Vision and Action

Our ability to move thru our environment is closely tied to visual perception. Simple examples include standing one one foot. It is easier to maintain balance with the eyes open than when closed. More complex examples include riding a bicycle on city streets or a mountain trail or driving a car.

Vision is also involved in flying a plane, particularly when taking off or landing. It was a consideration of this situation that led J. J. Gibson to develop his ecological perspective on perception.

Questions

Some questions that we will address:

1. What is an invariant and how are they used in perception?

2. How does the observer use information about motion to guide action?

3. What are some of the elements in vision that guide navigation?

4. Do the control of action and the perception of action share neural mechanisms?

The Ecological Perspective

In the ecological approach, as described by Gibson, the concern is for perception in the natural environment

1. The stimulus is described in terms of information in the environment as it projects onto the retina - the optic array.

2. Important information for perception is created by movement of the observer.

3. Motion and the optic array lead to invariant information (cues that remain constant).

4. Invariant information leads directly to perception.

Ecological Perspective - 2

This diagram shows the sequence of steps in Gibson's proposal. It is often referred to as "direct perception" since perception is based on invariant qualities extracted directly from the optic array.

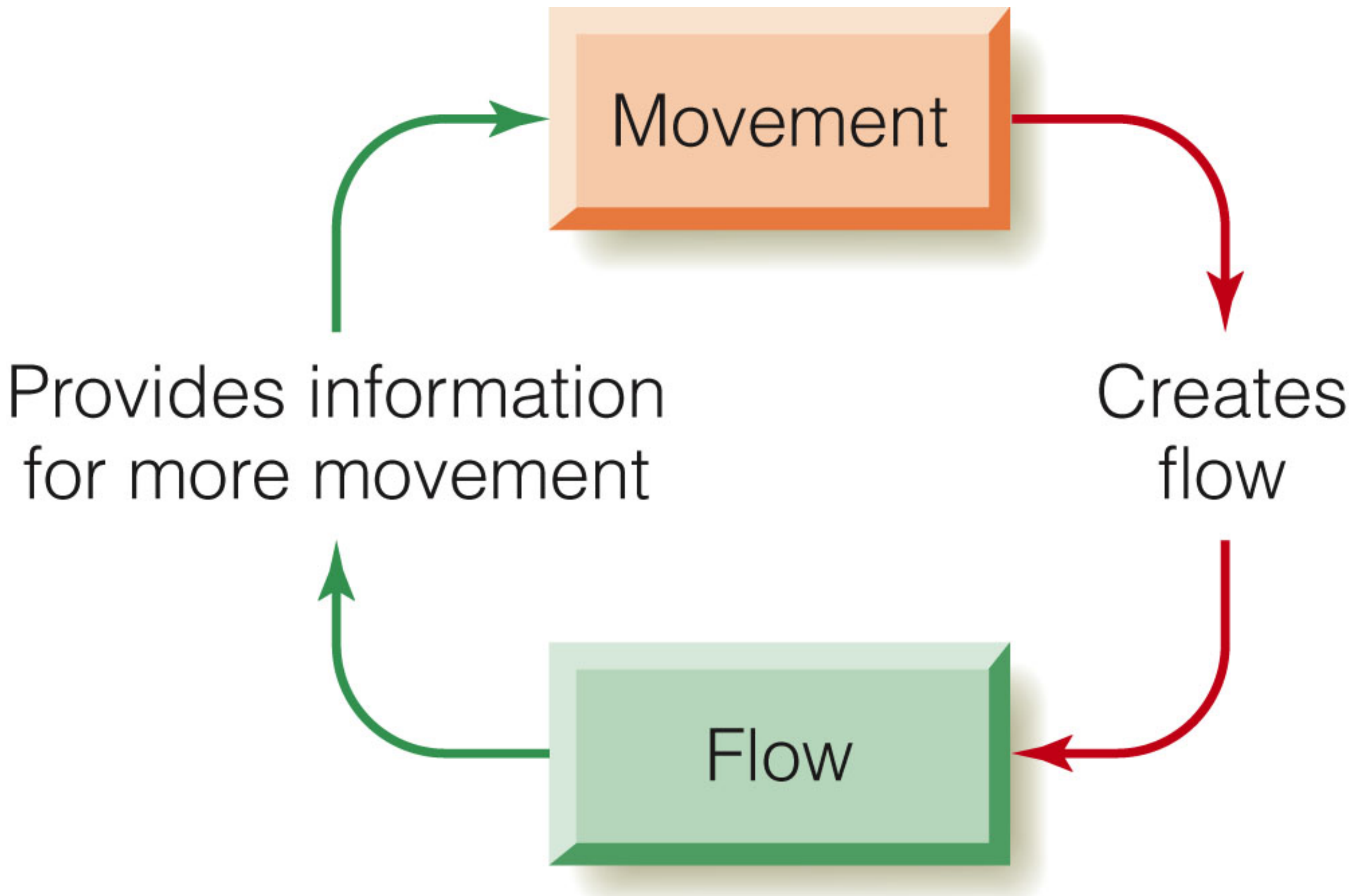
The Optic Array

