9.71 Functional MRI of High-Level Vision

Fall 2007

Neural Correlates of Scene Perception

27 September 2007

9.71

What's a scene?

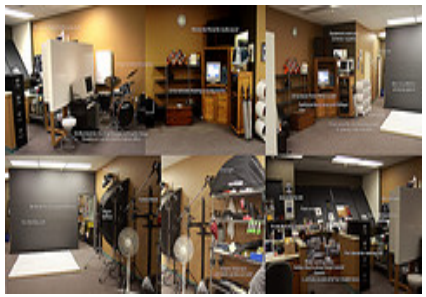


Photo courtesy of wizwow.

Photo courtesy of independentman.

Photo courtesy of Kitty Cats.

Photo courtesy of mikefats.

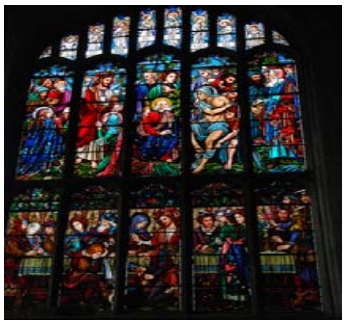
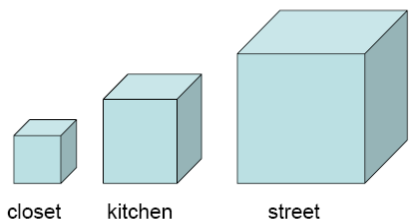


Photo courtesy of antonychammond.

Photo courtesy of John-Morgan.

Photo courtesy of equusignis.



- anything that's not an object?
- anything that extends beyond the scope of your view
- anything with a spatial layout
- Oliva: space is a 3d object with size and contents

What's a place?

Photo courtesy
of Rita Crane Photography.

- a semantically coherent (and often nameable) view

- of a real world environment

- with background elements and discrete objects

Photo courtesy
of folica.com.

"act on objects"

Photo courtesy
of exfordy.

"act in scenes"

(Henderson & Hollingworth 1999)

(Epstein 2005)

We’re very good at recognizing scenes

Photo courtesy
of Gaetan Lee.

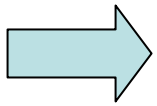
This is termed the “gist” of the scene.

What processes and representations mediates this rapid scene recognition?

Object

Courtesy of Nick Devenish.

“bunny”



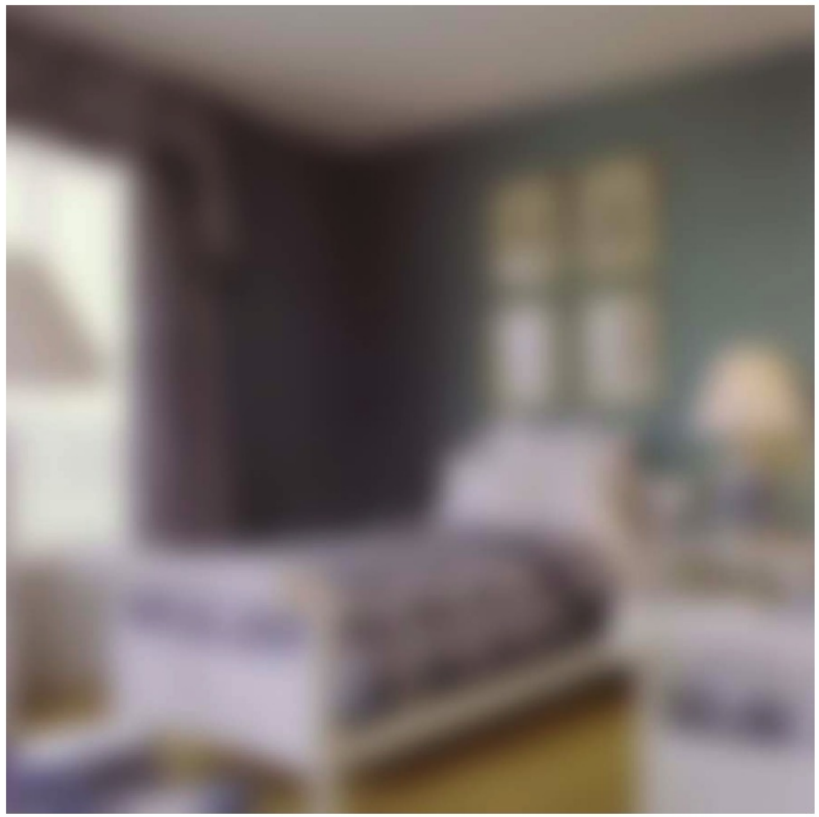
Scene

Courtesy of Per Ola Wieberg.

“field”

Do you know what this is?

Do you know what this is?



You do now!

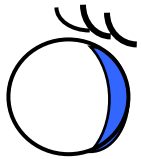
What processes and representations mediates this rapid scene recognition?

Possibility 1

World/
Visual field

Photo courtesy of Nick Devenish.

Eye/
Retinal image



Object Recognition

Matching

Object

Courtesy of Nick Devenish.

