Perceiving Motion

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Introduction

- We are always taking action. Whatever form action takes, it involves motion.
- We are not simply passive observers of the motion of others. We are often moving ourselves.
  - Simple case: We perceive motion when we are stationary, as when we are watching other people cross the street (**a**)
  - Complicated case: We also perceive motion as we ourselves are moving, as might happen when playing basketball (**b**).
- Complex "behind-the-scenes" mechanisms.

1 Functions of Motion Perception

- Motion perception has a number of different functions
  - from providing us with updates about what is happening,
  - to helping us perceive things such as the shapes of objects and people’s moods.

- Perhaps most important of all, especially for animals, the perception of motion is intimately linked to survival.

1.1 Motion Provides Information About Objects

- The idea that not moving can help an animal blend into the background is illustrated by the following demonstration.

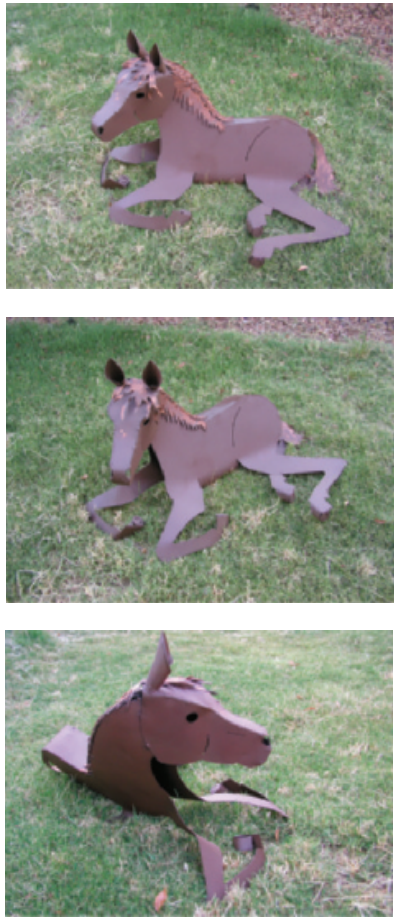
DEMONSTRATION

Perceiving a Camouflaged Bird

Prepare stimuli by photocopying the bird and the hatched-line pattern.
Hold the picture of the bird up against a window.
Turn the copy of the hatched pattern over so the pattern is facing out the window and place it over the bird.
Notice how the presence of the hatched pattern makes it more difficult to see the bird.
Then, slide the bird back and forth under the pattern, and notice what happens to your perception of the bird.

- The stationary bird is difficult to see when it is covered by the pattern because the bird and the pattern are made up of similar lines. But as soon as all the elements of the bird begin moving in the same direction, the bird becomes visible.
- Movement has perceptually organized all the elements of the bird, so they create a figure that is separated from the background.

- This seems like a special case because most of the objects we see are not camouflaged.
- Based on the discussion from object perception about how even clearly visible objects may be ambiguous, you can appreciate how motion of an object can reveal characteristics of the object that might not be obvious from a single, stationary view.
    - viewing the "horse" from different perspectives reveals that its shape is not exactly what you may have expected based on your initial view.
- Thus, our own motion relative to objects is constantly adding to the information we have about the objects.

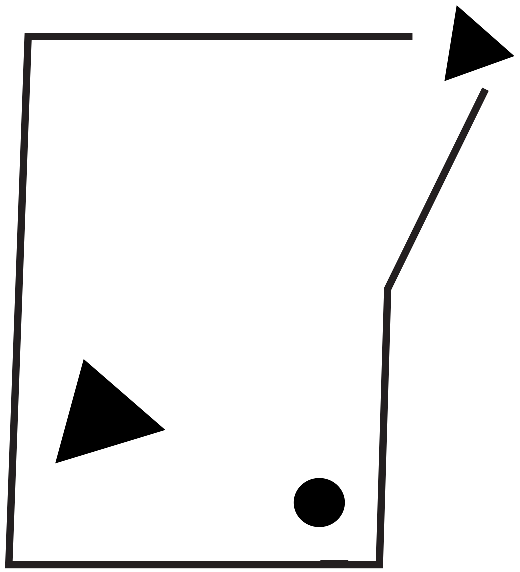


1.2 Motion Attracts Attention

- The ability of motion to attract attention is called attentional capture.
  - This effect occurs not only when you are consciously looking for something but also while you are paying attention to something else.
  - For example, as you are having a conversation, your attention may suddenly be captured by something moving in your peripheral vision.
- The fact that movement can attract attention plays an important role in animal survival.
  - Phenomenon: animals freeze in place when they sense danger.
    - If a mouse's goal is to avoid being detected by a cat, one thing it can do is to stop moving.
  - Freezing in place not only eliminates the attention-attracting effects of movement, it also makes it harder for the cat to differentiate between the mouse and its surroundings.

1.3 Motion Helps Us Understand Events in Our Environment

- Much of what you observe involves <u>information provided by motion</u>.
  - Crossing the street; Pouring water into a glass; Talking with others.
- A demonstration of motion's power to indicate what is happening.
  - who showed an animated film to subjects and asked them to describe what was happening in the movie.
  - The movie consisted of a "house" and three "characters"—a small circle, a small triangle, and a large triangle.
  - These three geometric objects moved around both inside and outside the house, and sometimes interacted with each other.
- Although the characters were geometric objects, the subjects created stories to explain the objects' actions, and often gave them humanlike characteristics and personalities.



2 Studying Motion Perception

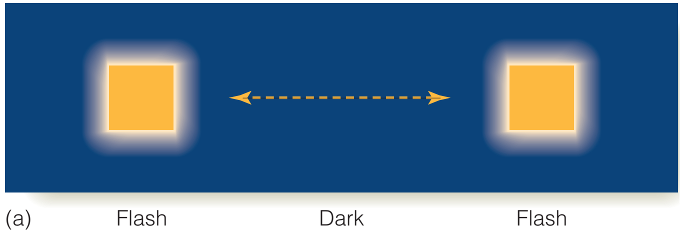
- To describe how motion perception is studied, the first question is:

When do we perceive motion?

2.1 When Do We Perceive Motion?

- We perceive motion when something moves across our field of view.
  - Actual motion of an object is called real motion.
  - Perceiving a car driving by, people walking.
- There are also a number of ways to produce the perception of motion that involve stimuli that are not moving, called illusory motion.

1. The most famous type of illusory motion is called apparent motion:
    - When two stimuli in slightly different locations are alternated with the correct timing, an observer perceives one stimulus moving back and forth smoothly between the two locations.
    - The basis for the motion we perceive in movies, on television, and in moving signs that are used for advertising and entertainment



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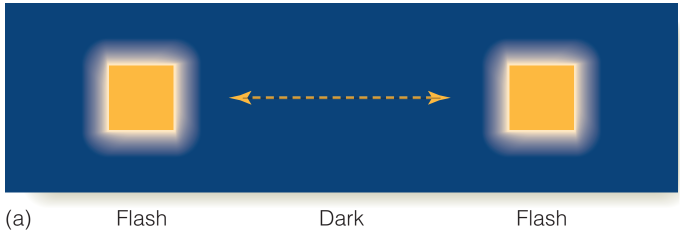

2. Induced motion occurs when motion of one object (usually a large one) causes a nearby stationary object (usually smaller) to appear to move.