The optic array is the pattern of light that falls upon the retina. Gibson emphasized the rich source of information about the external world carried by the optic array. Gibson used projective geometry to describe how light from a 3-D world is reflected onto the 2-D surface of the retina. Based on this analysis, he then emphasized that perception involves the extraction of qualities that are invariant in the optic array. These qualities stay the same even when the observer's vantage point changes.

Observer Motion

A second key element to the Ecological Perspective is that the observer is usually moving relative to the visual world. Even if standing still or sitting, we are often moving our head or our eyes. While the image on the retina changes, some properties of the optic array remain constant - invariant. These are the critical aspects of the optic array on which perception is based.

We refer to the change in the position of objects, edges, etc. on the retina because of motion as optic flow.


Movement
Creates flow
Flow
Provides information for more movement

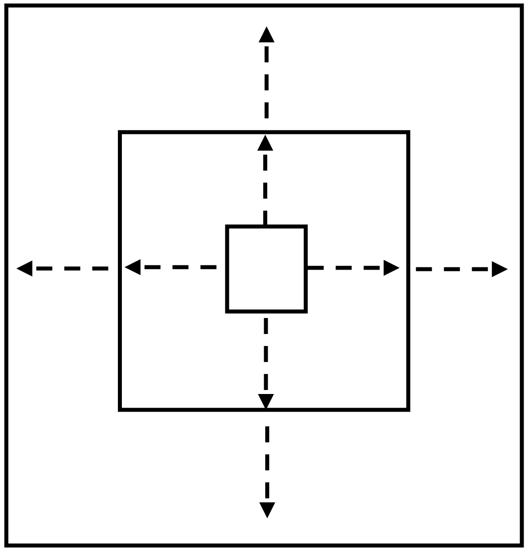
Movement and Motion - Optic Flow

What is the information that the observer uses in the optic flow pattern to judge motion and coordinate their own movement?

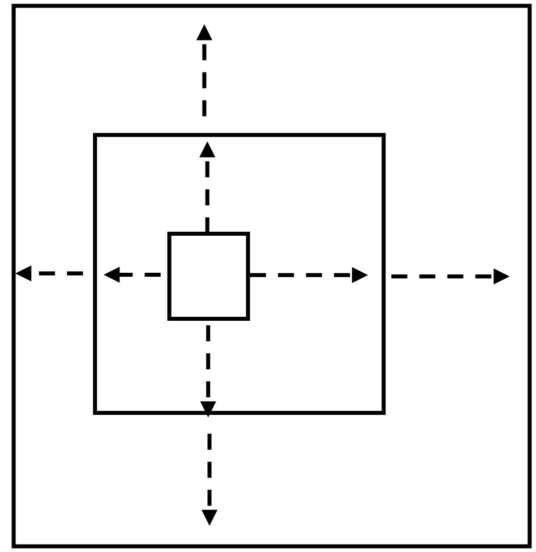
One possibility, proposed by Gibson, is the **focus of expansion**. If you are moving, then the focus of expansion is the point you are moving toward. It stays stationary on the retina (if you look at it) while the rest of the optic flow is outward to the periphery. If you were to periodically look at this point, you could use it to navigate to that particular point.

