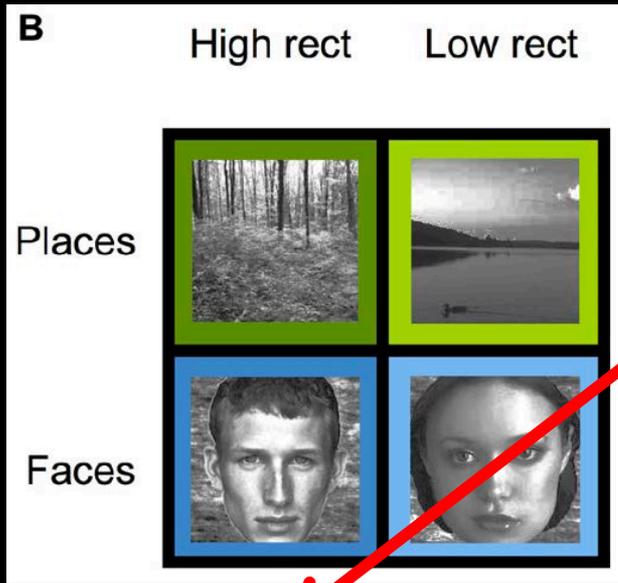
Bryan et al (2016)



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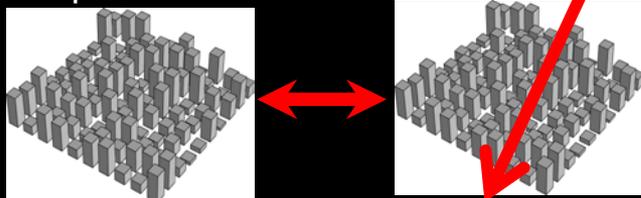
Bryan et al (2016)

Figure 4 uses multiple voxel pattern analysis (MVPA) to ask if the PPA (and other ROIs) hold information about rectilinearity/curvilinearity.



What does this cell represent?

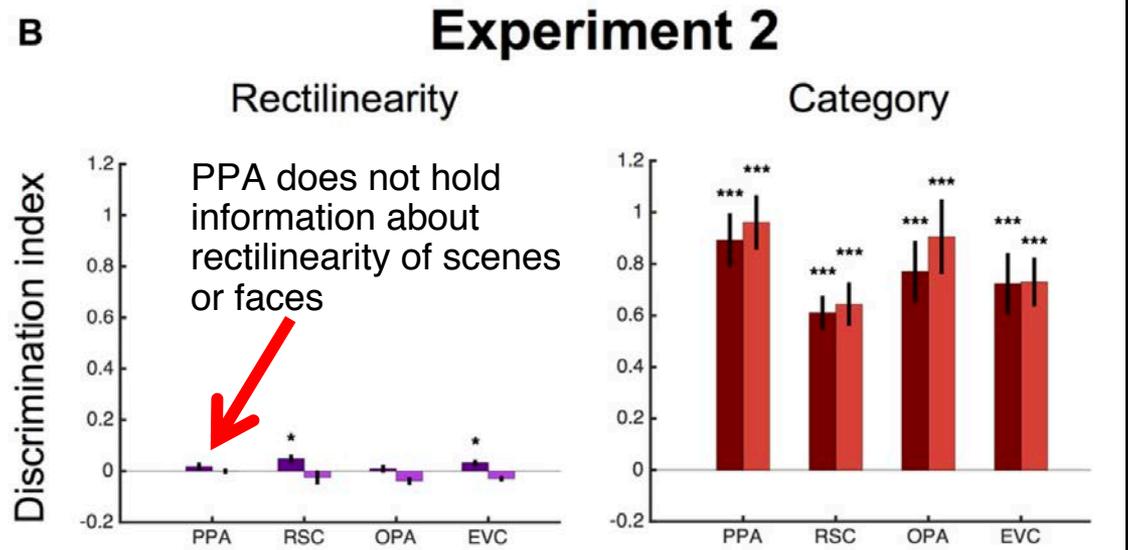
Each cell: Correlation r of pattern of response across voxels



What does this index mean?

How much info about rectilinearity of scenes is present in the fROI.

What does this figure show?