- For example, the moon usually appears stationary in the sky. However, if clouds are moving past the moon on a windy night, the moon may appear to be racing through the clouds.
- In this case, movement of the larger object (clouds covering a large area) makes the smaller, but actually stationary, moon appear to be moving.

3. Motion aftereffects occur when viewing a moving stimulus for 30 to 60 seconds causes a stationary stimulus to appear to move.

- One example is the waterfall illusion.
- If you look at a waterfall (**a**) for 30 to 60 seconds and then look off to the side at part of the scene that is stationary, you will see everything you are looking at—rocks, trees, grass—appear to move up for a few seconds (**b**).

- Our purpose is to understand some of the principles governing motion perception in general. To do this, we will focus on real and apparent motion.

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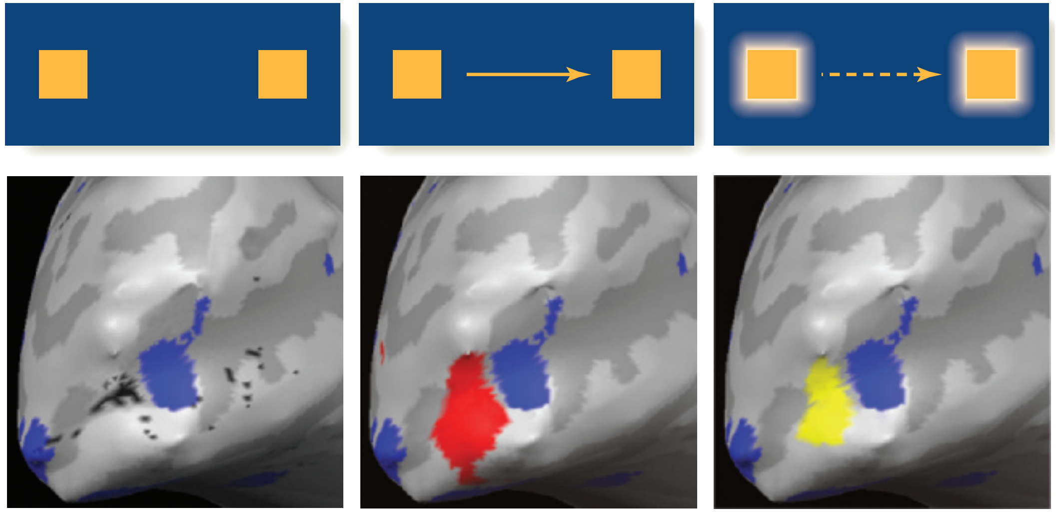
2.2 Comparing Real and Apparent Motion

- Researchers treated the apparent motion and the real motion as though they were separate phenomena, governed by different mechanisms.
- Three types of displays to a person in an fMRI scanner:
  - a *control condition*: two dots in slightly different positions were flashed *simultaneously* (**a**);
  - a *real motion display*: a small dot *moved* back and forth (**b**);
  - an *apparent motion display*: dots were *flashed* one after another (**c**).



(a) Control (b) Real (c) Apparent

- Because of the similarities between the neural responses to real and apparent motion, researchers study both types of motion together and concentrate on discovering *general mechanisms* that apply to both.

2.3 What We Want to Explain

- Our goal is to understand how we perceive things that are moving.

TABLE Conditions for Perceiving and Not Perceiving Motion Depicted in Figure

	SITUATION	OBJECT	EYES	IMAGE ON OBSERVER'S RETINA	OBJECT MOVEMENT PERCEIVED?
1	Look straight as an object moves past	Moves	Stationary	Moves	YES
2	Follow a moving object with eyes	Moves	Move	Stationary	YES
3	Look around the room	Stationary	Move	Moves	NO

  - Jeremy's image moves across Maria's retina.
  - motion perception can't be explained just by the motion of an image across the retina.
  - There is motion across the retina but no perception that objects are moving.
- In following, we will consider a number of different approaches to explaining motion perception. First, focuses on how information in the environment signals motion.

(a) Jeremy walks past Maria; Maria's eyes are stationary (creates local disturbance in optic array)

(b) Jeremy walks past Maria; Maria follows him with her eyes (creates local disturbance in optic array)

(c) Scans scene by moving her eyes from left to right (creates global optic flow)

3 Motion Perception: Information in the Environment

- Gibson’s approach: looking for information in the environment
  - The information is located not on the retina but “out there” in the environment.
  - Information in the environment in terms of the optic array
  - How movement of the observer causes changes in the optic array.
- Gibson’s Explanation
  - (a) portions of the optic array become covered as he walks by and are uncovered as he moves on, called a local disturbance, provides information about moving relative to the environment.
  - (b) Retina’s image is stationary, the same local disturbance information (covering and uncovering parts) remains available. This information indicates that Jeremy is moving.
  - (c) Everything moves at once in response to movement of the observer’s eyes or body is called global optic flow; this signals that the environment is stationary.
- According to Gibson
  - Motion is perceived when one part of the visual scene moves relative to the rest of the scene,
  - No motion is perceived when the entire field moves, or remains stationary.

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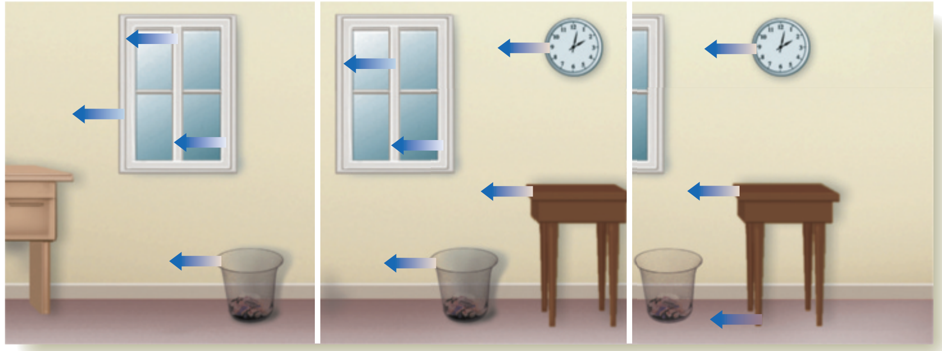


