Motion Perception

- The perception of motion is a key element of visual perception since both objects in the environment and the observer can move. Motion perception is essential to muscle control and movement.
- Illusions of motion include "motion pictures" and the motion of a pigeon's head when it walks. These illusions offer us a way to probe the nature of perception.
- Motion perception involves specialized neural mechanisms (motion sensitive cells), brain areas (MT, MTS) and pathways (dorsal).

Motion Agnosia

As an illustration of our dependence upon motion perception consider the disorder known as motion agnosia. Individuals with this usually have damage to a part of the cortex in the dorsal pathway (area MT in the primate).

The individual is "blind" to motion. In a crowded room with people moving around, their experience is a series of snapshots, with people changing location instantaneously. They can not cross the street easily since they can not "see" a car approaching. Even pouring liquid into a glass can not be done visually.

The Information Provided by Movement

1. Movement attracts attention. Detecting motion in peripheral vision usually triggers an eye movement to "see" the object.

2. Movement provides information about shape, size and depth. The change in perspective causes accidental properties on the retina to change while invariant properties remain (ecological perspective).

3. Motion helps separate figure from ground.

4. Movement and motion perception are essential for interaction with our environment.

The Stimulus for Motion Perception

There are numerous situations that lead to motion perception. So, the first question is that of the proximal stimulus. A key point here is that movement of an image on the retina is *neither necessary nor sufficient* for the perception of motion.

Motion on the retina can be caused by:

1. The movement of the physical object.

2. The movement of the observer or the observer's head.

3. The movement of the observer's eyes.

The Stimulus - 2

An object can be stationary on the retina because:

1. The physical object is stationary.

2. The object and the observer are moving together.

3. The observer is tracking a moving object (smooth pursuit movement of the eyes to maintain a stationary image on the retina).

Motion perception must sort these out to recover a percept that corresponds to the distal stimulus (physical world).

Illusions of motion

There are also forms of illusory motion.

1. **Stroboscopic motion**. A type of apparent motion. A series of stationary images can generate the illusion of motion.

2. **Motion aftereffect**. Sustained viewing of motion in one direction can cause stationary objects to appear to move in the opposite direction.

3. **Induced motion**. Related to the Gestalt notion of Figure and Ground. Motion of part of the background often results in the figure appearing to move in the opposite direction.

Illusions - Examples

Illusions of motion in the “real world” are common.

Induced Motion.

Observe a pigeon walk. The pigeon appears to move its head forward and backward as it walks. The actual motion is only forward. The pigeon extends the neck and moves the head forward. The head remains stationary as the body walks to catch up. Because the body is large, relative to the head, the head appears to move backward. This is **induced motion**.

Observe the moon on a partly cloudy, windy night. The moon appears to race past the clouds.

Illusion Examples - 2

Motion Aftereffect

Watch the water going down a waterfall. Fixate on one spot for 60-90 seconds. Then look at a stationary object. It will appear to move in the opposite direction.

This is a form of adaptation (like afterimages) that occurs in the neural processing of motion information.

Illusion Examples - 3

Stroboscopic (Apparent) Motion

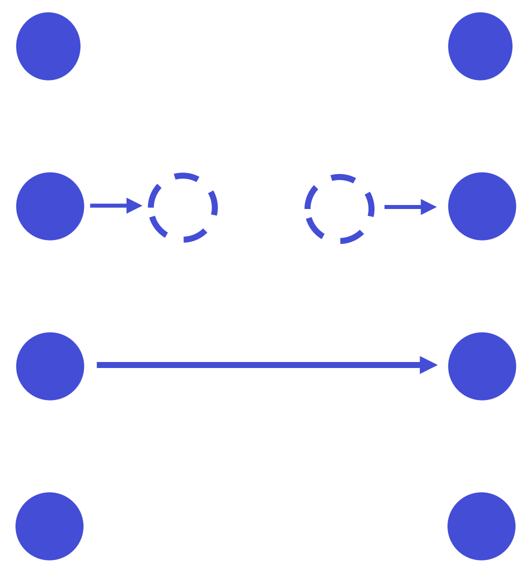
The traditional motion picture has no real motion. It is a series of still pictures. They are projected so that each is visible for a brief interval (about 30 msec at 30 frames per second). This creates the illusion of motion.

Illusions of this type have been central to our attempts to understand motion perception.

Apparent Motion

This table illustrates the percept for different displays

ISI	Time 1 Position 1	Time 2 Position 2	Percept
Less than 30 msec			simultaneous (no motion)
30 to 60 msec			partial motion
60 to 200 msec			smooth motion
More than 200 msec			successive (no motion)



Apparent Motion - 2

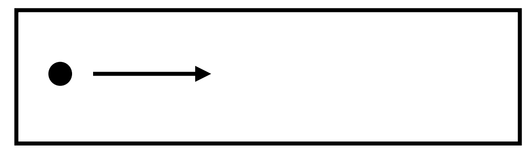
In addition to the timing between the flashes of the spot of light, the distance between the flashes is important.

If the distance is increased, then either the intensity of the lights must be increased, or the time interval between flashes must be increased to produce the illusion of smooth motion. However, if the time interval becomes too long (greater than 200 to 300 msec), no motion is seen.

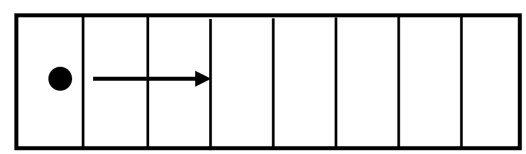
Real Motion - Thresholds

How slow can an object move and have its motion perceived?

Through a blank space, threshold is about 1/3 to 1/6 of a degree (visual angle) per second. When viewed from a distance of 1 foot, this is about 14 seconds to move 1 inch.



When there is more texture in the display, the slowest speed is 1/60 degree per second (280 seconds to move 1 inch at a 1 foot viewing distance).



Real Motion - 2

These threshold data show two important points.