Focus of Expansion

(a)



(b)



Rate of angular expansion. As an object gets closer, its image size on the retina expands. If all edges expand outward uniformly, you are heading straight for it (a). If one side expands more rapidly, you are heading to one side of the object (b). This works in reverse for objects moving away from the observer.

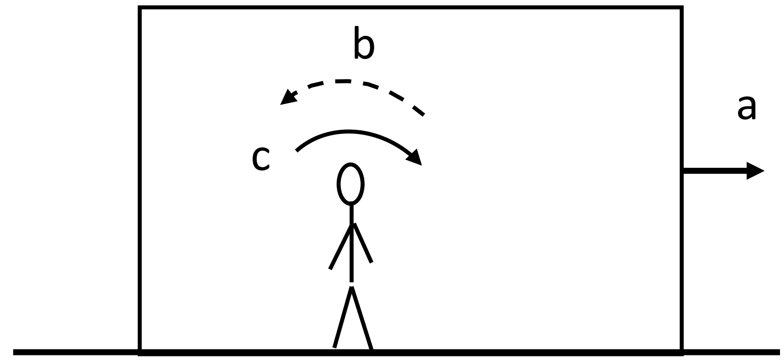
Focus of Expansion - 2

The focus of expansion is an invariant (as is the rate of angular expansion). It indicates where the observer is headed or how an object is moving toward the observer.

Gibson proposed that if you are moving, then the focus of expansion is the point you are moving toward. It stays stationary on the retina (if you look at it) while the rest of the optic flow is outward to the periphery. If you were to periodically look at this point, you could use it to navigate to that particular point.

Motion and Balance

The influence of motion perception on balance can be demonstrated experimentally using a room or display where the walls move (a). Observers react as if they were leaning in the opposite direction (b) and try to compensate (c).



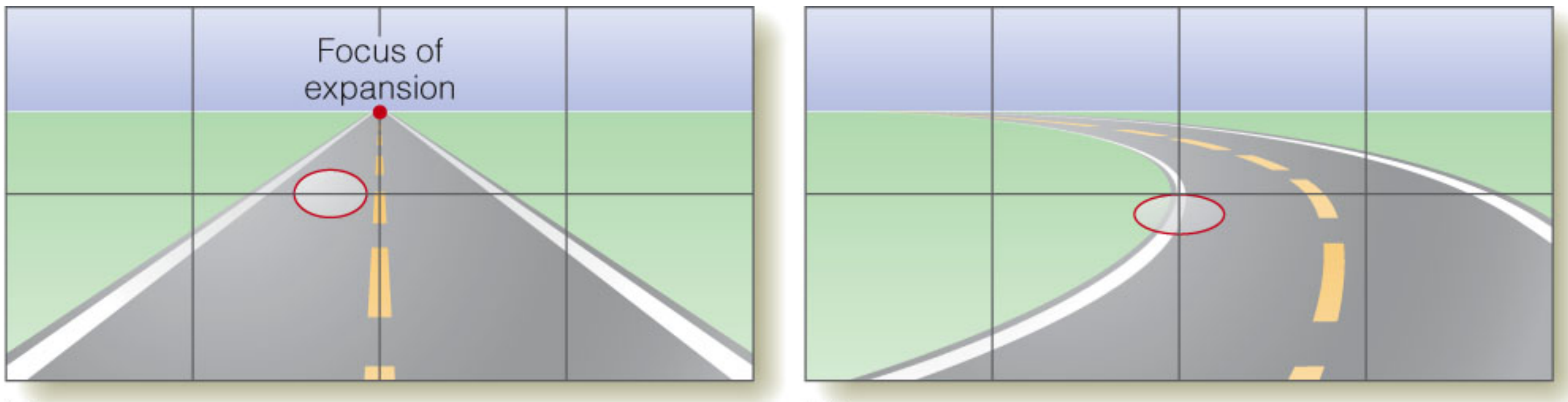
If this experiment is done with 13 to 16 month-old toddlers, fully 33% fall down while about half sway or stagger.

Motion and Driving

If we monitor eye movements and where a person is looking while driving, they do *not* look at the focus of expansion.