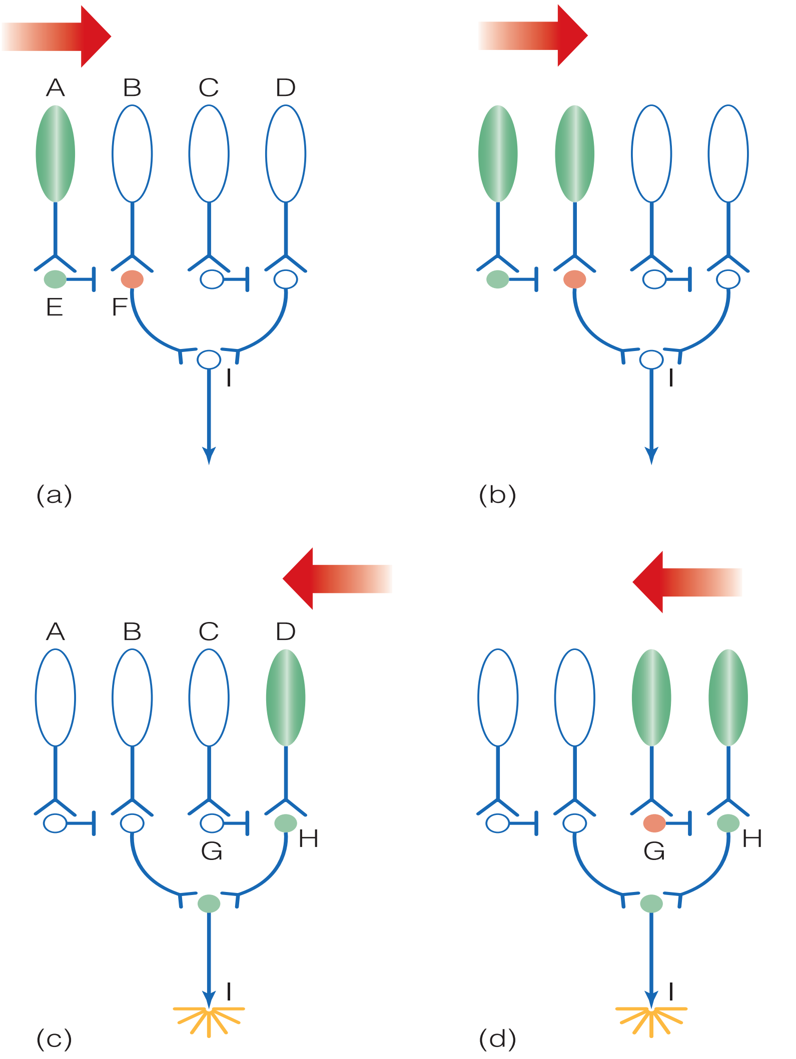
(c) Scans scene by moving her eyes from left to right (creates global optic flow)

4 Motion Perception: Retina/ Eye Information

- Gibson’s approach focuses on information that is “out there” in the environment.
- Another approach to explaining the various movement situations is to consider the neural signals that travel from the eye to the brain.

4.1 The Reichardt Detector

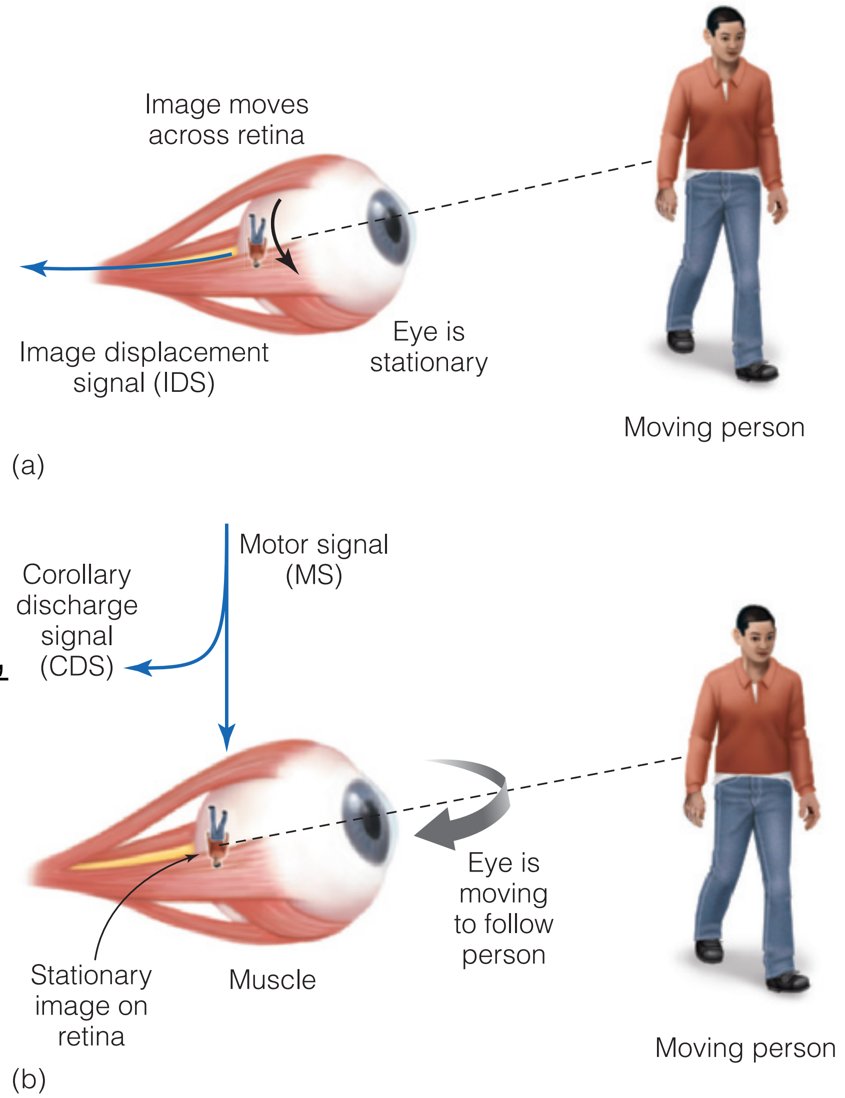
- An early neural explanation for motion perception is a neural circuit proposed by Werner Reichardt (1969) called the Reichardt detector, which results in neurons that fire to movement in one direction.
- The basic principle of the Reichardt detector.
  - Excitation and inhibition are arranged so that movement in one direction creates inhibition that eliminates neural responding,
  - Whereas movement in the opposite direction creates excitation that enhances neural responding.
- Neuron I, therefore, does not fire to movement to the right (a, b) but does fire to movement to the left (c, d).