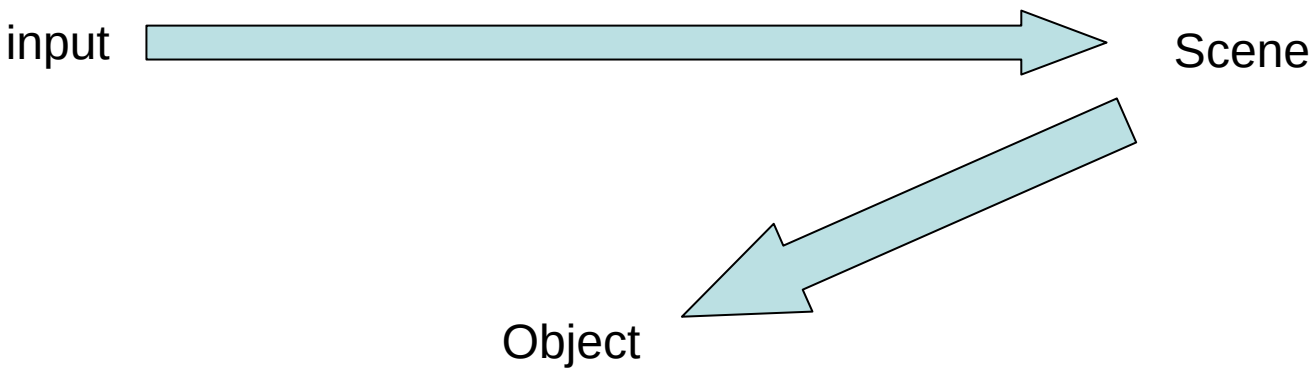
"bunny"

Scene

Courtesy of Per Ola Wieberg.

"field"

So… knowing the scene helped you recognize the object!



Another Example – What do you think are the hidden objects?

Courtesy of Wonderlane.

Another Example – What do you think are the hidden objects?

Courtesy of Wonderlane.

Answering this question does not require knowing what the objects look like. It is all about context.

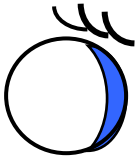
What processes and representations mediates this rapid scene recognition?

Possibility 1

World/
Visual field

Photo courtesy of Nick Devenish.

Eye/
Retinal image



Object Recognition

Matching

Object

Courtesy of Nick Devenish.

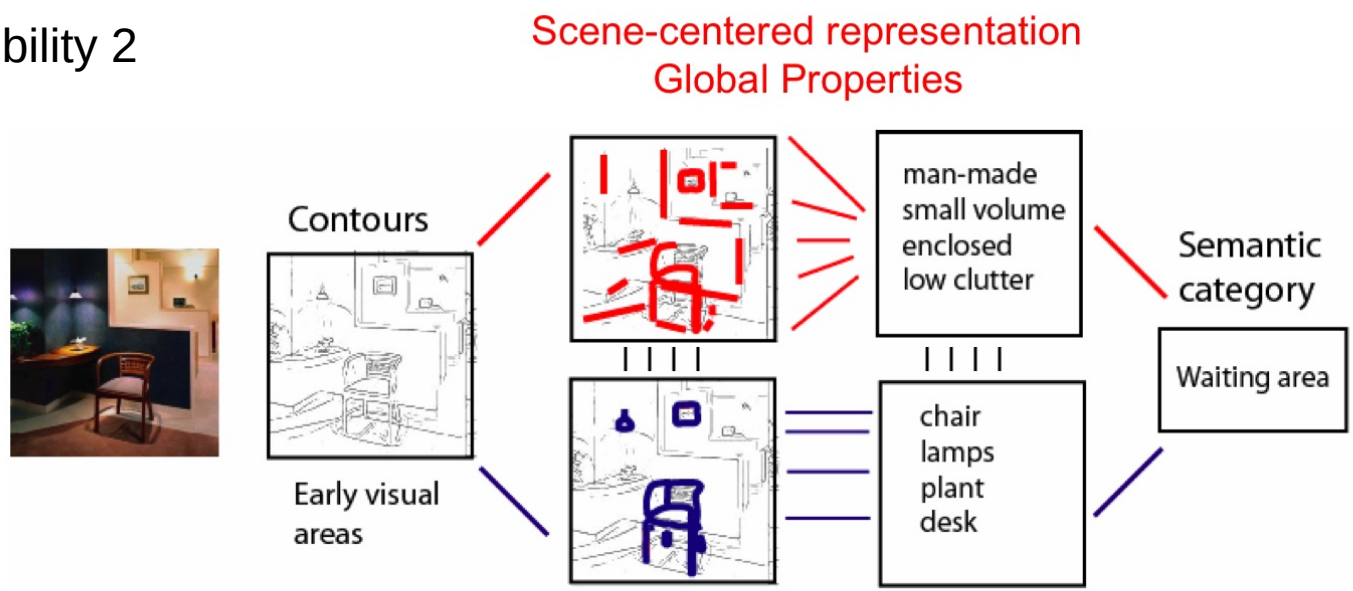
"bunny"

Scene

Courtesy of Per Ola Wieberg.