On a straight stretch of road, their focus is on the vehicle ahead or on the oncoming lane (see panel a in next slide).

On a curve, their focus is often on the edge of the road (panel b).



(a) (b)

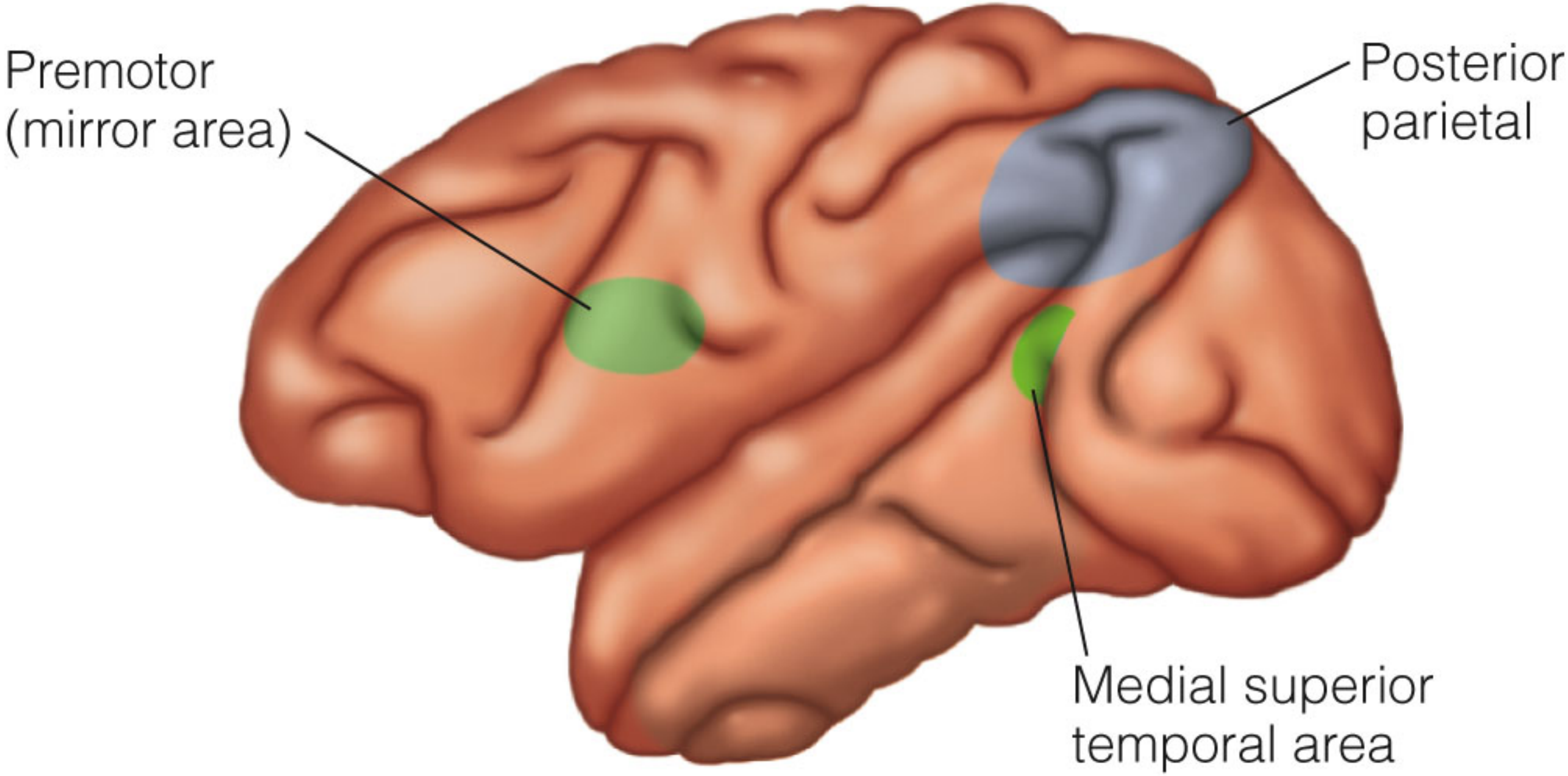
Optic Flow in Driving

If the optic flow matches edges in the image then you are moving parallel to those edges. This would allow a driver to drive straight or turn and follow a curve. The driver simply has to keep the optic flow parallel to the edges of the road or the lane stripes.