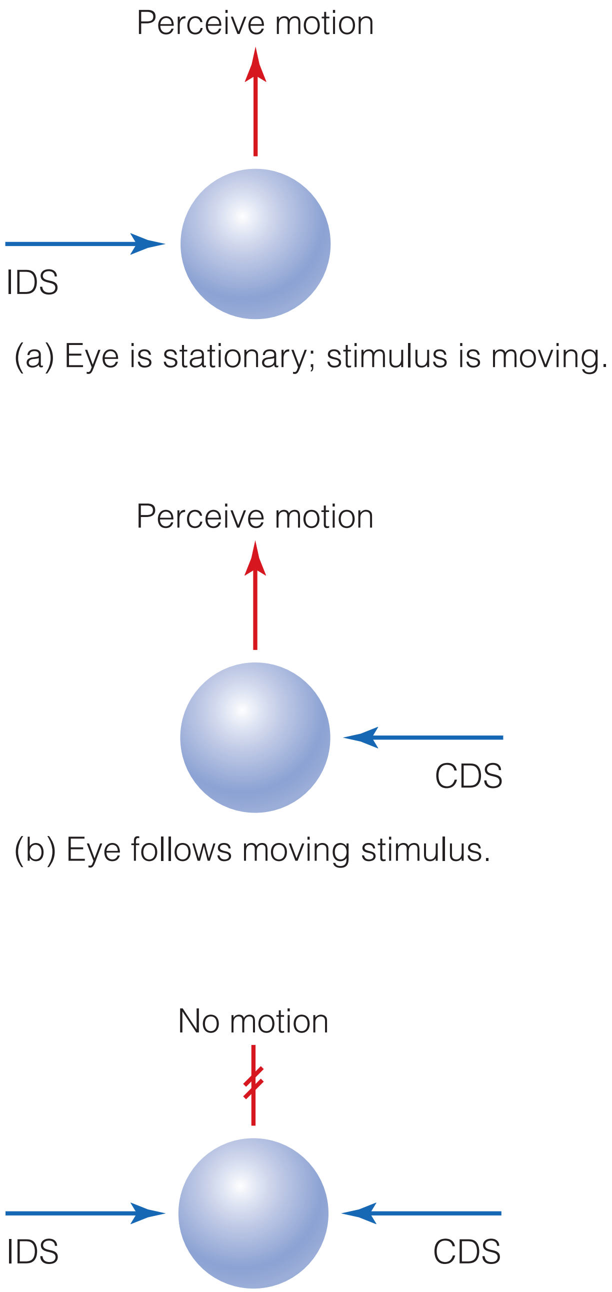
4.2 Corollary Discharge Theory

- Reichardt detectors can detect motion in a specific direction, but they can only explain the situation 1 when an image sweeps across the receptors.
- In order to explain situations like those (when Maria moves her eyes to follow Jeremy's movements) and (when Maria scans the room), we need to take into account not only how the image is moving on the retina but also how the eye is moving.
- Corollary discharge theory takes eye movements into account.
  - The first step is to consider how neural signals associated with the ***retina*** and with ***the eye muscles*** are related to the three situations.

- **Signals From the Retina and the Eye Muscles**
  - An image displacement signal (IDS) occurs when an image moves across receptors in the retina, as when Jeremy walks across Maria's field of view while she stares straight ahead.
  - A motor signal (MS) occurs when a signal is sent from the brain to the eye muscles. This signal occurs when Maria moves her eyes to follow Jeremy as he walks across the room.
  - A corollary discharge signal (CDS) is a copy of the motor signal that, instead of going to the eye muscles, is sent to a different place in the brain.
- So perhaps the solution is this: <u>When only one type of signal, either the IDS or the CDS, is sent to the brain, motion is perceived.</u>
  - Situation 1, only an IDS occurs.
  - Situation 2, only a CDS occurs.
  - Furthermore, if both signals occur, as happens in situation 3, then no motion is perceived.



- **Comparator:**
  - According to corollary discharge theory, the brain contains a structure or mechanism called the comparator that receives both the IDS and the CDS.
- The operation of the comparator is governed by the rules
  - If just one type of signal reaches the comparator, either the IDS or the CDS, it relays a message to the brain that “movement has occurred”, and motion is perceived.
  - If both the CDS and IDS reach the comparator at the same time, they cancel each other, so no signal is sent to the area of the brain responsible for motion perception.
- Where the comparator is located?
  - The comparator is most likely not located in one specific place in the brain but may involve a number of different structures.
  - Similarly, the CDS probably originates from a number of different places in the brain.
- There is some behavioral and physiological evidence to support the theory.



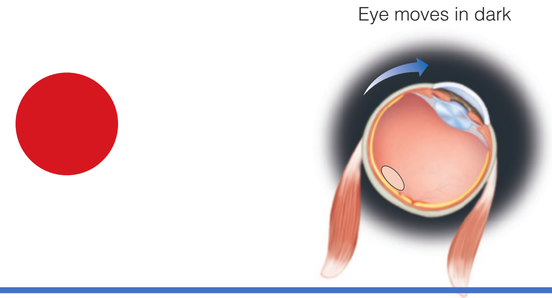
(a) Eye is stationary; stimulus is moving.
(b) Eye follows moving stimulus.
(c) Eye moves across stationary scene.

- **Behavioral Evidence for Corollary Discharge Theory**
- Why does the afterimage appear to move when you move your eyes?
  - Without motion of the stimulus across the retina, there is no image displacement signal.
  - However, the motor signals sent to move your eyes are creating a corollary discharge signal, which reaches the comparator alone, so the afterimage appears to move.
- Why do you see motion when you push on your eyelid?
  - The push in their eyelid didn't cause their eyes to move, because the observer's eye muscles were pushing back against the force of the finger to keep the eye in place.
  - The motor signal sent to the eye muscles to hold the eye in place created a corollary discharge signal, which reached the comparator alone.
- These demonstrations support the central idea proposed by corollary discharge theory.

DEMONSTRATION

Eliminating the IDS with an Afterimage

Look at the circle for about 60 seconds. Then go into a completely dark room and observe what happens to the circle's afterimage. Notice that the afterimage moves in synchrony with your eye motions.



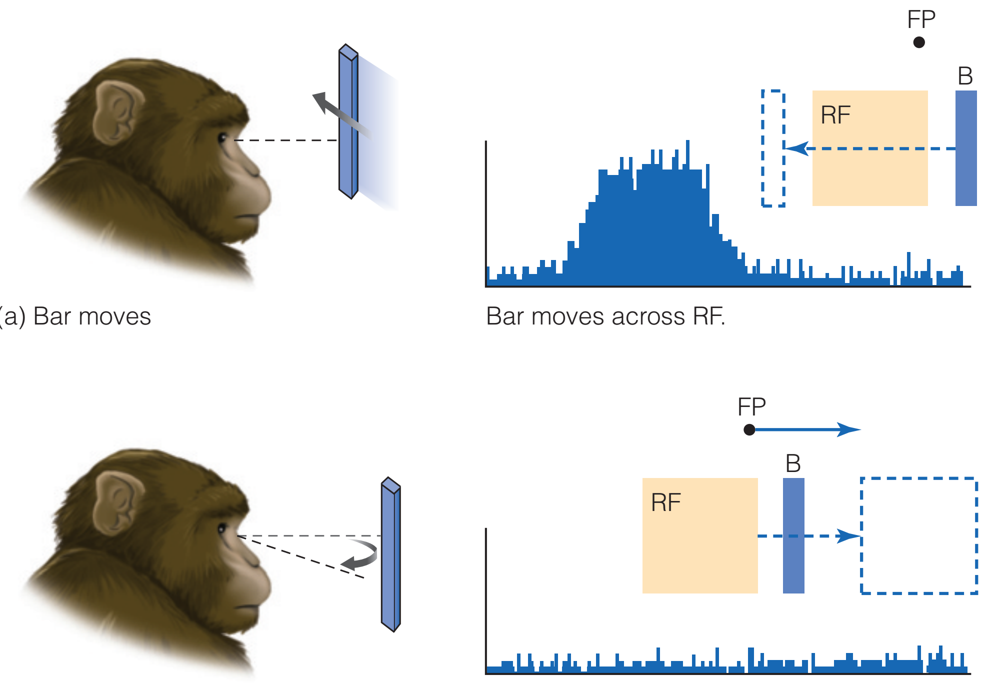
DEMONSTRATION

Seeing Motion by Pushing on Your Eyelid

Pick a point in the environment and keep looking at it while *very gently* pushing back and forth on the side of your eyelid, and see the scene move.

- **Physiological Evidence for Corollary Discharge Theory**
- What would happen if there were no corollary discharge signal but there *was* an image displacement signal?
  - A patient who experienced vertigo (dizziness) anytime he moved his eyes or experienced motion when he looked out the window of a moving car.
  - Behavioral testing revealed that the stationary environment appeared to move with a velocity that matched the velocity with which he was moving his eyes.
  - A brain scan revealed the medial superior temporal (MST) area's lesions, the damage eliminated the CDS. Because only the IDS reached the comparator.