"field"

Possibility 2



Courtesy of Aude Oliva. Used with permission. (Oliva and Torralba, 2006)

Questions

1) Are scenes processed differently from objects in the brain?

2) Is there evidence that scenes and objects are processed in different parallel pathways in the brain?

Are there brain regions that respond selectively to scenes?

Courtesy of Jason Gulledge.

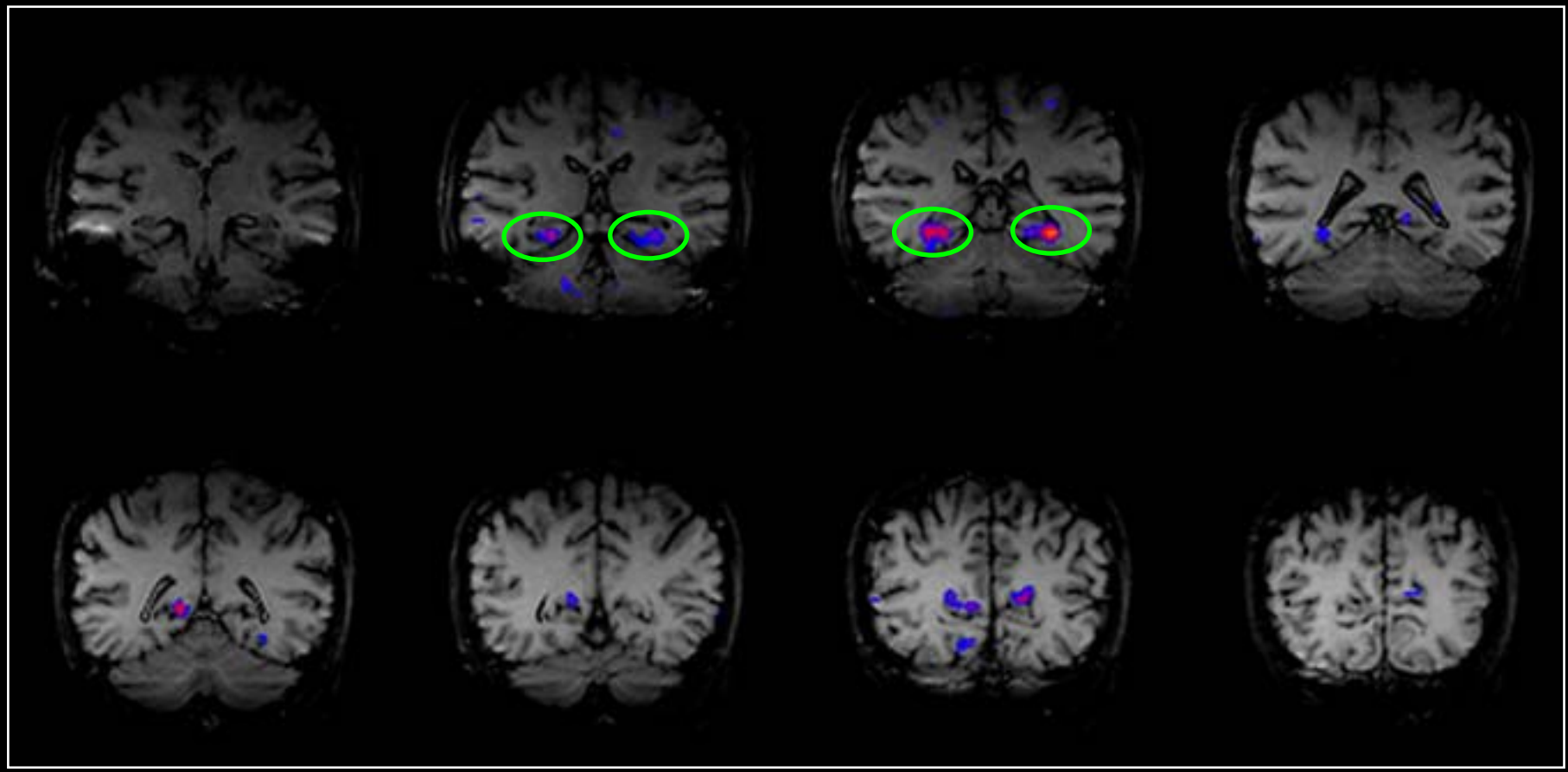
?

Courtesy of wrestlingentropy.

Face photos modified by OCW for privacy considerations.