Optic Flow

The rate of angular expansion also indicates the speed that the observer and object are approaching. Observers can use this to estimate the time to collision. Observers *underestimate* this time, but their estimates are proportional to the actual time.

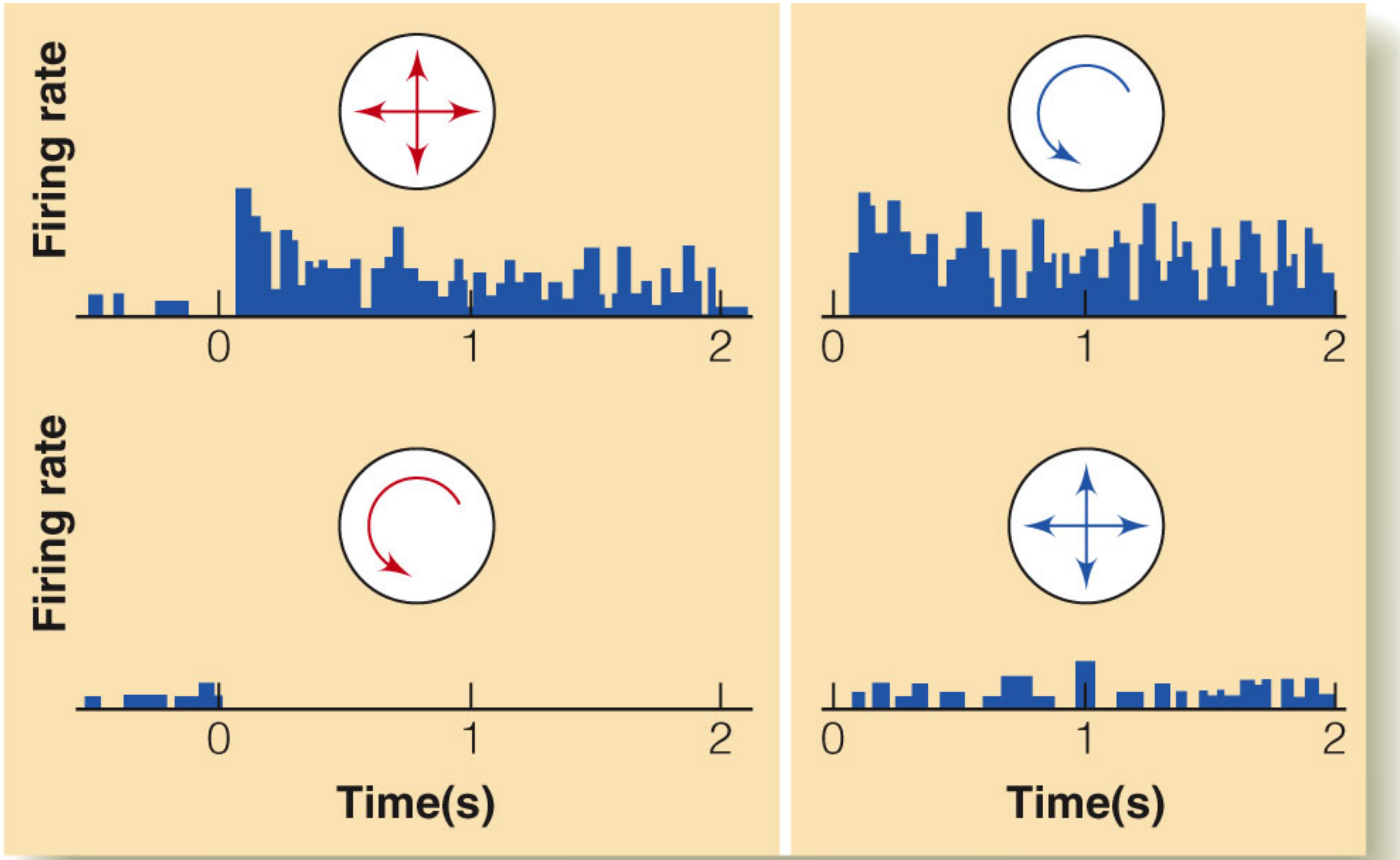
In the medial superior temporal area (MST) of monkey cortex, there are neurons that respond to rate of angular expansion. If a pattern of dots expands outward, a neuron would respond. Other patterns of movement did not cause the neuron to respond. Other neurons in MST respond to other patterns of motion.