- Evidence of recording from neurons in the monkey's cortex.
  - Response recorded from a motion-sensitive neuron in the monkey's extrastriate cortex, called a real-motion neuron
  - This neuron responds strongly when the monkey looks steadily at the fixation point (FP) as a moving bar sweeps across the neuron's receptive field (RF) (**a**).
  - But if the monkey moves its eyes to follow a moving fixation point so its eyes sweep across a stationary bar (**b**), the neuron doesn't fire.
  - This real-motion neuron must be receiving information like the corollary discharge signal, which tells the neuron when the eye is moving.



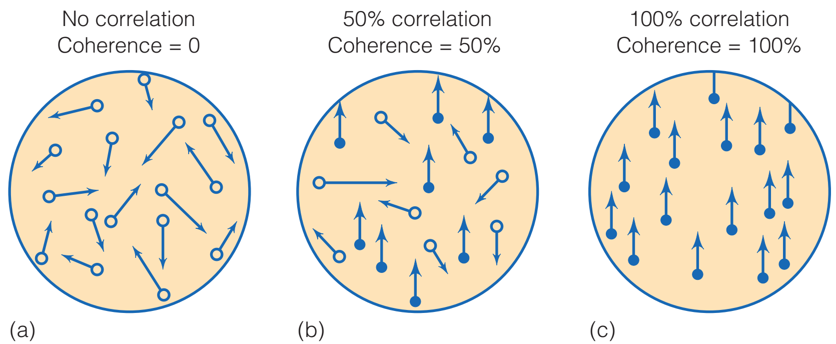
(a) Bar moves
Bar moves across RF.
(b) Eye moves
RF moves across bar.

5 Motion Perception and the Brain

5.1 The Movement Area of the Brain

- Hubel and Wiesel's (1959, 1965) pioneering work: neurons in the visual receiving area that responded to bars that moved in a specific direction.
- Another area that contains many directionally sensitive cells is the middle temporal (MT) area.
- Experiment about moving dot stimuli to determine the relationship between
  - A monkey's ability to judge the direction in which dots were moving;
  - The response of a neuron in the monkey's MT cortex.

- Result:
  - As the dots' coherence increased, two things happened: the monkey judged the direction of motion more accurately, and the MT neuron fired more rapidly.
  - The monkey's behavior and the firing of the MT neurons were so closely related that the researchers could predict one from the other.

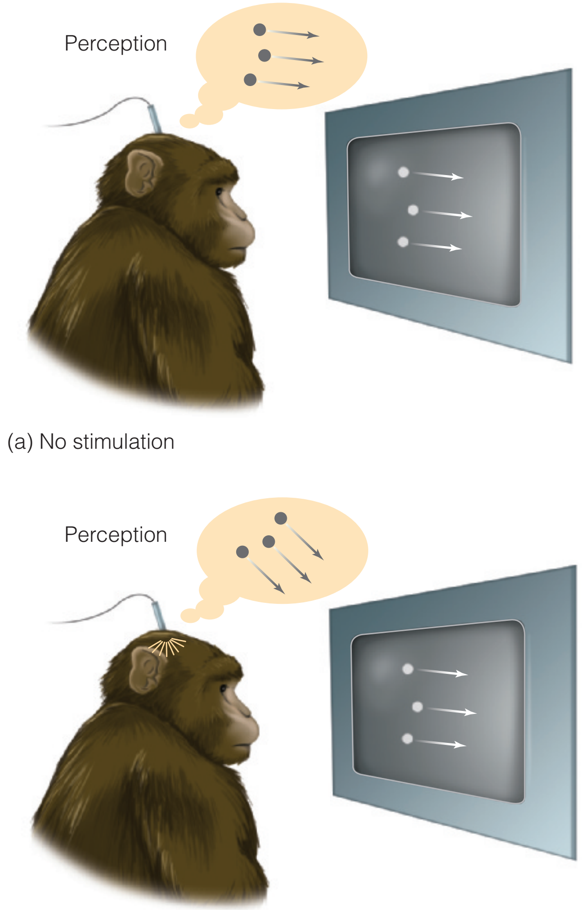


Coherence: 0% 50% 100%

The term coherence indicates the degree to which the dots move in the same direction

5.2 Effect of Microstimulation

- The fact that stimulating the MT neurons shifted the monkey’s perception of the direction of movement provides more evidence linking MT neurons and motion perception.
- Evidence from a microstimulation procedure:
  - **(a)** shows that as the monkey observed dots moving to the right, it reported that the dots were moving to the right.
  - **(b)** shows that when stimulated a column of MT neurons that preferred downward motion, the monkey began responding as though the dots were moving downward and to the right.
- Remember that there are areas specialized to respond to faces (the fusiform face area) and bodies (the extrastriate body area), yet these objects also activate many other areas of the brain.
- Similarly, the MT and MST (medial superior temporal) cortex are specialized to respond to motion, yet motion also activates a number of other areas distributed across the brain.