Scan subjects while they look at these three kinds of stimuli

Scenes > Faces & Objects
in 1 subject

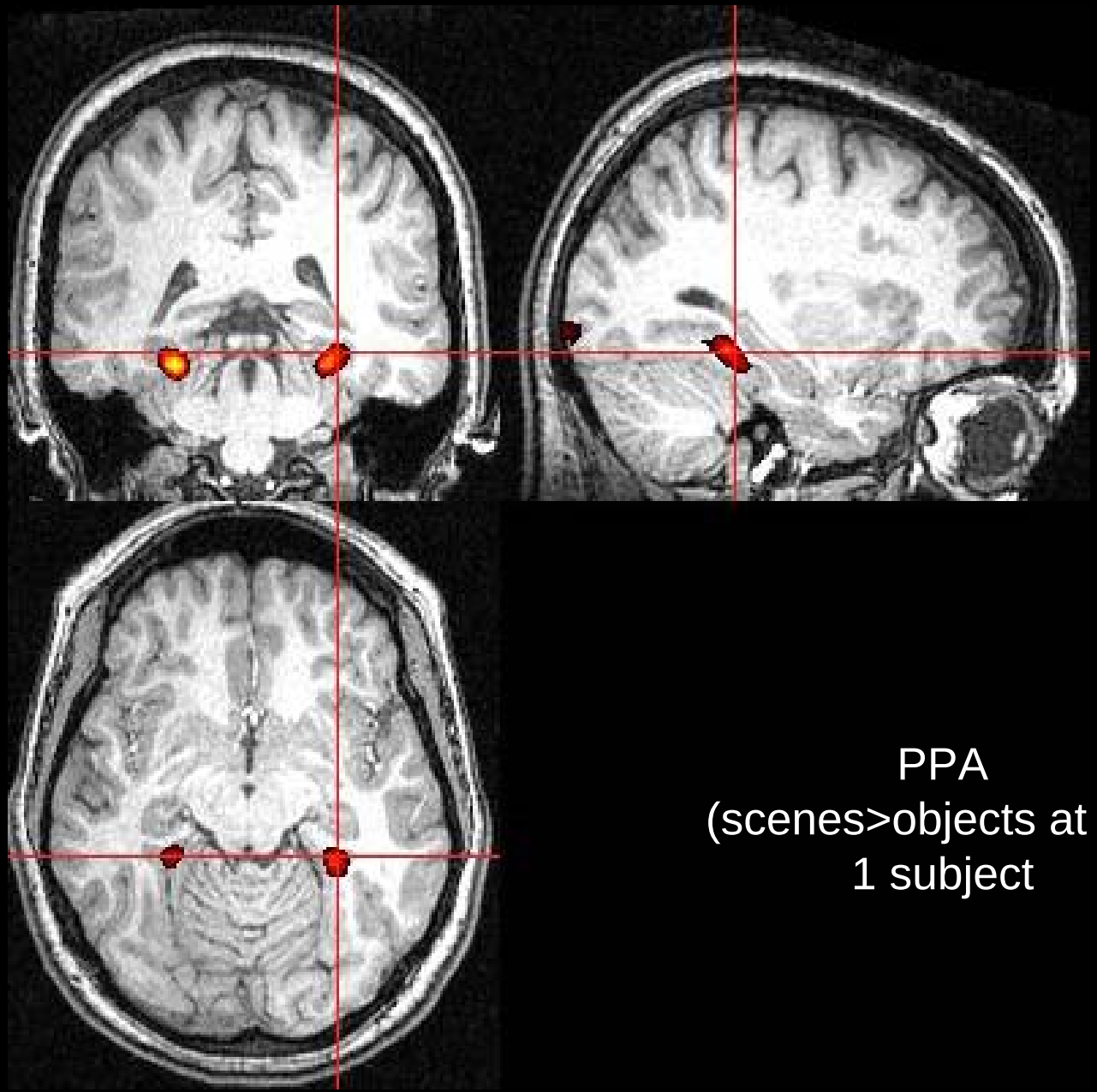


“Parahippocampal Place Area” (PPA)

PPA in all 9 subjects

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

http://web.mit.edu/bcs/nklab/media/pdfs/EpsteinKanwisher98.pdf



PPA
(scenes>objects at t>4)
1 subject

Region of Interest Analysis

- Using a separate set of localizer scans, define PPA.
- Then look at response to stimuli of interest *within* PPA during test scans:

Images removed due to copyright restrictions.
Fig. 1b and part of Fig. 2b (left) in Epstein, Russell and Kanwisher, Nancy. "A cortical representation of the local visual environment." *Nature* 392 (1998): 598 - 601.