1. We are quite sensitive to motion.

2. Motion perception is dependent upon the surroundings (texture gradient) against which it occurs.

Neural Mechanisms

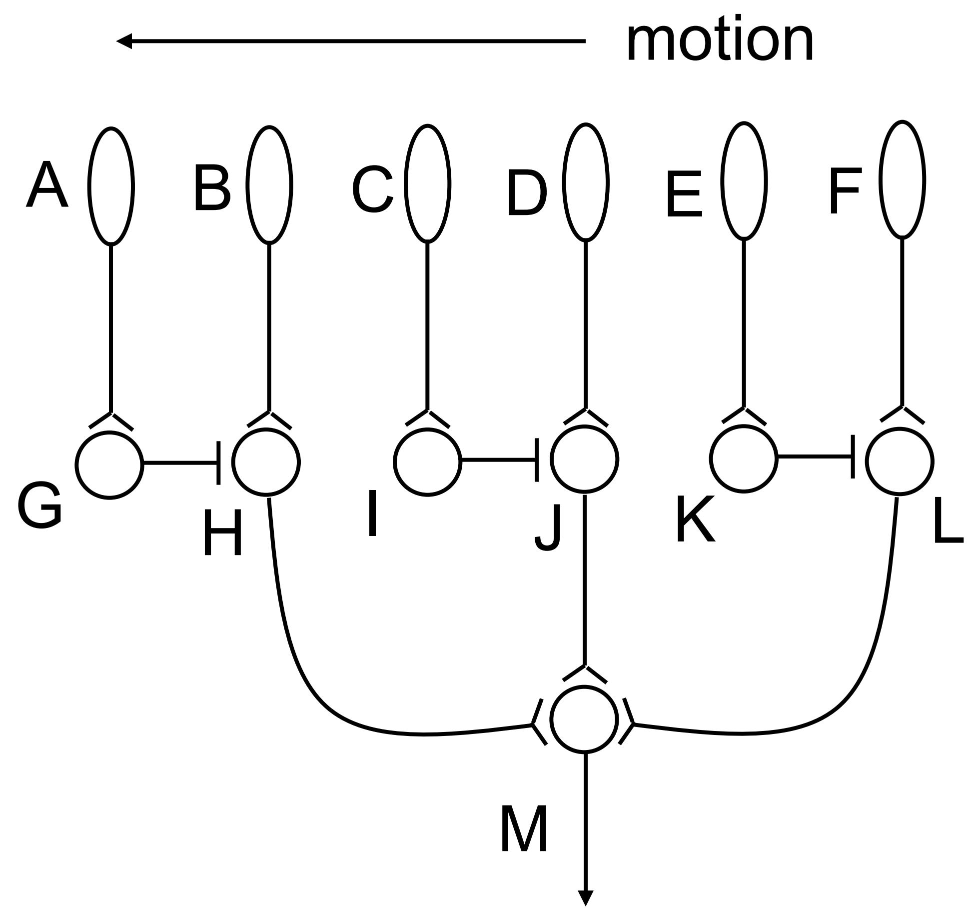
In examining the neural mechanisms involved in motion perception, we will look at two distinct systems.

1. The cells in the visual cortex and dorsal pathway and how they code the direction of motion.

2. How the brain uses eye movement information together with retinal information to determine what is moving and what is not.

Neural Wiring for Direction of Motion

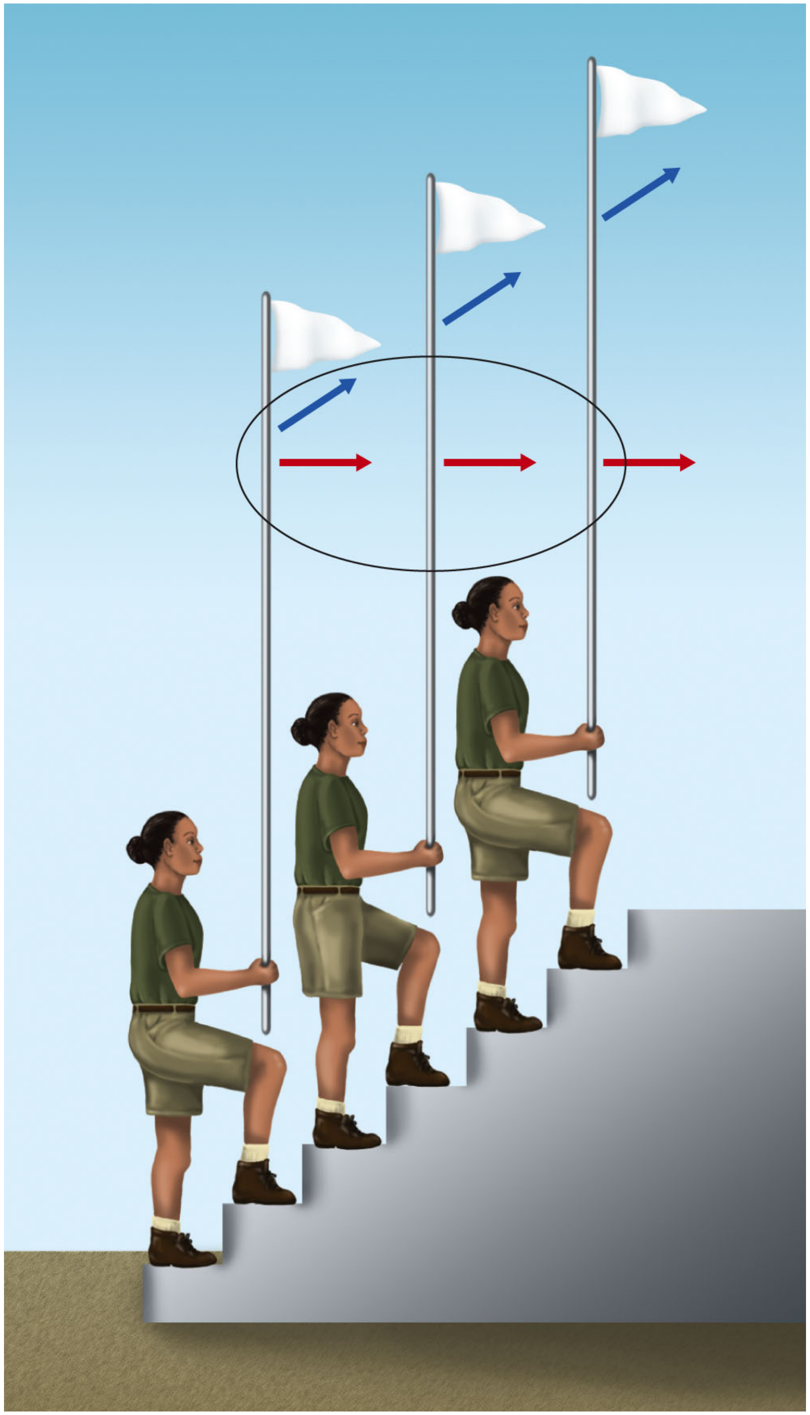
In the circuit shown at the right, as a light moves from right to left across the receptors (F E D C B A), cell M responds. For a light moving left to right, M does not respond. The result is that M is direction sensitive.