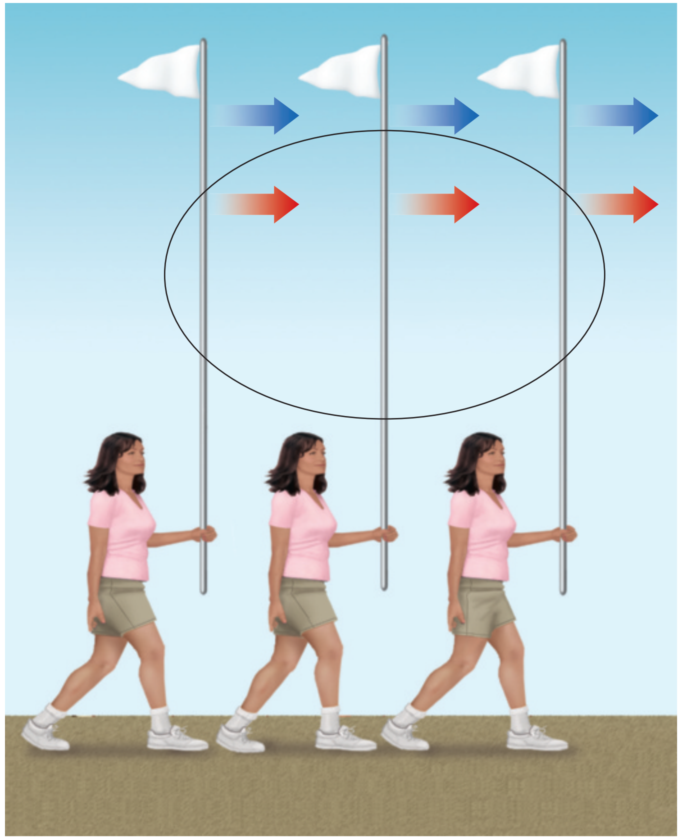


(a) No stimulation

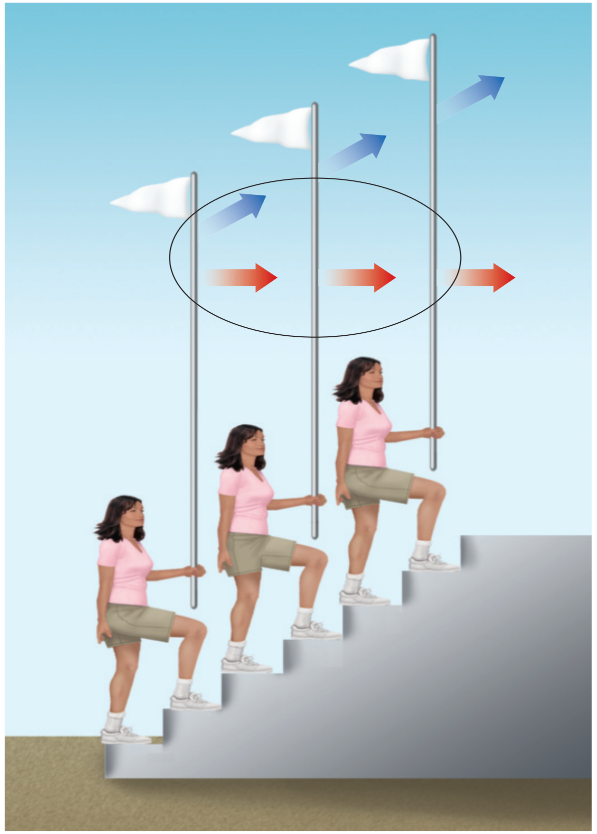
(b) Stimulation

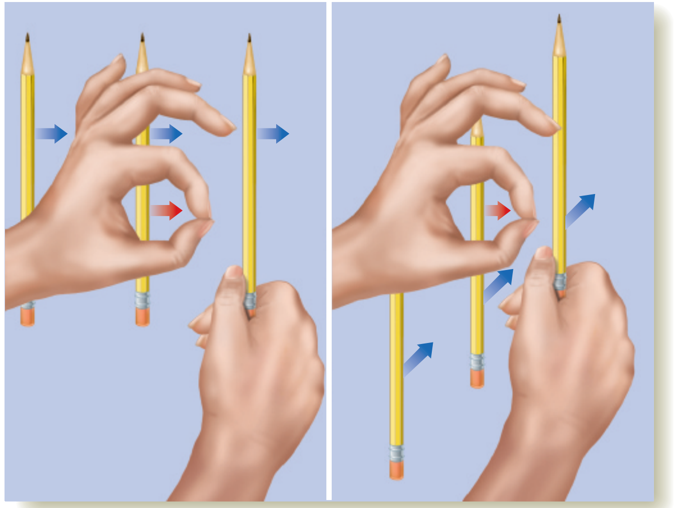
5.3 Motion From a Single Neuron’s Point of View

- How motion perception is served by the firing of single neurons within the MT cortex?
  - The obvious answer: the directionally selective neurons were activated that respond to movement in a specific direction.
  - It turns out that the response of individual directionally selective neurons does not provide sufficient information to indicate the direction of movement.
- Considering how a directionally selective neuron would respond to movement of a vertically oriented pole like the one being carried by the woman.
  - The ellipse represents the area of the receptive field of a neuron in the cortex that responds when a vertical bar moves to the right across.
  - As the pole moves to the right, it moves across the receptive field in the direction indicated by the red arrow, and the neuron fires.



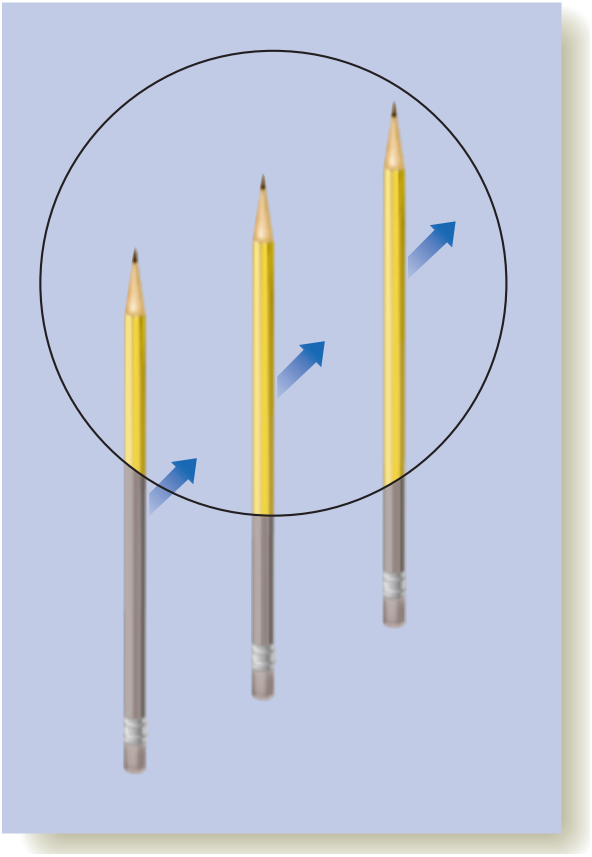
- But what happens if the woman climbs some steps?
  - As she walks up the steps, she and the pole are now moving up and to the right (blue arrow). We know this because we can see the woman and the flag moving up.
  - But the neuron, which only sees movement through the narrow view of its receptive field, only receives information about the rightward movement.
- Viewing only a small portion of a larger stimulus can result in misleading direction information, called the aperture problem.
  - The movement of an edge across an aperture occurs *perpendicular to the direction in which the edge is oriented*.
  - So based just on the activity of this neuron, it isn't possible to tell whether the pencil is moving horizontally to the right or upward at an angle.





(a) (b)

- The visual system appears to solve the aperture problem by pooling the responses of a number of neurons.
  - Found that the MT neurons' initial response to the stimulus, about ***70 msec*** after the stimulus was presented, was determined by the orientation of the bar.
  - However, ***140 ms*** after presentation of the moving bars, the neurons began responding to the *actual* direction in which the bars were moving.
- MT neurons receive signals from a number of neurons in the striate cortex and then combine these signals to determine the actual direction of motion.
  - A neuron could use information about the end of a moving object (such as the tip of the pencil) to determine its direction of motion, which have been found in the striate cortex.
- The visual system apparently solves this problem
  - Using information from neurons in the MT cortex that pool the responses of a number of directionally selective neurons.
  - Using information from neurons in the striate cortex that respond to the movement of the ends of objects.