Premotor
(mirror area)
Posterior
parietal
Medial superior
temporal area

Motion Neurons in MST

In the next slide, in panel a, on the left, the response of a neuron in MST is shown to a display of dots moving outward (flow as if observer is moving toward an object) on top and rotational motion (on the bottom). This neuron responds to expansion, but not rotation (or other motion).

On the right (panel b) is the response of a different MST neuron. It has a strong response to counter-clockwise circular motion, but not to expansion.



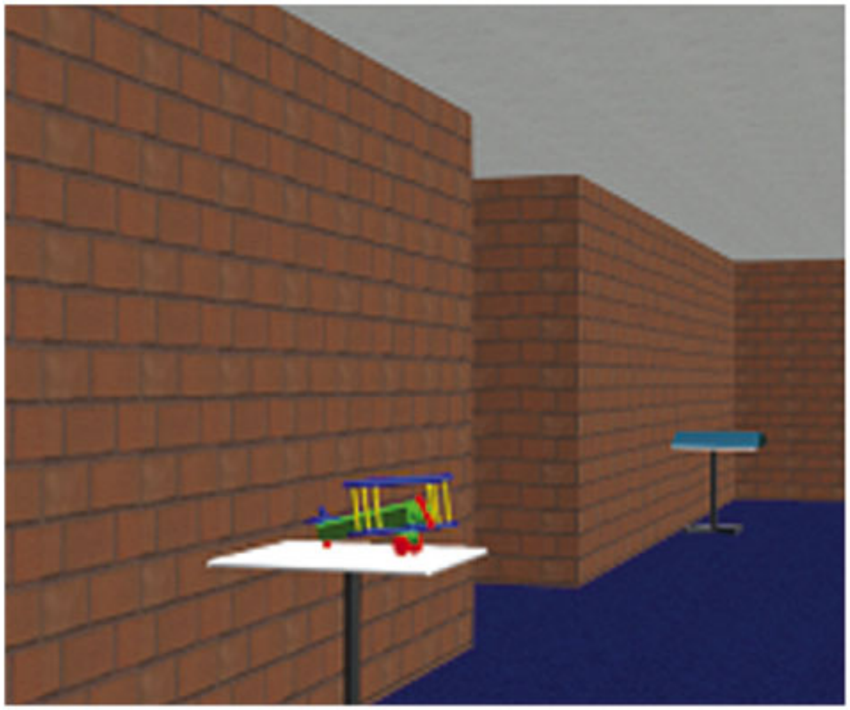
(a) Neuron 1
(b) Neuron 2

Navigation

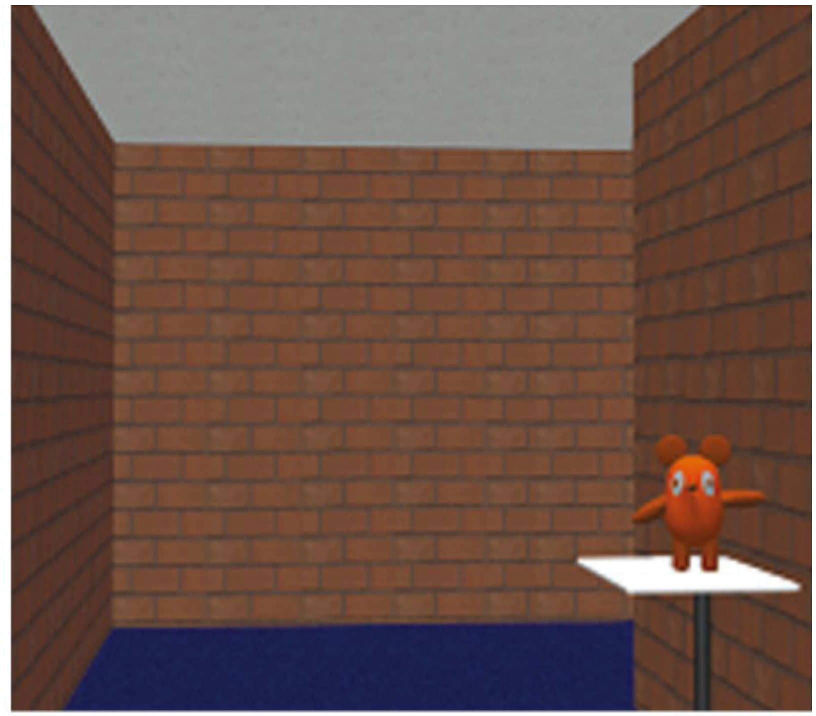
In order to navigate thru the environment, we use "landmarks" in addition to optic flow information. This will be dependent on memory.