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Interrim Summary on the PPA

1. PPA responds much more to scenes than objects, faces, etc.
2. It responds to the spatial layout information of a scene, not just complexity or the multiplicity of objects.
3. The PPA responds more to boxes than circles, this rectilinearity bias cannot account for scene selectivity

*What is a key question not answered by fMRI studies of the PPA?
How might we test that?*

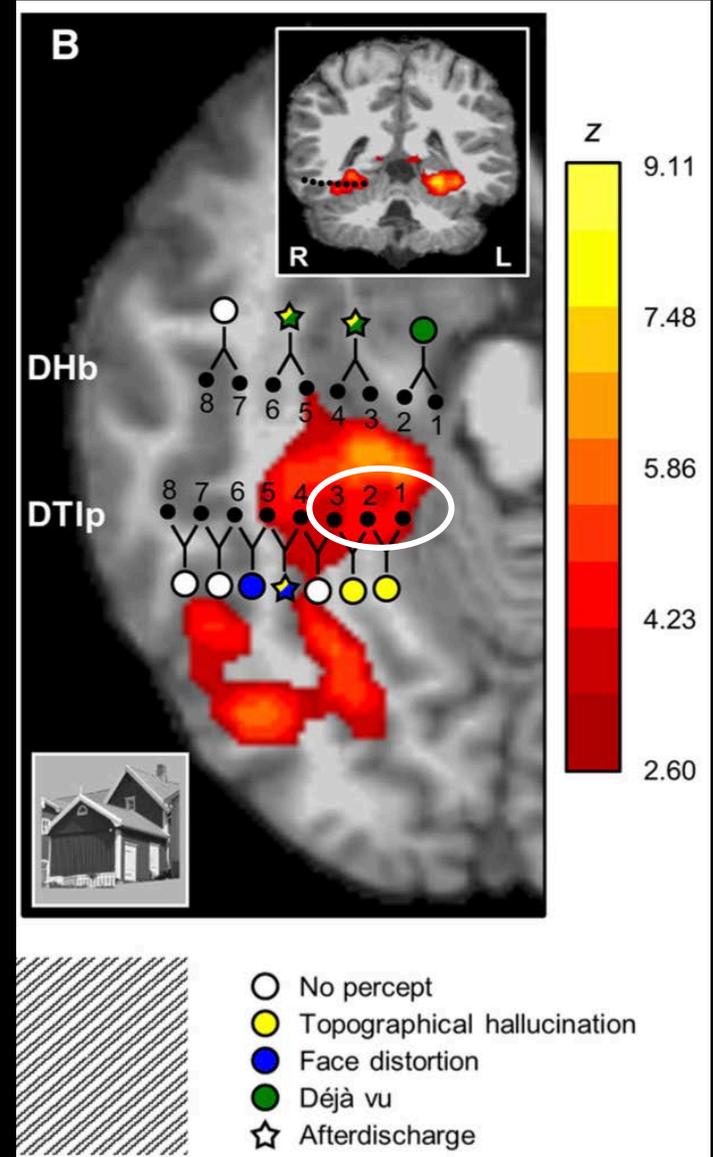
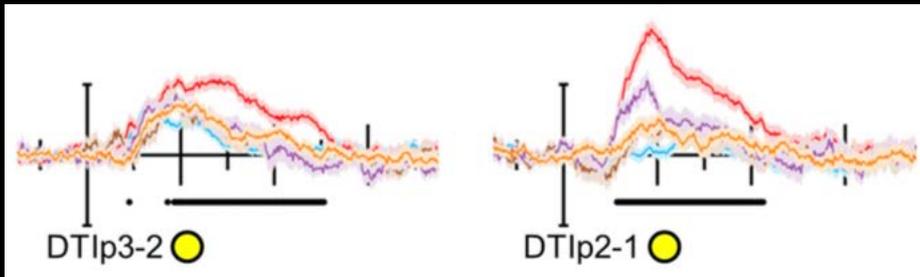
Direct Electrical Stimulation of the PPA

(Megevand et al. 2014)

How do we know we are in the PPA?