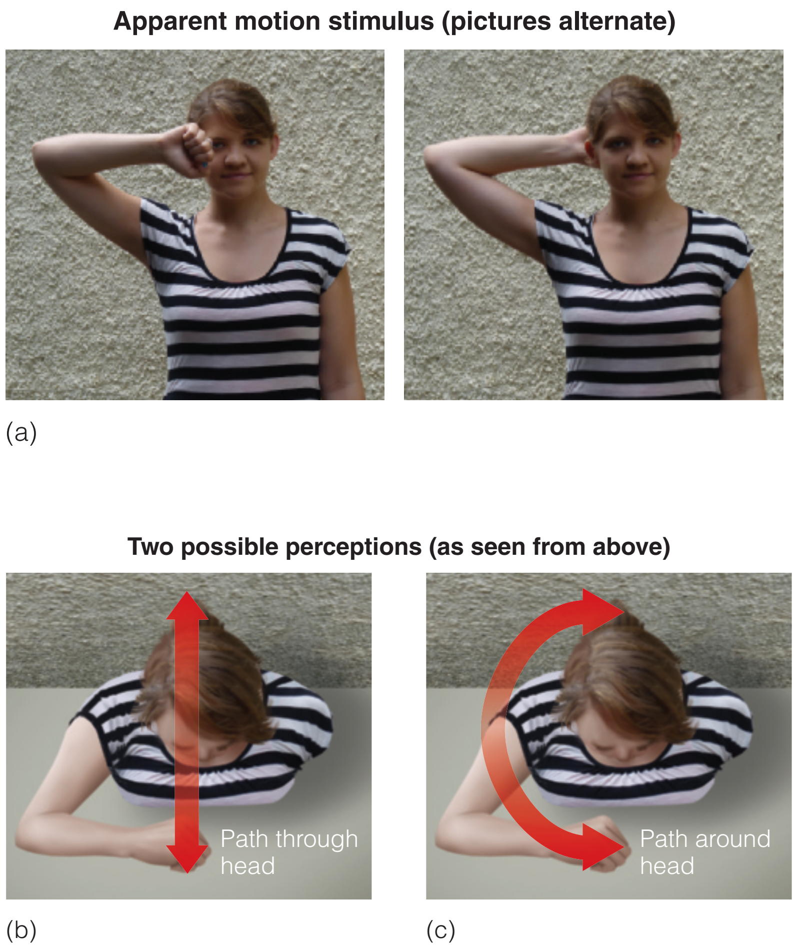


6 Motion and the Human Body

- We have just seen that experiments using ***dots*** and ***lines*** as stimuli have taught us a great deal about the mechanisms of motion perception.
- But what about the more complex stimuli created by moving humans and animals that are so prevalent in our environment?
- We will now consider two examples of the ways in which researchers have studied how we perceive movement of the ***human body***.

6.1 Apparent Motion of the Body

- *Apparent motion:* movement tends to occur along the shortest path between two stimuli, following a principle called the shortest path constraint.
  - View photographs alternating rapidly.
  - According to the shortest path constraint, observers would see the woman's hand as moving through her head.
- When the rate of alternation was slowed (<5 time/s), the hand appeared to move around the woman's head. Two reasons:
  - The meaning of the stimulus that influences the way movement is perceived.
  - The visual system needs time to process information in order to perceive the movement of complex meaningful stimuli;
- What is happening in the cortex?
  - Both movement through the head and movement around the head activated areas in the parietal cortex associated with movement.
  - When the observers saw movement as occurring around the head, the motor cortex was activated as well, but isn't activated when the perceived movements are not possible.
  - This connection between the brain area associated with perceiving movement and the motor area reflects ***the close connection between perception and taking action***.



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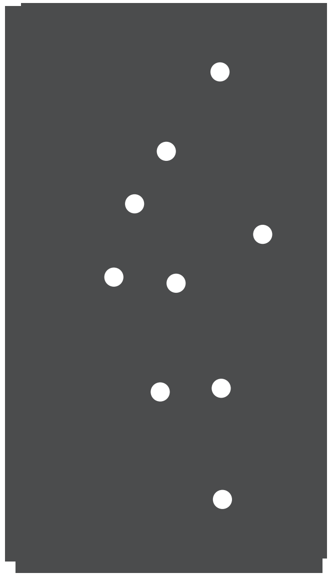
6.2 Motion of Point-Light Walkers

- Another approach to studying motion of the human body involves stimuli called point-light walkers
- **Perceptual Organization**
  - Movement can cause individual elements to become perceptually organized.
  - Similarly, motion creates organization for point-light walkers.
    - When the person wearing the lights is stationary, the lights look like a meaningless pattern.
    - As soon as the person starts walking, the motion of the lights is immediately perceived as being caused by a walking person.
  - This self-produced motion of a person is called **biological motion**.
- One reason we are particularly good at perceptually organizing the complex motion of an array of moving dots into the perception of a walking person is that we see biological motion all the time.

Brain Mechanisms

- Some researchers suspected that there may be an area in the brain that responds to biological motion, just as there are areas such as the extrastriate body area (EBA) and fusiform face area (FFA) that are specialized to respond to bodies and faces, respectively.
- Evidences supporting the idea of a specialized area in the brain for biological motion
  - A small area in the superior temporal sulcus (STS) was more active when viewing biological motion than viewing scrambled motion in all eight of their observers.
  - Other regions, such as the FFA, were activated more by biological motion than by scrambled motion, but that activity in the EBA did not distinguish between biological and scrambled motion.



- They concluded that there is a network of areas, which includes the STS and FFA, that is specialized for the perception of biological motion.

Brain Mechanisms

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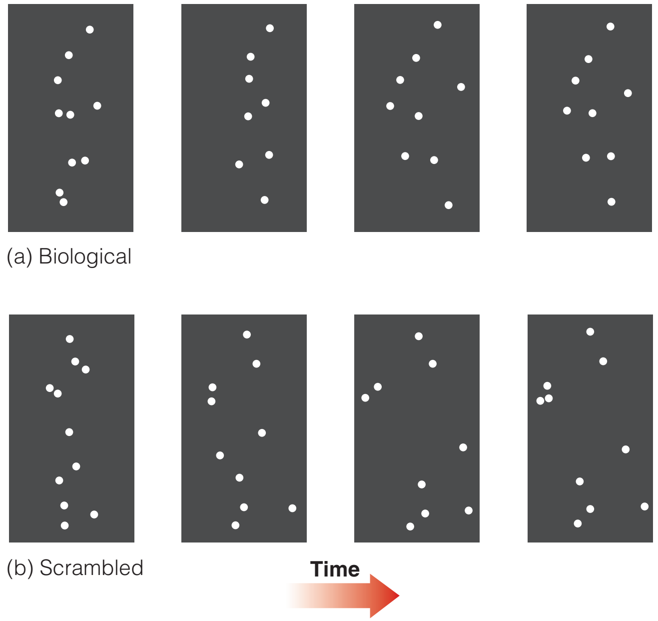

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- They concluded that there is a network of areas, which includes the STS and FFA, that is specialized for the perception of biological motion.

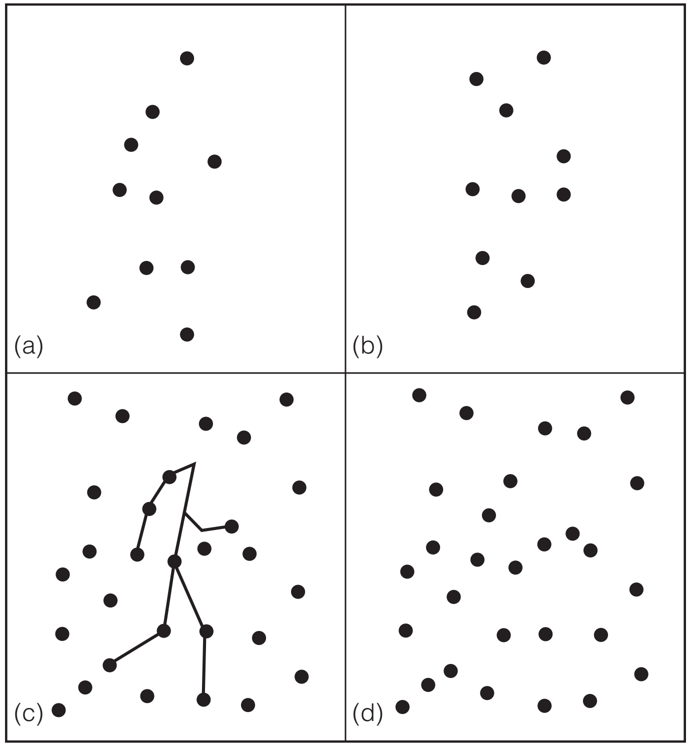
- One of the principles we have discussed is that just showing that a structure responds to a specific type of stimulus does not prove that the structure is involved in *perceiving* that stimulus.
- Disrupting operation of the STS in humans decreases the ability to perceive biological motion, using a procedure called *transcranial magnetic stimulation.*