http://web.mit.edu/bcs/nklab/media/pdfs/EpsteinKanwisher98.pdf

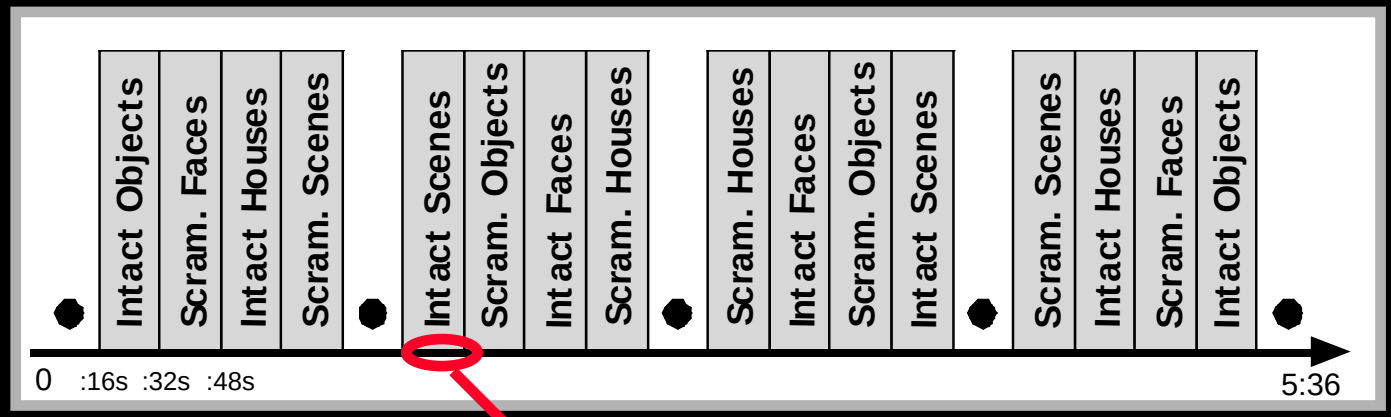
Epstein & Kanwisher, 1998

Image removed due to copyright restrictions.
Fig. 1a in Epstein, Russell and Kanwisher, Nancy.
"A cortical representation of the local visual environment." *Nature* 392 (1998): 598 - 601.

http://web.mit.edu/bcs/nklab/media/pdfs/EpsteinKanwisher98.pdf

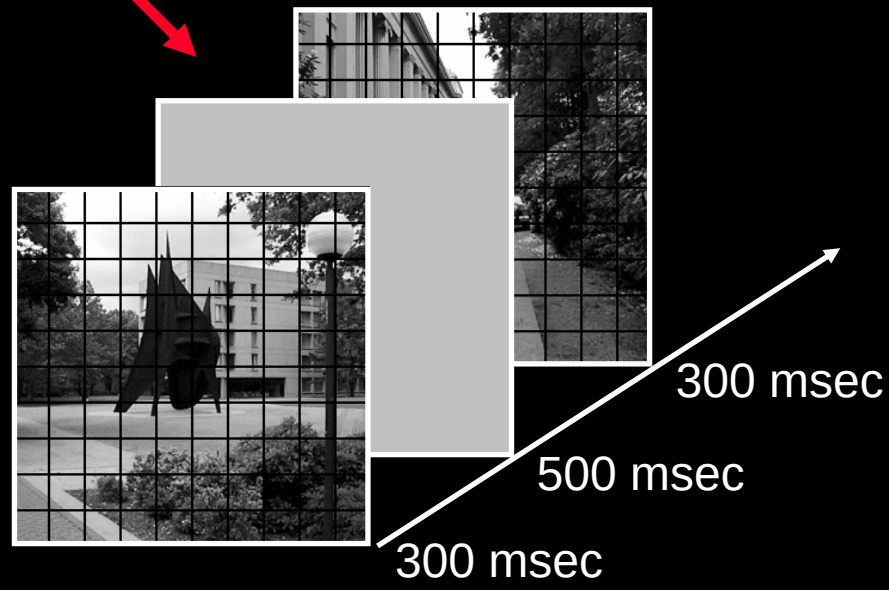
Procedure

Each Scan:



Each Epoch:

(20 pictures in an epoch)



Tasks: Passive Viewing or 1-Back Repetition Detection

Results

average % signal change for each condition (N=9)

Image removed due to copyright restrictions.
Fig. 1a in Epstein, Russell and Kanwisher, Nancy. "A cortical representation of the local visual environment." *Nature* 392 (1998): 598 - 601.

http://web.mit.edu/bcs/nklab/media/pdfs/EpsteinKanwisher98.pdf

Why does the PPA respond to scenes?

Courtesy of Jason Gulledge.

Courtesy of greenbroke.

?

Courtesy of wrestlingentropy.

Face photos modified by OCW for privacy considerations.

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

- spatial layout

Scene

Furniture Arrays

Empty Rooms

Courtesy of Jason Gulledge.

Courtesy of ZapTheDingbat.

Courtesy of greenbroke.

Courtesy of Baltimike.

Predictions:

- visual/semantic complexity
- multiplicity of objects

} Furniture ?? Empty Rooms

- spatial layout

Furniture ?? Empty Rooms

Scene

Furniture Arrays

Empty Rooms

Courtesy of Jason Gulledge.

Courtesy of ZapTheDingbat.

Courtesy of greenbroke.

Courtesy of Baltimike.

1.3 **0.5** **1.2** **PSC (N=6)**

[p<0.01]

Predictions:

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

} Furniture > Empty Rooms

- spatial layout

Furniture < Empty Rooms

Experiment 3

If the PPA responds to spatial layout, then its response to surfaces that do *not* define a space should be low.