B. Regions that displayed greater fMRI responses to houses than other visual stimuli

D. ECOG response to these categories of images.



Direct Electrical Stimulation of the PPA

(Megevand et al. 2014)

- Electrical stimulation of the PPA (place-selectivity verified by fMRI and iEEG), induced a topographic visual hallucination:
- The patient described seeing indoor and outdoor scenes that included views of the neighborhood he lives in. By contrast, stimulating the more lateral aspect of the basal temporal lobe caused distortion of the patient's perception of faces.
- How does this finding go beyond the fMRI findings?

The PPA is just one part of the navigation system....

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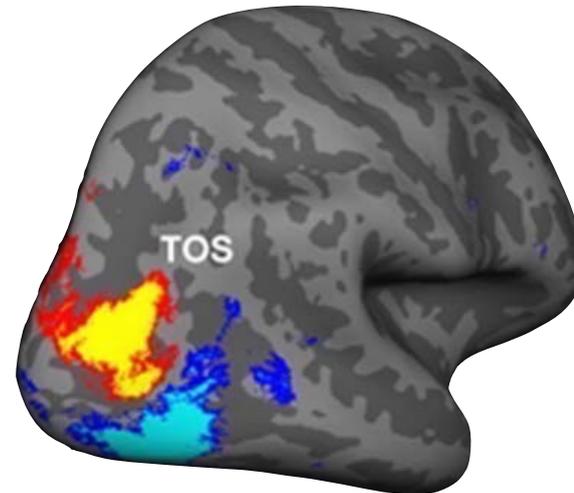
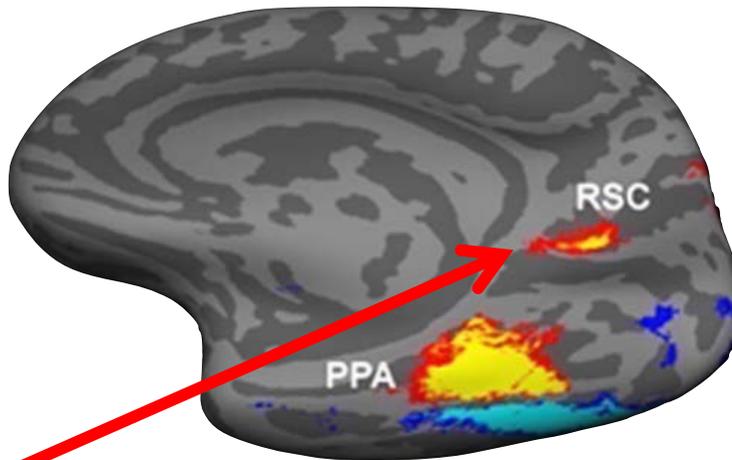
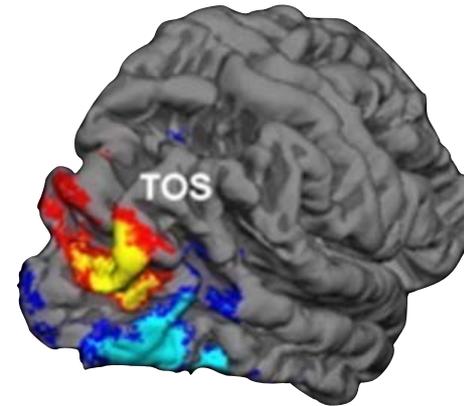
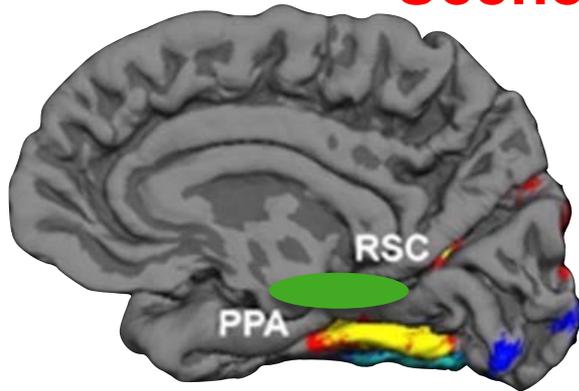
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II. Reorientation