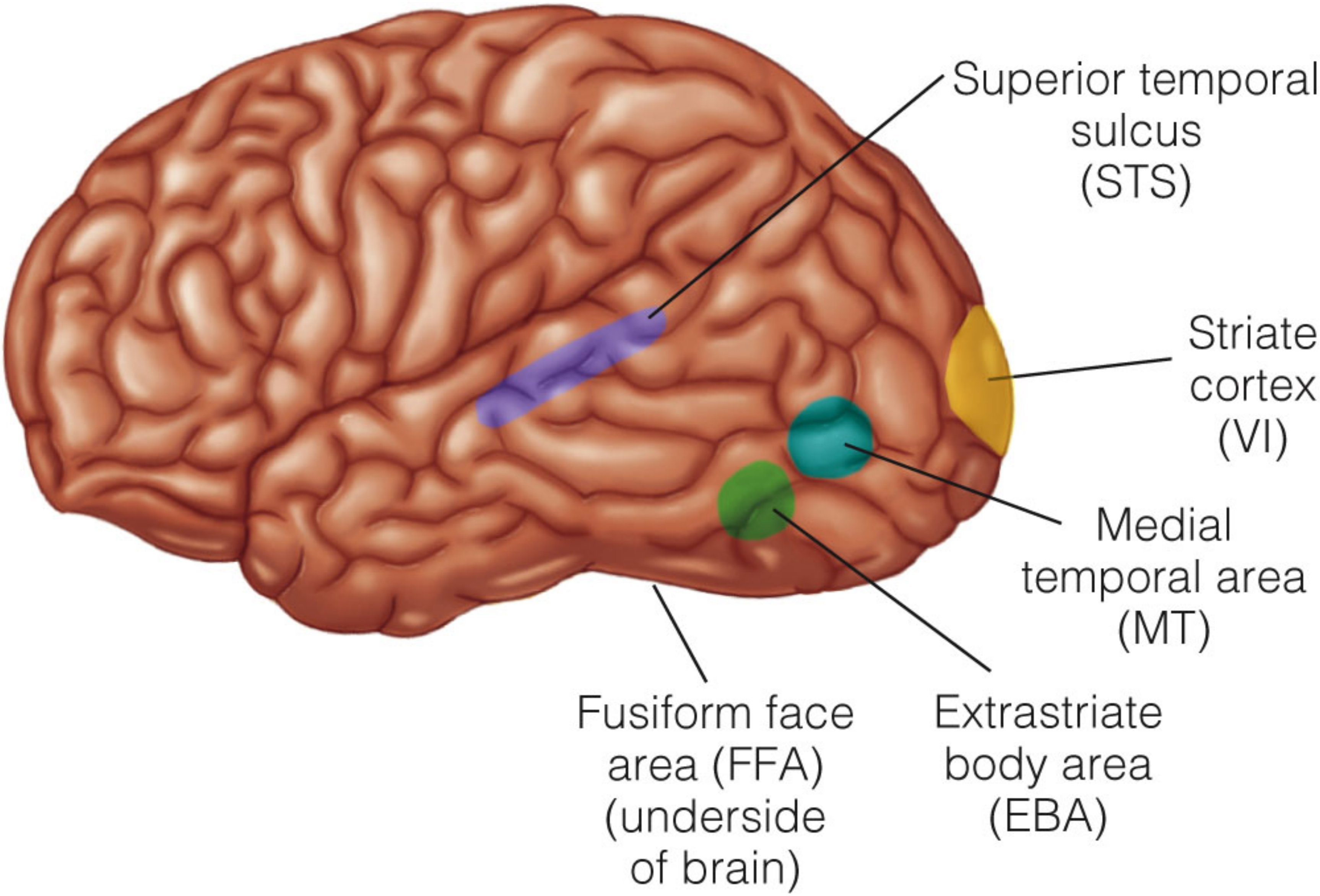


The Striate Cortex Motion Code

Complex cells and hyper-complex cells in striate cortex are orientation selective and respond to motion at a right angle to their orientation. The perception of motion, however, is likely to be based on the pattern of response across a set of cells responsive to different orientations and directions. This is because the response of a single cell is ambiguous. (See text for an explanation of the aperture effect.)

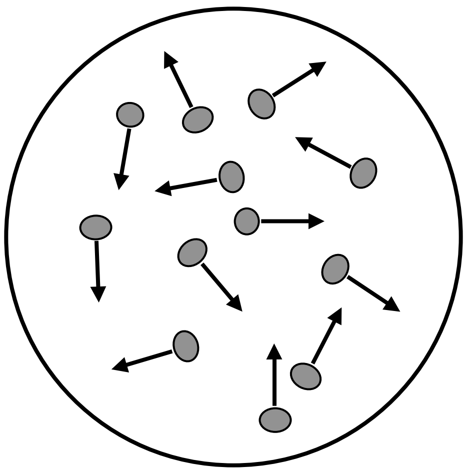
The cells further up the dorsal pathway are also involved in motion perception.