We start by having observers watch an animated movie that shows a path thru a virtual building. In the hallways of the building are objects (toys): some occur at points where there are alternative paths, some occur at other locations.

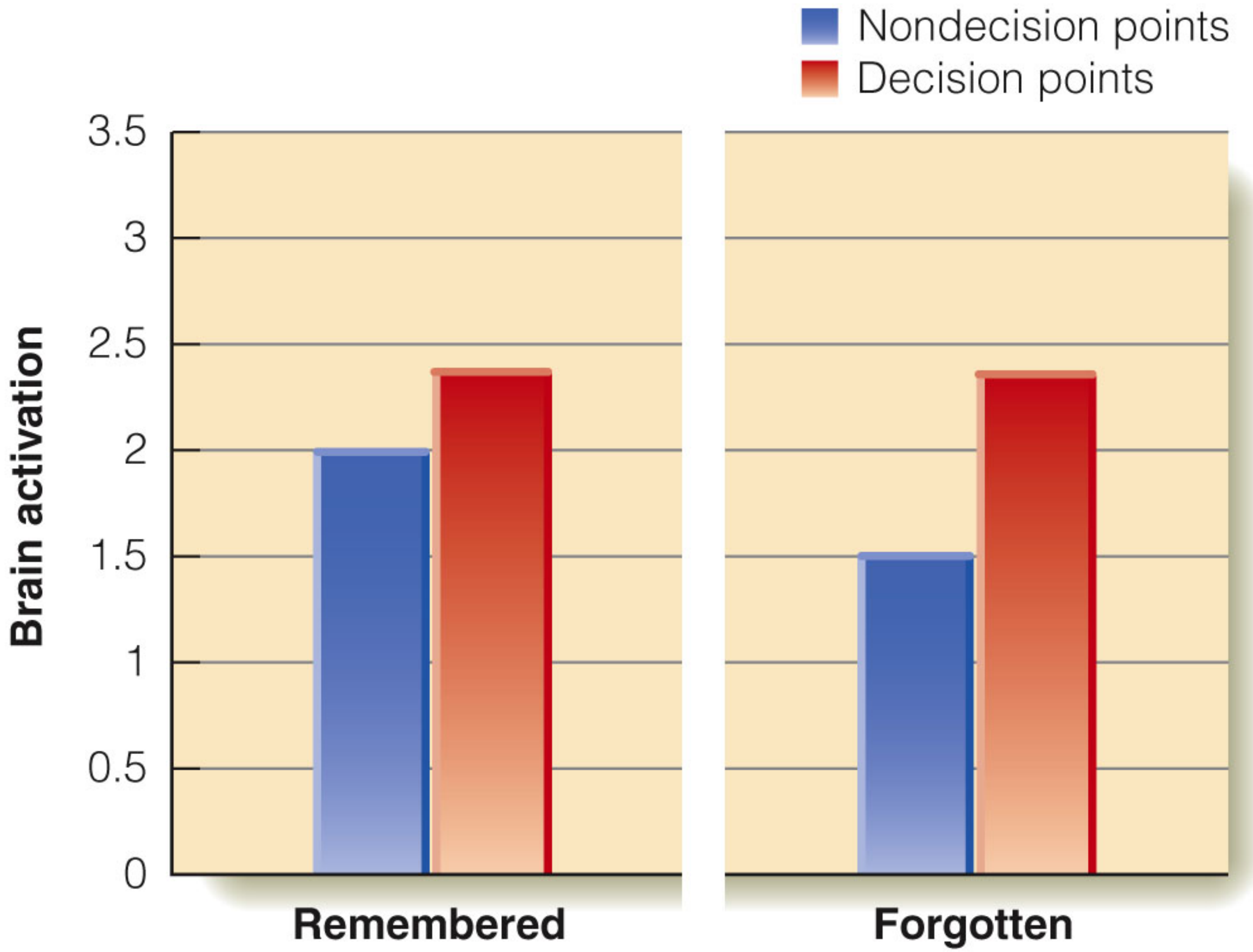
Later, observers get a recognition memory test for toys in the movie and we use fMRI to see their brain activation in the right parahippocampal gyrus.