Not Just the PPA

Scenes > Objects



PPA

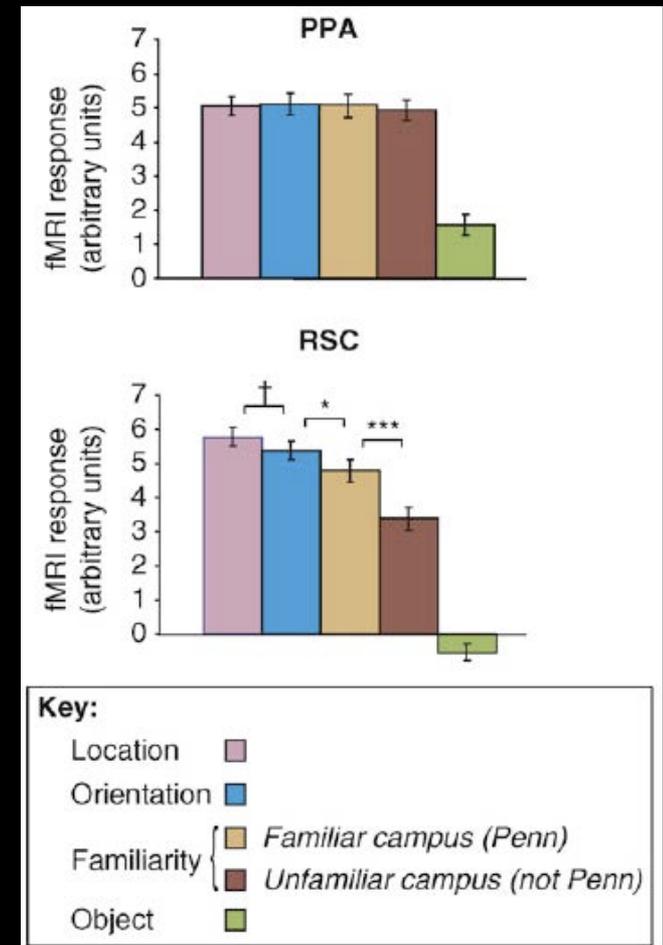
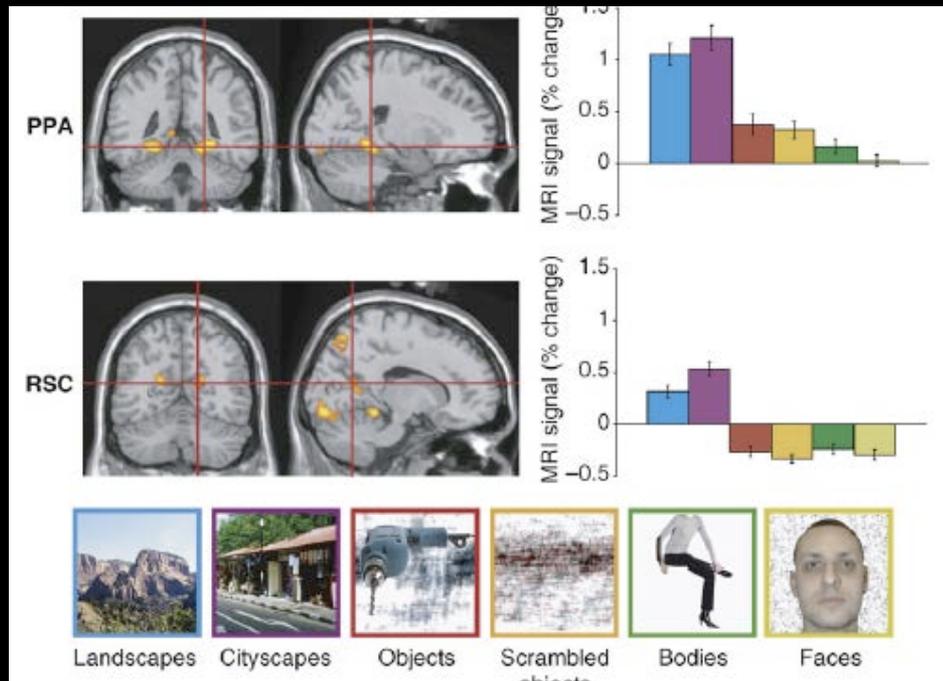
RSC

TOS (=OPA)

How does each region help us navigate?