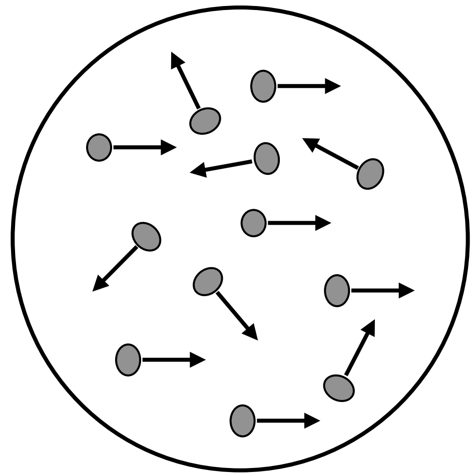

Superior temporal sulcus (STS)
Striate cortex (VI)
Medial temporal area (MT)
Extrastriate body area (EBA)
Fusiform face area (FFA) (underside of brain)

Area MT and Motion Perception

Displays of randomly arranged dots are presented. The number of dots moving in the same direction is varied. Single cell activity in MT and behavior are recorded.



Uncorrelated motion



50% correlated motion

MT and Motion Perception

When the motion of the dots was almost uncorrelated, MT cells did not respond. The monkey was at chance in determining motion direction. As dot motion became correlated, MT neurons firing rate increased. The monkey's accuracy in responding to motion direction also increased.

This strong relation between behavior and MT cell activity implies that the pattern of response across these cells may be directly responsible for motion perception.

MT and Motion Perception - 2

If area MT is lesioned, much greater coherence of motion in our random dot pattern is required for the monkey to respond to motion.

Microstimulation of MT cells while a monkey is viewing a moving dot display can alter their perception (as indicated by their behavior).

This strong relation between behavior and MT cell activity implies that the pattern of response across these cells may be directly responsible for motion perception.

A Problem - Eye Movements

So far, it appears as if retinal motion is the key element.

However, if an object moves and you move your eyes with it (track the object), the object is seen as moving in spite of the fact that its image is stationary on the retina.

Suppose the object is stationary and you move your eyes. The image moves on the retina but the object is seen as stationary.

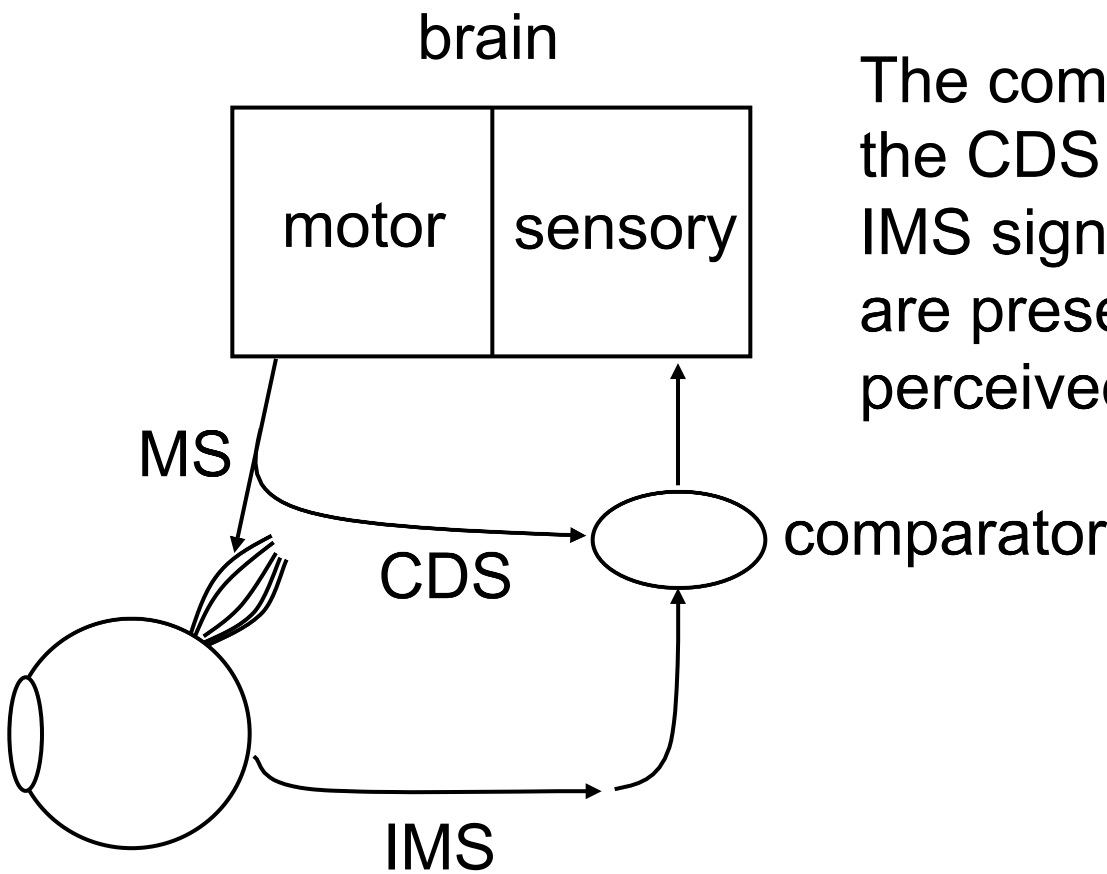
How does this come about?

Corollary Discharge Theory

Corollary Discharge Theory proposes that part of the brain (maybe the Superior Colliculus) monitors both the motor signal to move the eyes and the image motion signal from the eye. By comparing the two, it determines what is moving.

When only the motor signal or only the image motion signal is present, the object is moving. When both are present, the object is stationary.

Corollary Discharge Diagram



The comparator subtracts the CDS signal from the IMS signal. When both are present, no motion is perceived.

Corollary Discharge - Data

1. Stare at circle (see text figure 8.20) for 60 - 90 sec. Now, in a dark room, observe the afterimage as you move your eyes. It appears to be moving. The afterimage is stationary on the retina. The apparent motion is due to the corollary discharge signal (CDS).

2. Track a moving object (e.g., a person walking). You see them as moving even though their image is stationary on the retina. Again, the CDS is responsible. The background is moving across the retina but appears stationary. The background IMS (image motion) and CDS cancel one another.