Image removed due to copyright restrictions.
Fig. 4 in Epstein, Russell and Kanwisher, Nancy. "A cortical representation of the local visual environment." *Nature* 392 (1998): 598 - 601.

http://web.mit.edu/bcs/nklab/media/pdfs/EpsteinKanwisher98.pdf

Experiment 3 Results

average % signal change in PPA for each condition (N=5)

Image removed due to copyright restrictions.
Fig. 4 in Epstein, Russell and Kanwisher, Nancy. "A cortical representation of the local visual environment." *Nature* 392 (1998): 598 - 601.

http://web.mit.edu/bcs/nklab/media/pdfs/EpsteinKanwisher98.pdf

Experiment 4

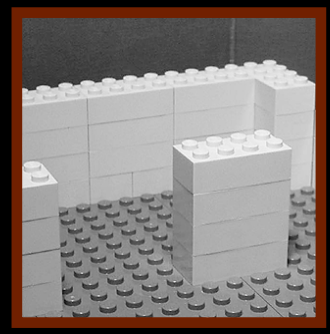
Issue: Is it the *layout* (physical structure) or the *placeness* (meaning) of the scene that drives the PPA response?

To Test: Examine PPA response to layouts that are not real places in the world.

Courtesy of greenbroke.

Layout, Real Place in World

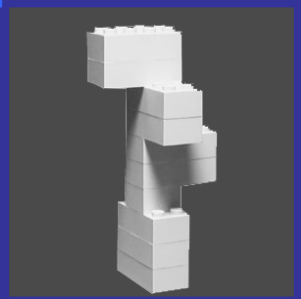
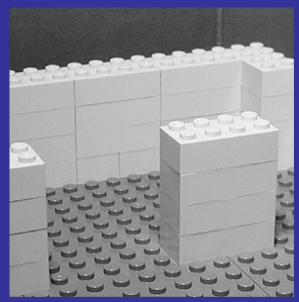
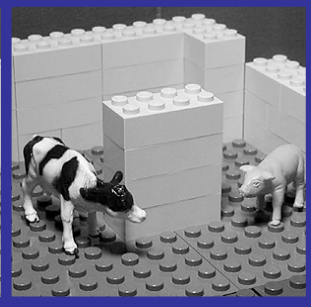
vs.



Layout, Not Real Place

Experiment 4

Question: Does the PPA respond strongly to spatial layouts that are not real places?

Objects	Lego Objects	Lego Layouts	Layout+Anim.	Empty Rooms	Furn. Rooms
					

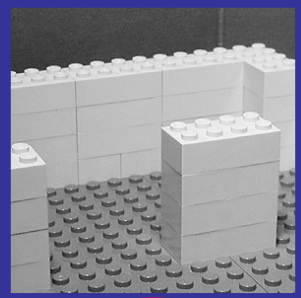
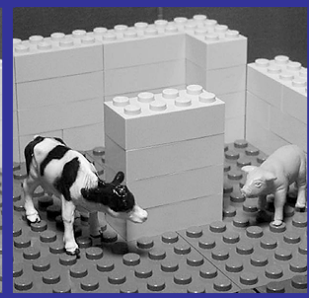
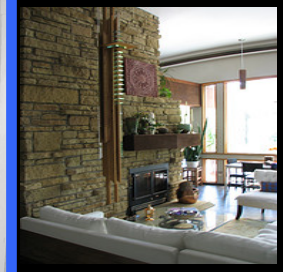
Courtesy of wrestlingentropy.

Courtesy of Baltimike.

Courtesy of greenbroke.

Experiment 4 Results

Avg. % signal change in PPA (N=6):

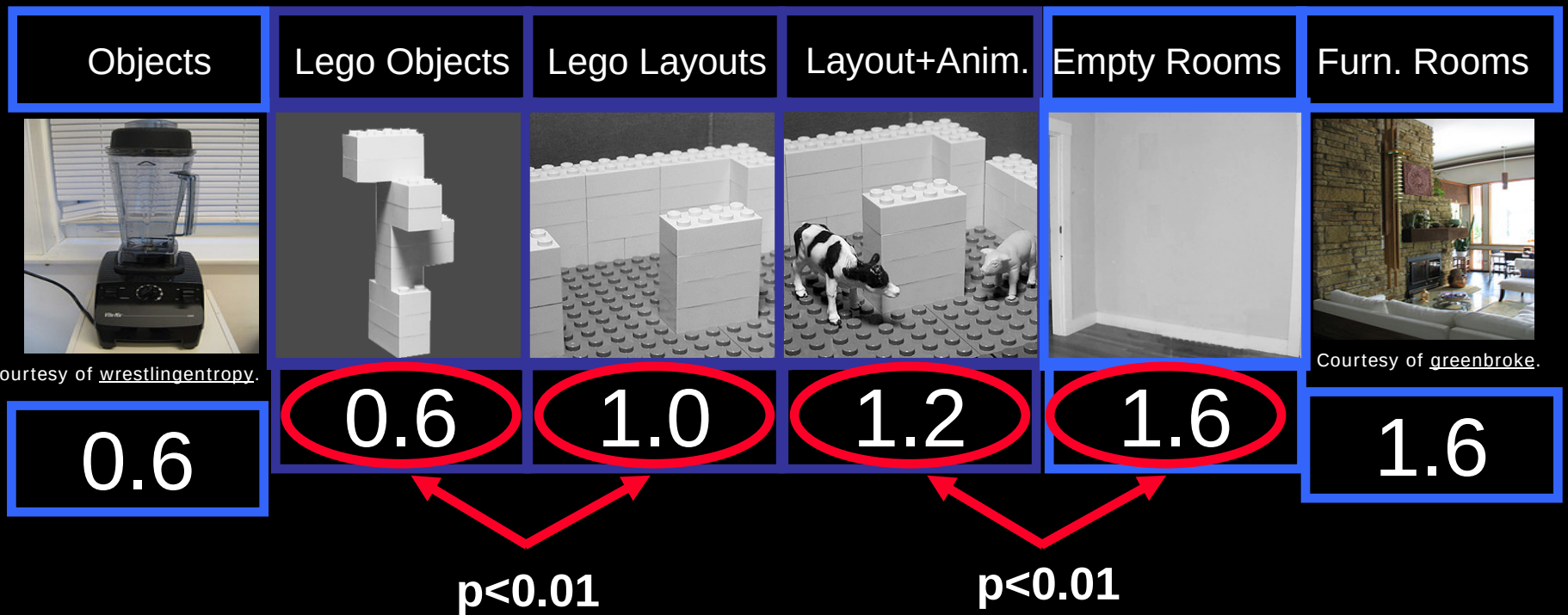
Objects	Lego Objects	Lego Layouts	Layout+Anim.	Empty Rooms	Furn. Rooms
 Courtesy of wrestlingentropy.					 Courtesy of greenbroke.
0.6	0.6	1.0	1.2	1.6	1.6