Hippocampus

Restrosplenial Cortex (RSC)



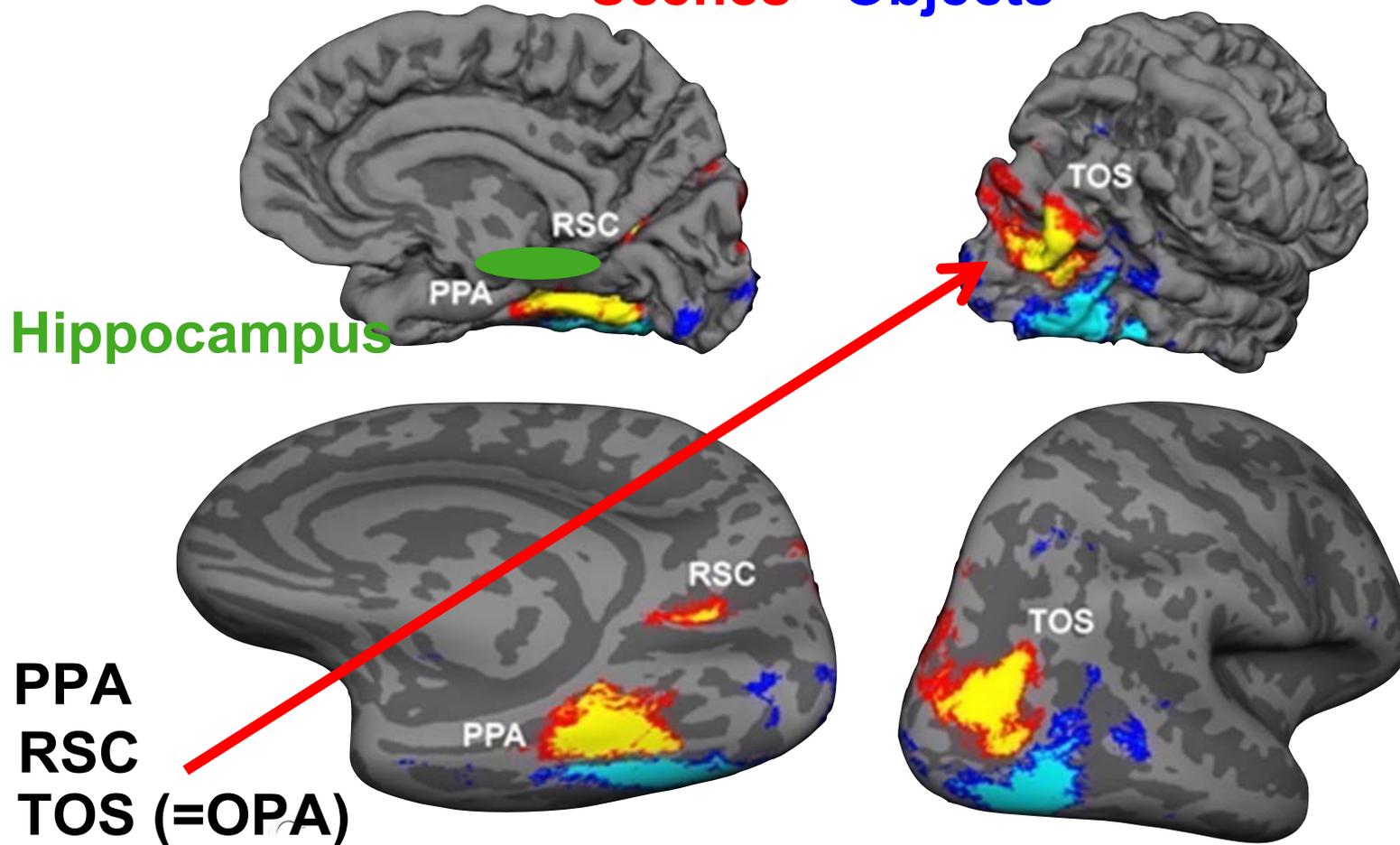
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- RSC shows large familiarity effects, PPA small
- RSC: relationship to the larger environment
- Report of a patient with damage in RSC: " he could recognize buildings and the landscape and therefore understand where he was, but the landmarks he recognized did not provoke directional information about any other places with respect to those landmarks"