Corollary Discharge Data - 2

3. What would happen if you tried to move your eyes (but they didn't move)?

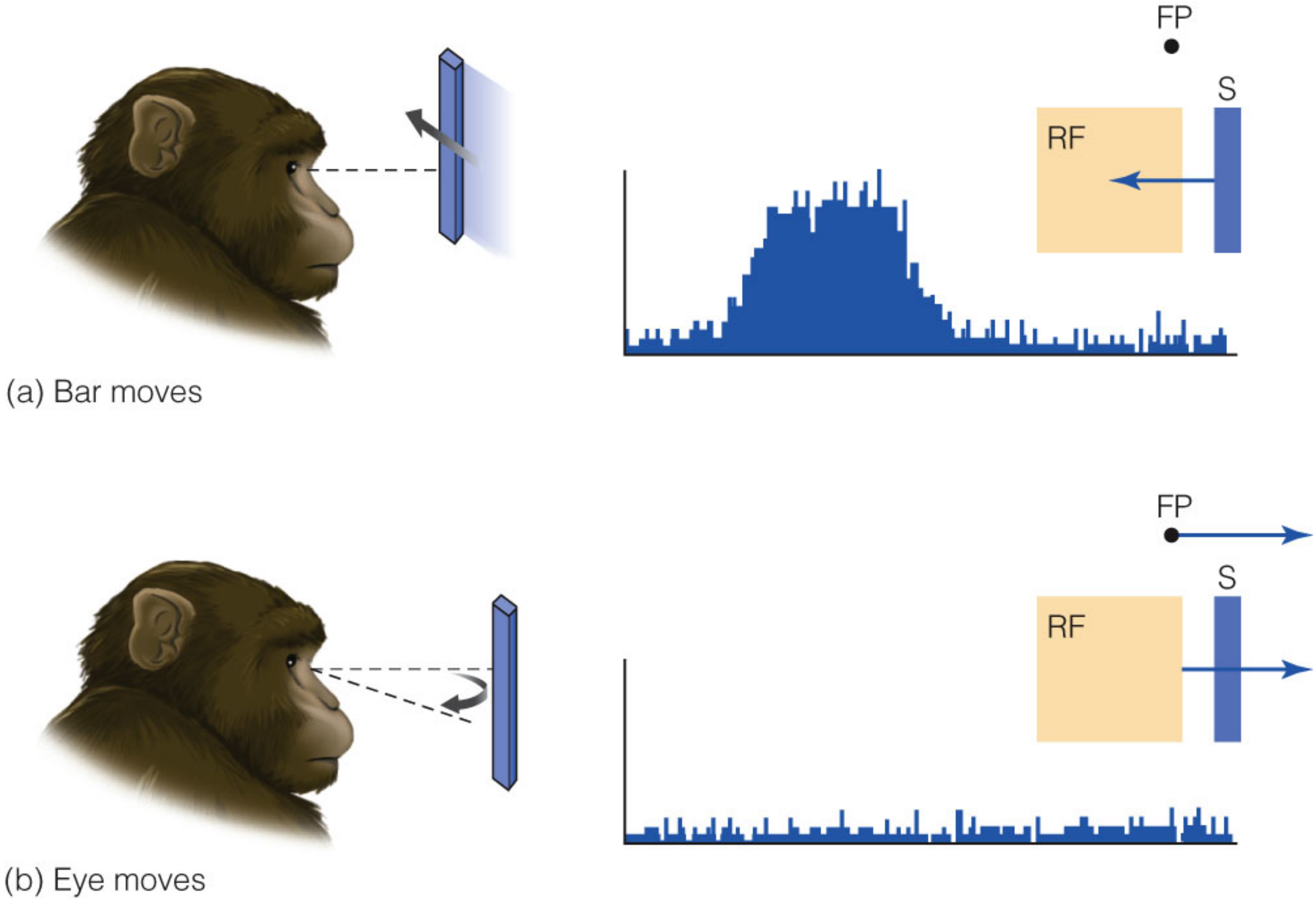
Observer had muscles paralyzed. When he tried to move his eyes, scene appeared to jump. This shows that it is not actual movement of the eyes. Rather, it is the motor control signal to move the eyes that is important.

4. If you push on the eye with your finger, the world seems to move (see text Figure 8.22).

Corollary Discharge - Physiology

We do not (yet) know the source of the corollary discharge signal or all of the neural structures that are involved.

We do have evidence of cells that respond to real motion and not retinal motion. In V3 (part of dorsal pathway), there are neurons that respond when an oriented bar is swept through their receptive field while the monkey holds its eyes steady. If we hold the bar steady and have the monkey move its eyes, then on the retina, the bar sweeps through the receptive field of the V3 cell. However, the V3 cell does not respond much differently than during baseline. This cell responds to *real* motion.