(a) Toy at decision point



(b) Toy at nondecision point


Nondecision points
Decision points
3.5
3
2.5
2
1.5
1
0.5
0
Brain activation
Remembered
Forgotten

(c)

The results show that activation was higher for objects at decision points (landmarks) than for other objects. This occurred even when the observer was incorrect in recognizing the object (saying "no" to one that they had seen previously, panel on right in previous slide).

Thus, memory contained two types of information – that an object had been seen before and that an object was part of a path or route.

Reaching and Grasping

Vision is also used to control reaching and grasping an object. Gibson describes this process as involving *affordance*.

Affordance is a property of the object related to how we can interact with it. An area (GEON) of an object that is the size and extent that it fits the hand is an affordance for grasping.

Object Recognition versus Object Manipulation

Recall that one of the neurological disorders that we previously described is a person with temporal lobe damage (in the ventral visual pathway) that results in difficulty naming objects.

An individual (M.P.) with this damage was tested on object recognition in two different ways. He saw a series of pictures and was asked to press a button when he saw:

a) a cup
b) an item you could drink from

M.P.

M.P. was faster and more accurate in identifying the picture of the cup when given it's functional description.

This indicates that the processing of and recognition of the function of something (its affordances) is at least partly separate from the ability to name the object.

Reaching and Brain Activity

A monkey is taught to reach for a blue square when is is present on a screen. Then it is taught that if the blue square turns red, to wait, it will turn blue again after a delay and they can complete the task.

If the blue square turns green, they are to stop reaching and just watch the square.

Neurons in the posterior parietal area were found that were active both when the monkey was reaching for the blue square and while the monkey was waiting to reach (but not while just looking at the square).

Reaching and Brain Activity - Human

Analogous experiments done with humans and fMRI show that increased activity is present in the parietal area that controls reaching. The activity is present when reaching or when "planning" to reach (when a signal is presented).

Mirror Neurons

There are neurons in the pre-motor area that fire when the monkey reaches for and grasps an object (e.g. a peanut). They also fire when the monkey “sees” the researcher’s hand reach for and grasp the peanut. These neurons do not fire for other objects interacting with the peanut (e.g. watching the researcher pickup the peanut with a pair of pliers).

These neurons are called mirror neurons.

Mirror Neurons - 2

There are also audio-visual mirror neurons that respond both for an action and to hearing the sound associated with the action (see Figure 7.18 in text).

The corresponding area of cortex in humans shows enhance activity for both performing an action and watching it performed. In addition, this response is stronger for actions that the observer is, themselves, familiar with performing.

Mirror Neurons - 3

What role do mirror neurons play in perception and action? Might they be related to our ability to interpret peoples intentions or anticipate the behavior of others?

Could they have a role in the recognition of action? That is, do we "understand" an action by virtue of our own ability to carry it out? Or, is this simply a part of memory for actions?

Where Next?

The role of mirror neurons, and the complex interactions among areas of the cortex in tasks involving action, are only partly understood.

However, they are understood well enough to use EEG ("brainwaves") to allow an observer to control actions by thought. This may lead to devices that allow a paralyzed individual (spinal chord damage) the ability to interact with the environment, including the control of their own limbs.