***Bob!**

Multiple Scene Selective Regions

Scenes > Objects



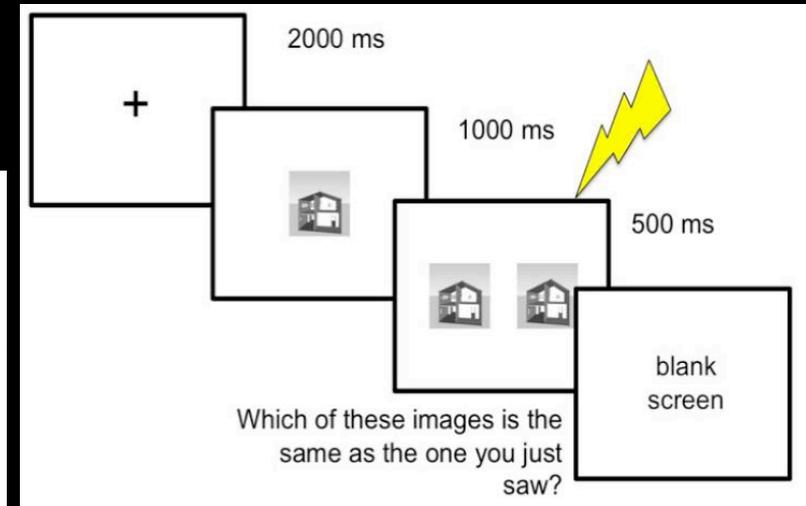
RSC: recognizing a familiar place, getting bearings (location and orientation) w/ respect to cognitive map.

A Role of TOS/OPA in Scene Perception

(Dilks et al., 2014)

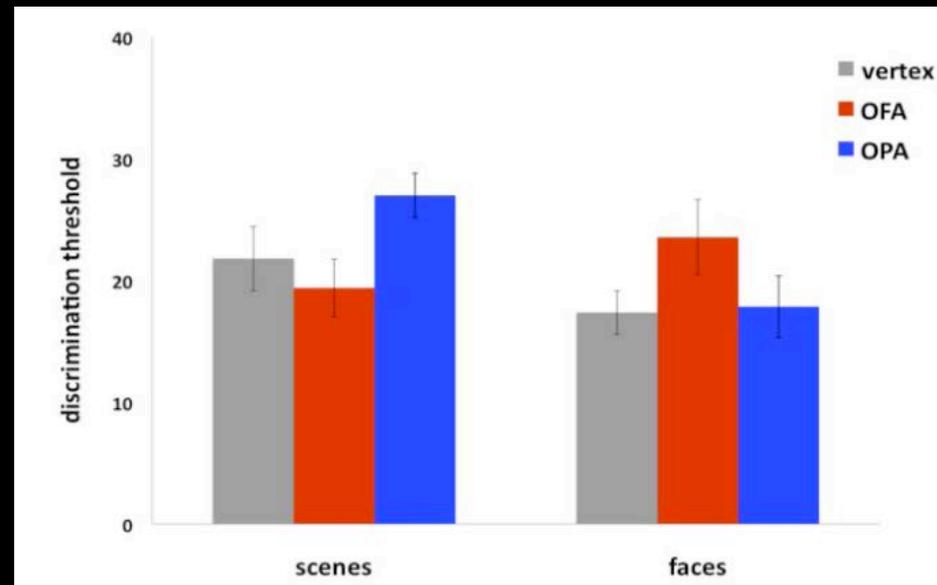
Is TOS/OPA causally involved in scene perception?

Measure discrimination threshold.



Result:

Zapping OPA disrupts scene discrimination, not face discrimination, causally implicating OPA in scene but not face perception.