FP
S
RF
(a) Bar moves
FP
S
RF
(b) Eye moves

Ecological Information

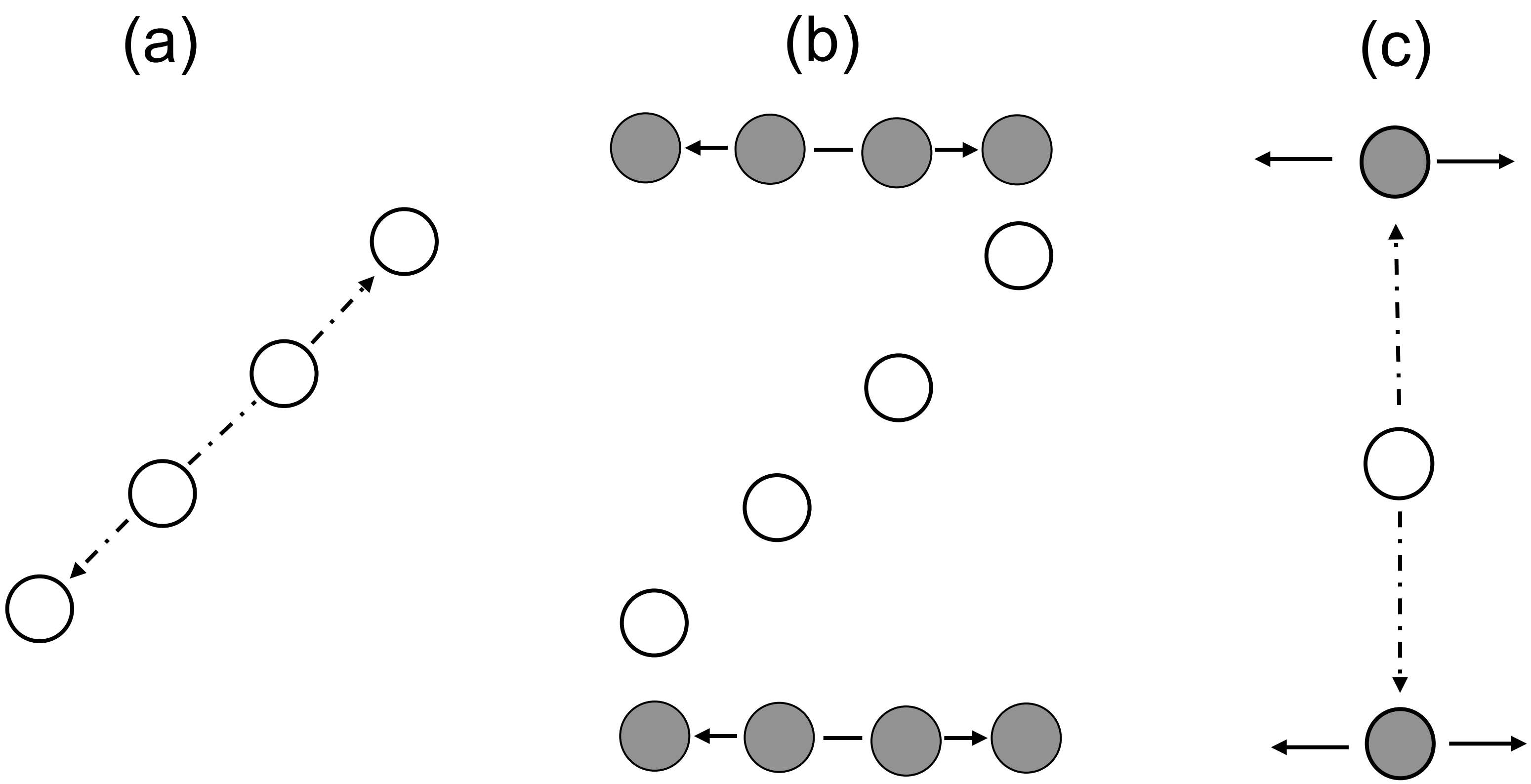
There is also environmental information about real motion.

1. Local motion. When an object moves, we have a **local motion signal**. Some parts of the visual world move while others do not (whether observer tracks object or does not).

2. Global Motion. When the observer moves, we have a **global optic flow**. All of the visual world appears to move, or flow, together.

In local motion, we get local accretion and deletion as the moving object covers and uncovers the background. In global optic flow, the changes are more uniform across the visual field.

Effects of Context on Apparent Motion



Motion and Context - 2

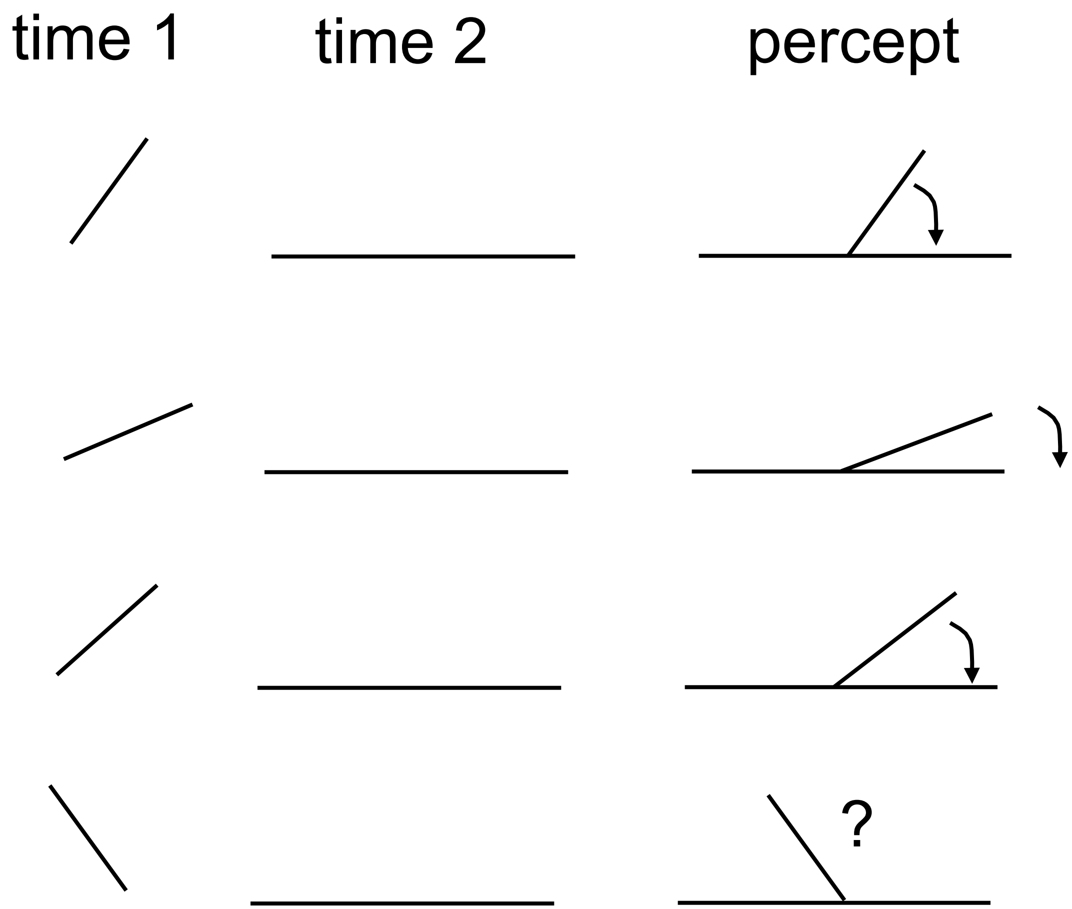
When the white dot moves alone, as in (a), it is seen as moving back and forth along a diagonal path.