p<0.01

Yes: The PPA is strongly activated by spatial layouts that do not represent real places in the world.

Experiment 4 Results

Avg. % signal change in PPA (N=6):



Yes: The PPA is strongly activated by spatial layouts that do not represent real places in the world.

However, PPA response is even greater to real scenes.

Experiment 5

Question: Is the PPA involved in the recognition of a 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.

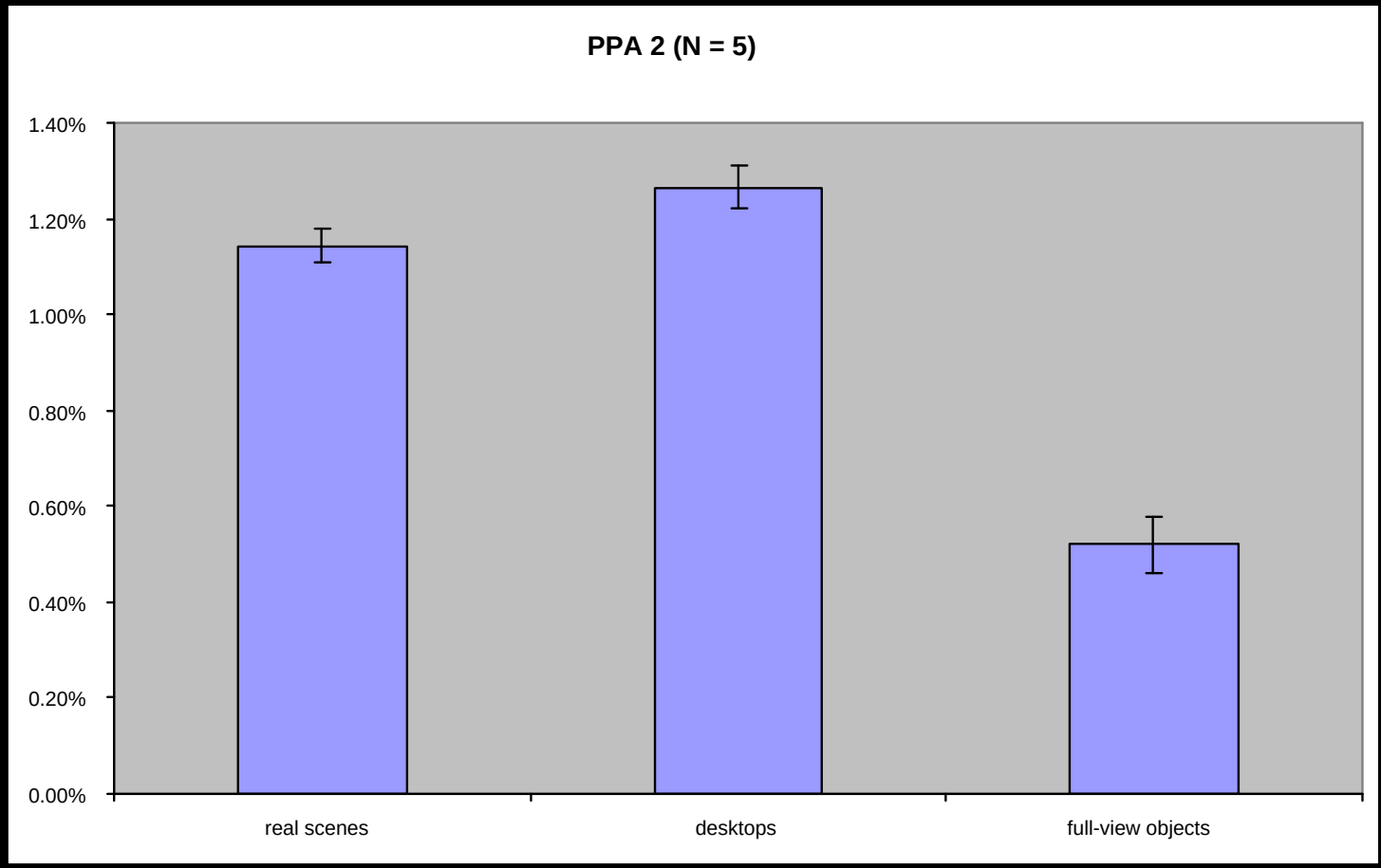
Conclusion: The PPA does not conduct semantic or other postrecognition processing on scenes.