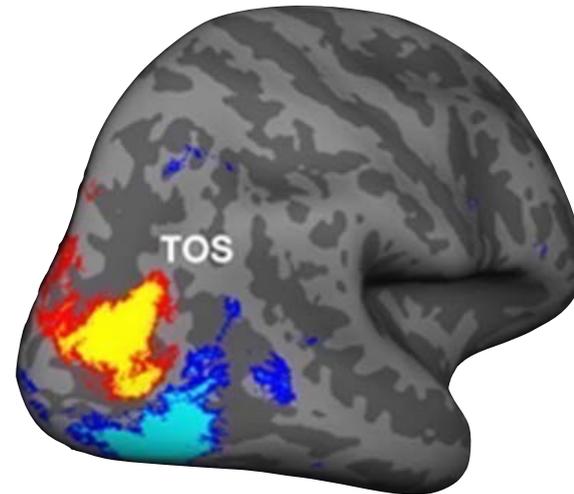
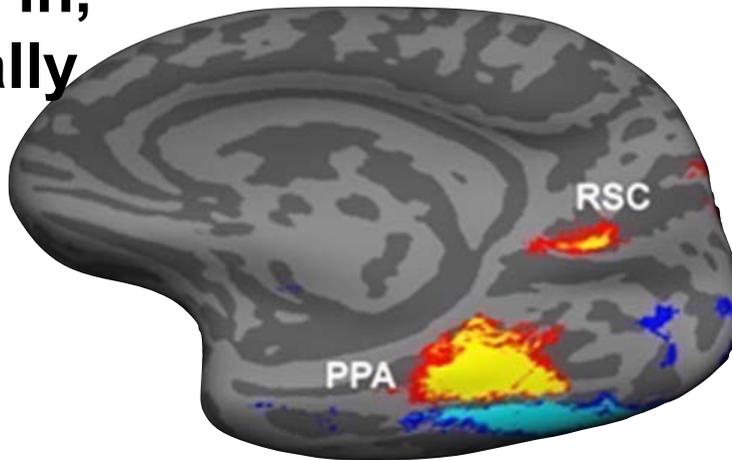
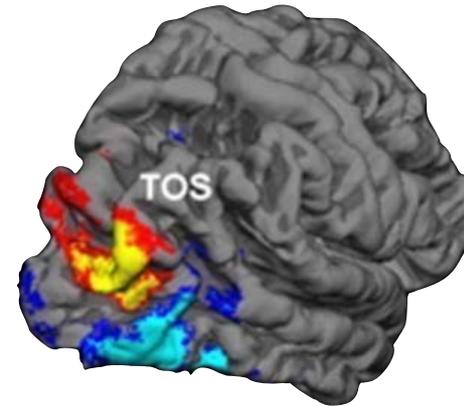
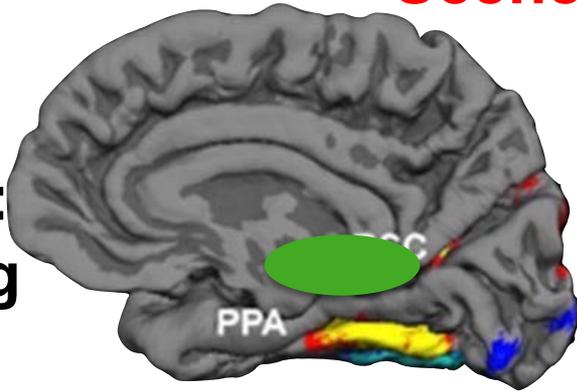


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Multiple Scene Selective Regions

Scenes > Objects

PPA & OPA/TOS: perceiving the scene you are in, especially spatial layout



RSC: recognizing a familiar place, getting bearings (location and orientation) w/ respect to cognitive map.

Hippocampus: The Cognitive Map: More on this Wednesday

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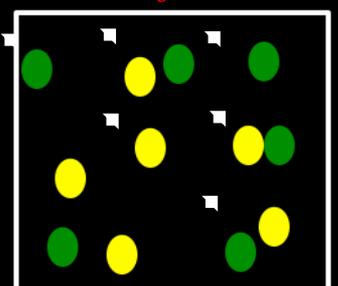
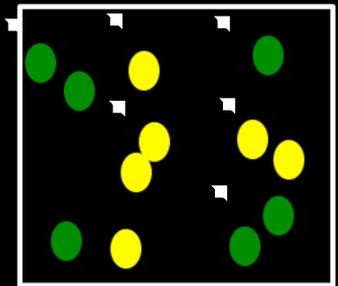
Event-Related fMRI Adaptation works even if no clustering

Goal: We want to know if neural populations in a particular region can discriminate between two stimuli.