When this same motion is accompanied by two gray dots moving horizontally with the white dot, as in (b), the observer reports that the white dot is moving up and down, as if bouncing between the moving gray dots as shown in (c).

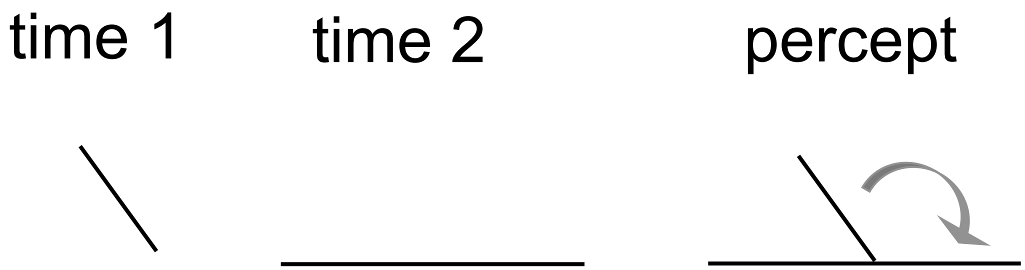
The perception of motion has been altered by the context in which it occurred.

Motion and Context - 3

The sequence at right is seen as moving clock-wise. This is the shortest path for motion. A whole sequence of these are presented to the observer, followed by the bottom sequence.



Motion and Context - 4

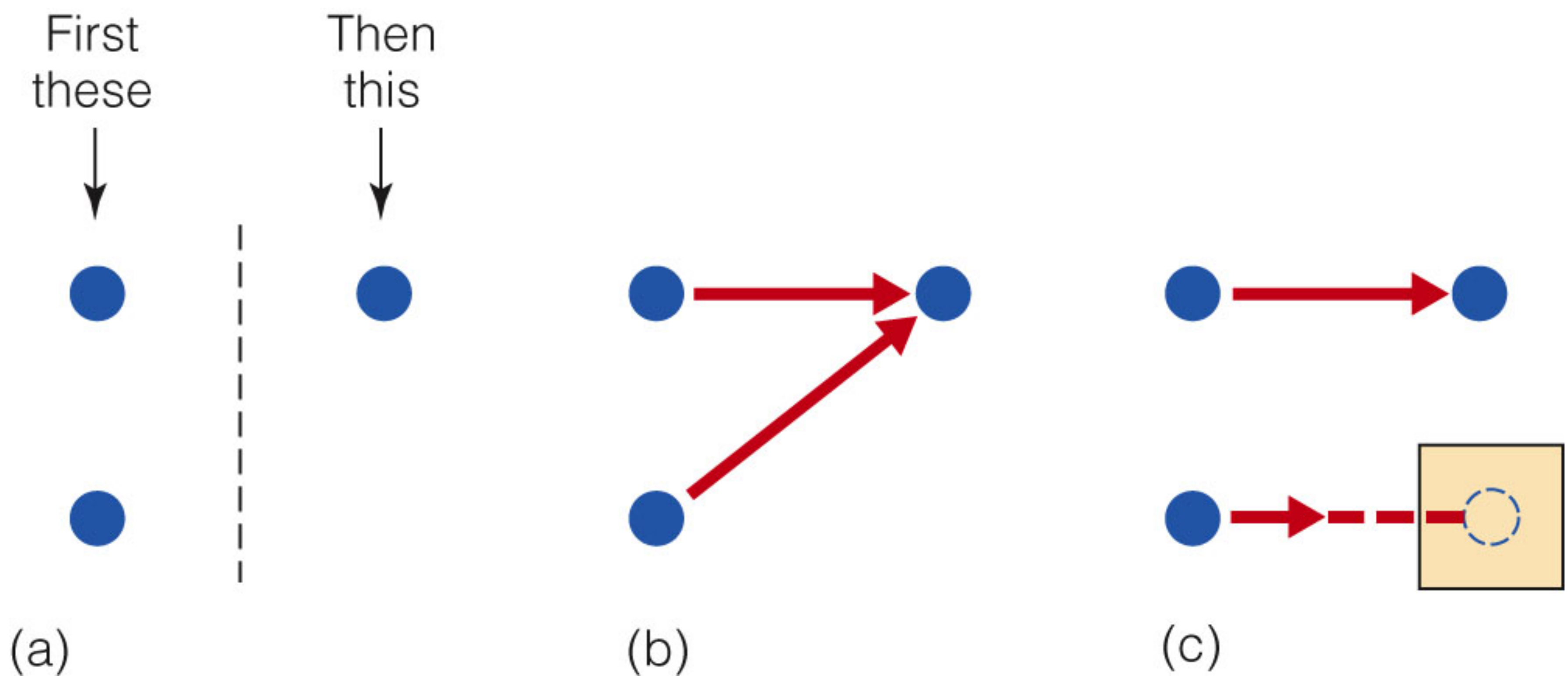


In this case, the perceived motion is through the longer path. This is the same direction as the previous displays. The context (previous displays) has affected the perception of this display and resulted in motion that does not follow the shortest path.

Motion and Context - 5

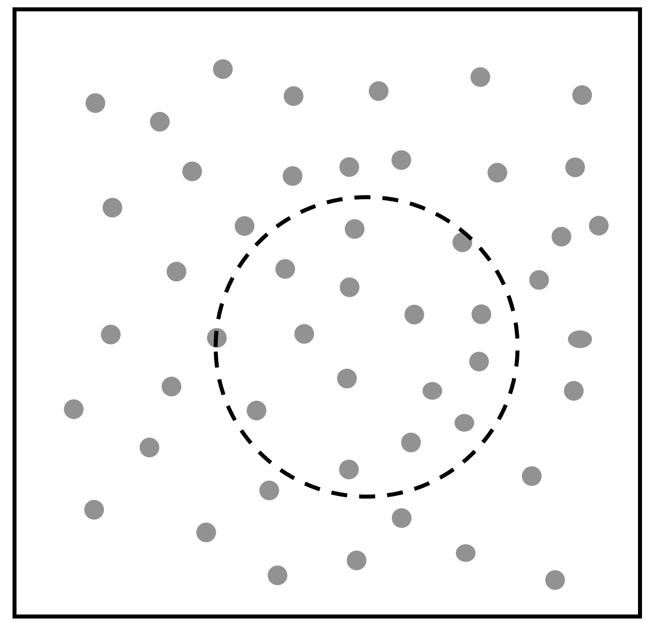
In the next slide, the perception of motion is shown to depend upon the presence of other "objects" in the world.