Experiment 6

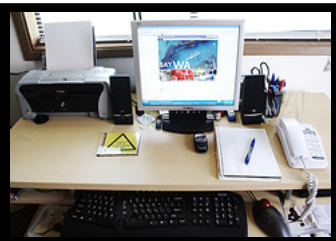
Question: Is the PPA involved in planning navigation?

To Test: Examine the PPA response to places you cant navigate in: “desktop scenes”.

Experiment 6: The PPA responds as strongly to tabletops as to “full” scenes.



Courtesy of Per Ola Wieberg.



Courtesy of Living Juicy.

Courtesy of independentman.

Experiment 6

Question: Is the PPA involved in planning navigation?

To Test: Examine the PPA response to places you cant navigate in: “desktop scenes”.

Result:

Response is just as high for tabletop as “real” scenes.

Conclusions:

The PPA is not specific to navigational planning..

Summary of Exps. 1-6

Exp. 1 There is region of parahippocampal cortex that responds selectively and automatically to scenes.

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

Exp. 3 When the surfaces of the scenes are rearranged so that they no longer define a coherent space, the response is significantly reduced.

Exp. 4 Response to layouts is strong even if they do not represent real places in the world.

Exp. 5&6 The PPA does not respond differentially to familiar & unfamiliar scenes, or to navigable versus non-navigable scenes.

The PPA analyzes the shape of the local environment.

Unanswered Questions

What exactly does the PPA *do* with scene information?

- what information does it represent?
- what tasks is it engaged in?
  - just seeing spatial layout?
  - scene *recognition* (specific versus general?)?
  - navigation? (construed broadly? web "navigation"?)
  - other?
- what functions would you lose if you did not have a PPA?

What about those other scene-selective regions?

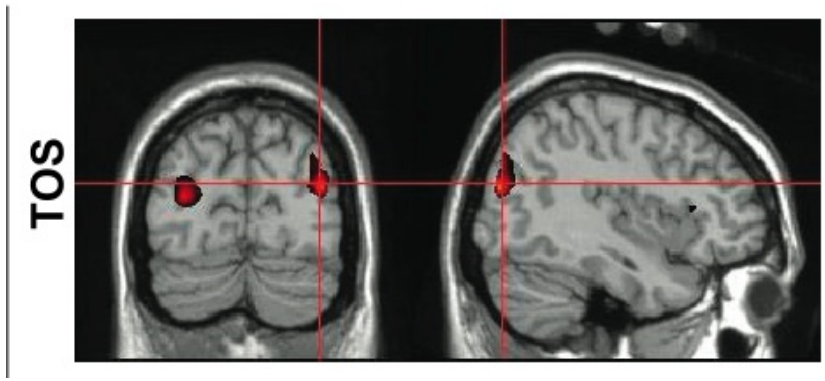
- are they functionally different from the PPA? How?

[How] do these regions interact with each other and the rest of the brain?

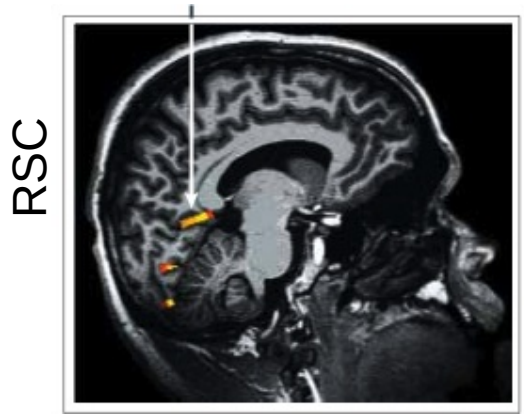
Beyond the PPA

- There are **three** contiguous brain regions that you find which have greater activity for scenes than objects:

Parahippocampal Place Area



Transverse Occipital Sulcus



Retrosplenial Cortex

Presentations

1) Are scenes processed differently from objects in the brain?

   Yes! There is an area called the PPA that selectively responds to scenes and not objects.

   What about the other scene selective areas you mentioned?

   Epstein et al, 2007. Presented by Christina.

2) Is there evidence that scenes and objects are processed in different parallel pathways in the brain?

   Steves et al. 2004. Presented by Jess.

3) What is the role of the PPA in during navigation?

   Janzen & van Turennout 2004. Presented by Steve.