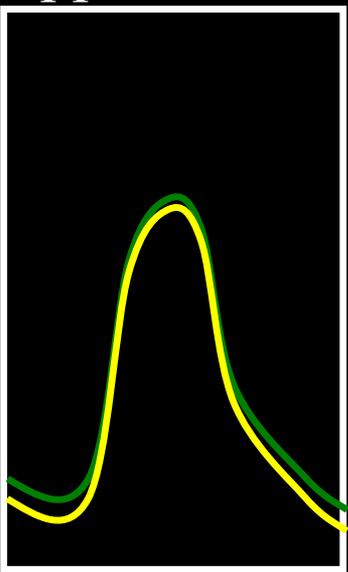
Example: Do neurons in the FFA distinguish between this:
MVPA only works when neurons are clustered spatially on scale of voxels.



vs.

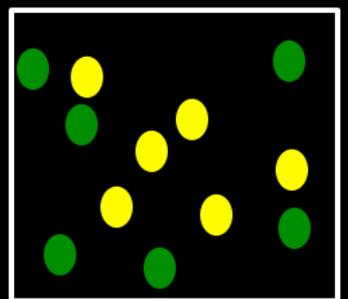


Suppose: We measure the fMRI response in FFA and find this:



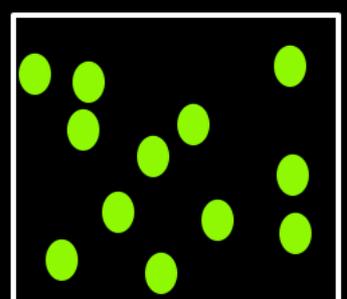
Does that mean that neural populations in the FFA cannot discriminate these two faces?
Can we tell which is true?

Neural populations in the FFA could have these selectivities:



This neural population discriminates **C** from **T**

Or these: all neurons responding equally to both



This neural population does not discriminate

Event-Related fMRI Adaptation

Basic idea: Any measure that is sensitive to the sameness vs. diff. btwn 2 stimuli can reveal what the system takes to be the same vs. diff.

Example: If brain region X discriminates btwn two similar stimuli, say.... Then if we measure fMRI response in that region to same vs. diff trials:

DIFFERENT

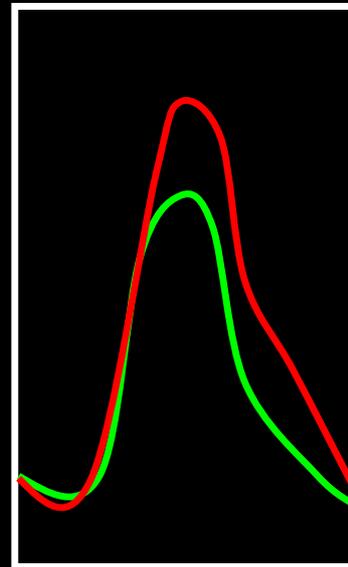


250ms 500ms 250ms

SAME



If we see this:



Then region X can discriminate these 2 stimuli. (assuming proper counterbalancing, with TT and CT conditions).

Now we can also ask what images region X “thinks” are the same, e.g....

Event-Related fMRI Adaptation

Basic idea: Any measure that is sensitive to the sameness vs. diff. betwn 2 stimuli can reveal what the system takes to be the same vs. diff.

TEST



Does region X “think” these are same?
A way to test invariances (like MVPA).

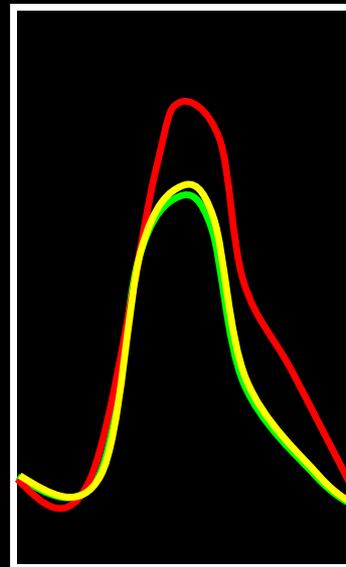
DIFFERENT



If we see this:

Then region X can discriminate these 2 stimuli. (assuming proper counterbalancing, with **TT** and **CT** conditions).

250ms 500ms 250ms



Now we can also ask what images region X “thinks” are the same, e.g....

SAME



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9.13 The Human Brain

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