The motion in panel (c) obeys Gestalt simplicity and shortest path constraints.


First
these
Then
this
(a)
(b)
(c)

Motion and Form Perception

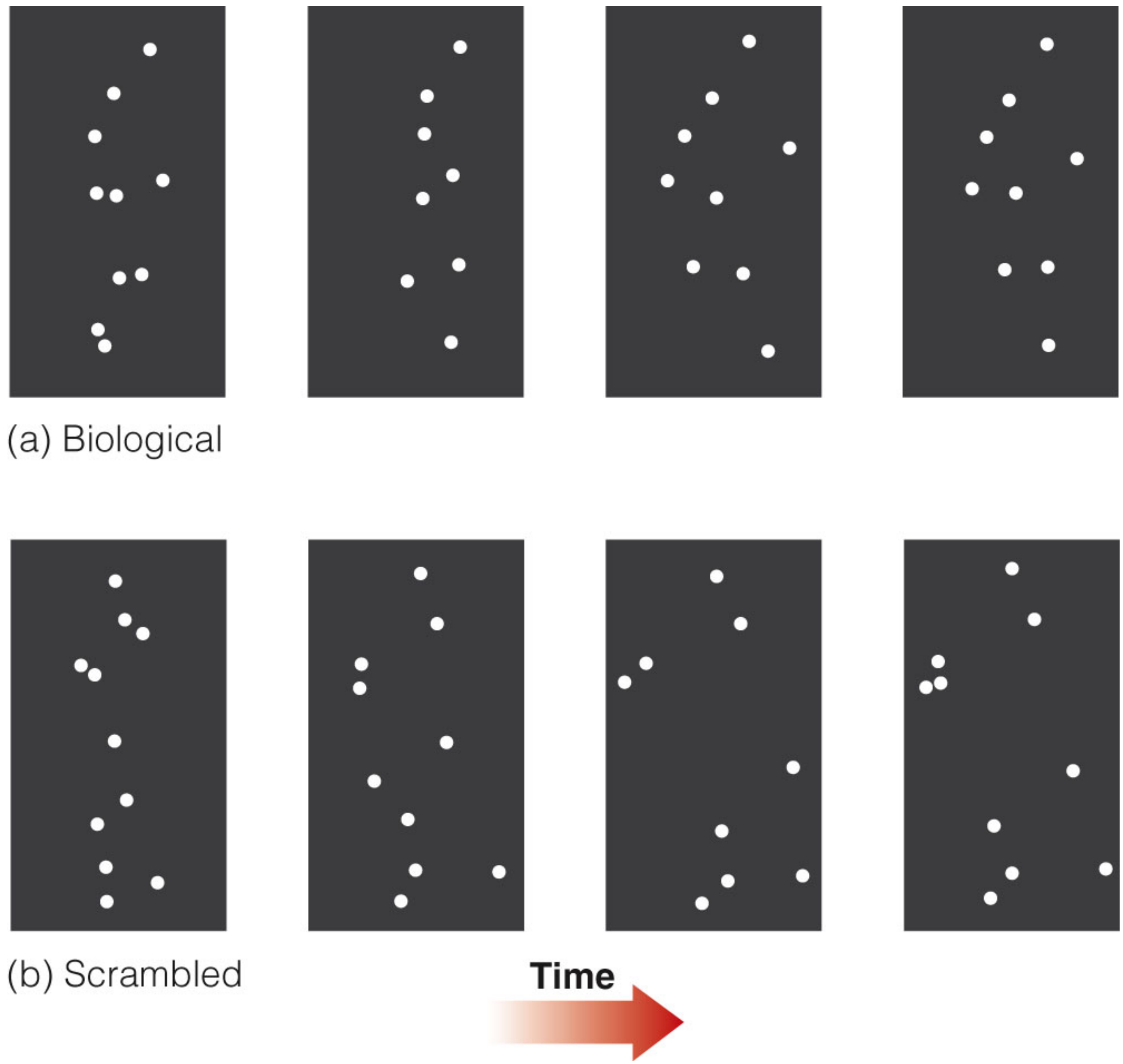
A rectangular area is filled with a set of 256 dots, randomly positioned. A set of these dots in a circular area is set in motion as if they were on the surface of a rotating sphere. The observer reports a rotating sphere. It the dots stop, or move randomly, no object is seen.



Biological Motion

A person is dressed in dark blue and filmed in the dark against a dark blue background. With this arrangement, they are invisible to the camera.

Small lights are attached to the ankles, knees, hips, elbows, wrists, and shoulders. When the person is stationary, observers report a random array of lights. When the person moves, observers report a person moving and can accurately describe what the person is doing (walking, bending over, getting up from sitting in a chair, etc.)


(a) Biological
(b) Scrambled
Time

Biological Motion - 2

The motion of the individual lights is complex. When only one light is used, observers do not perceive a human form or biological motion. Scrambling the lights does not lead to a biological motion percept. It is the coordinated motion that is perceived as a person.

See http://www.biomotionlab.ca/ then go to Demos for examples.

Some neurons in the superior temporal area of the monkey respond to images of people walking. These same neurons also respond to the point-light display of a person walking.

Biological Motion - 3

In humans, the corresponding part of the brain is the superior temporal sulcus (STS). PET scans show that this area responds to both moving humans and point-light motion displays. This brain region does not respond to stationary point-light displays or non-biological motion.

If activity in the STS is temporarily suppressed by *Transcranial Magnetic Stimulation*, observers find it more difficult to distinguish between biological and non-biological motion. Using TMS on area MT in humans does not result in difficulty in biological motion perception.

Motion Summary

- Motion perception influences the perception of form, balance, and our own movement.
- It is based on specialize neural mechanisms.
- It involves information on the entire retina (optic flow) and eye movements.
- Although it usually obeys a shortest path constraint in perception, it is influenced by context, learning, and other factors.