METHOD

Transcranial Magnetic Stimulation (TMS)

One way to investigate whether an area of the brain is involved in determining a particular function is to remove that part of the brain. It is possible to temporarily disrupt the functioning of a particular area by applying a pulsating magnetic field using a stimulating coil placed over the person's skull.
A series of pulses presented to a particular area of the brain for a few seconds interferes with brain functioning in that area for seconds or minutes.
If a particular behavior is disrupted by the pulses, researchers conclude that the disrupted area of the brain is involved in that behavior.

- The observers viewed point-light stimuli for activities such as walking, kicking, and throwing (**a**), and they also viewed scrambled point-light displays (**b**).
- The task was to determine whether a display was biological motion or scrambled motion.
    - The researcher made it more difficult by adding extra dots to create "noise" (**c** and **d**).
    - Presenting transcranial magnetic stimulation to the area of the STS caused a significant decrease in the observers' ability to perceive biological motion.
    - Such magnetic stimulation of other motion-sensitive areas, such as the MT cortex, had no effect on the perception of biological motion.
- Normal functioning of the "biological motion" area, STS, is necessary for perceiving biological motion.
- The conclusion is also supported by studies showing that people who have suffered damage to this area have trouble perceiving biological motion.



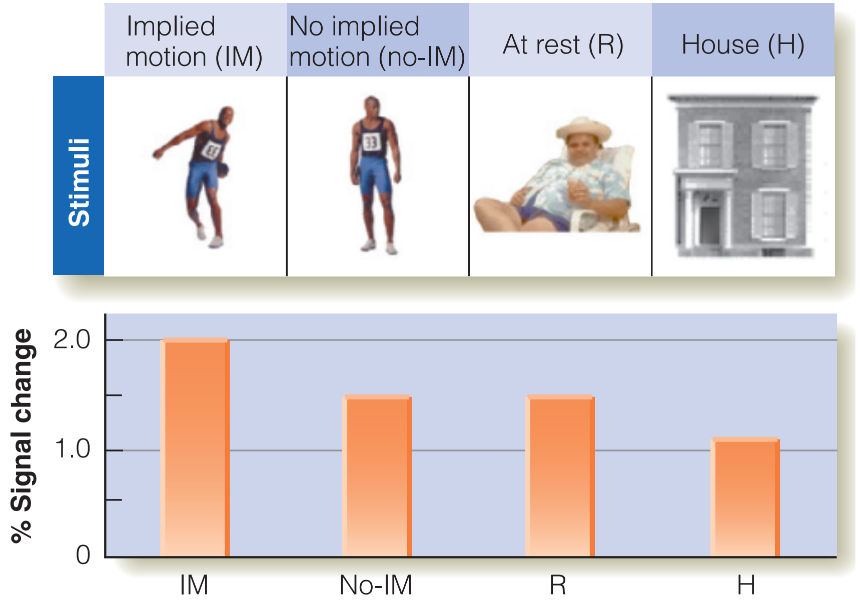
7 Representational Momentum: Motion Responses to Still Pictures

- Most people perceive this picture as a “freeze frame” of a skiing action that involves motion.
- It is not hard to imagine the person moving to a different location immediately after this picture was taken.
- A situation such as this, in which a still picture depicts an action involving motion, is called **implied motion**.

- Experiment involving implied motion.
- Observers might "remember" the picture as depicting a situation that occurred slightly later in time.
- The task was to indicate, as quickly as possible, whether the second picture was the same as or different from the first picture.
    - Found that subjects took longer to decide if the time-forward picture was ***the same or different.***
- Concluded that the time-forward judgment was more difficult because the subjects had anticipated the downward motion that was about to happen and so confused the time-forward picture with what they had actually seen.

(a) First picture (b) Forward in time (c) Backward in time

- The idea that the motion depicted in a picture tends to continue in the observer's mind is called **representational momentum**.
  - An example of *experience influencing perception* because it depends on our knowledge of the way situations involving motion typically unfold.
- If implied motion causes an object to continue moving in a person's mind, then it would seem reasonable that this continued motion might be reflected by activity in the brain.
- The fMRI response in the MT and MST cortex to pictures
  - Found that the area of the brain that responds to actual motion also responds to *pictures* of motion, and that implied-motion (IM) pictures caused a greater response than no-implied-motion (no-IM) pictures, at rest (R) pictures, or house (H) pictures.
  - Thus, activity occurs in the brain that corresponds to the continued motion that implied-motion pictures create in a person's mind.

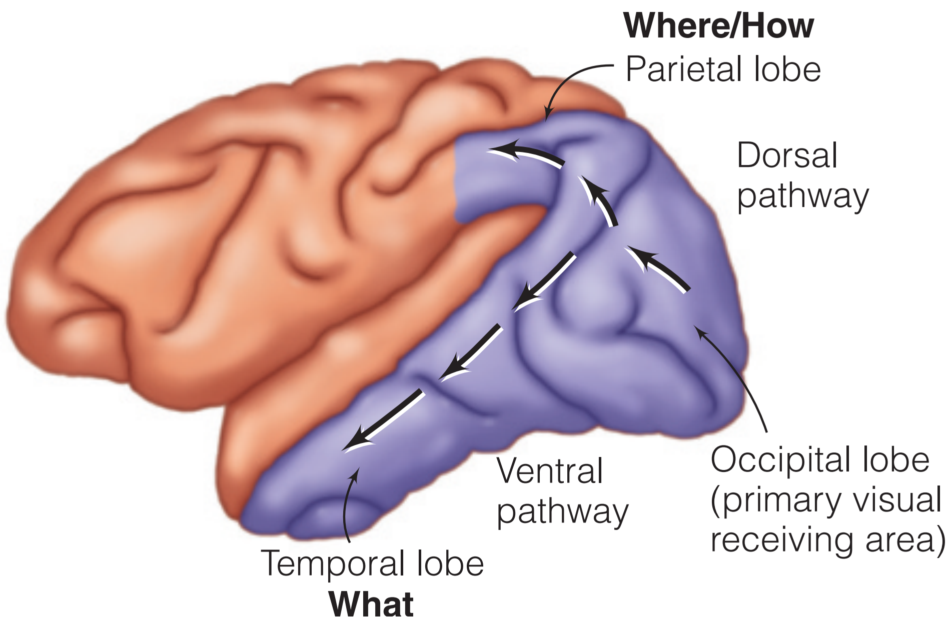


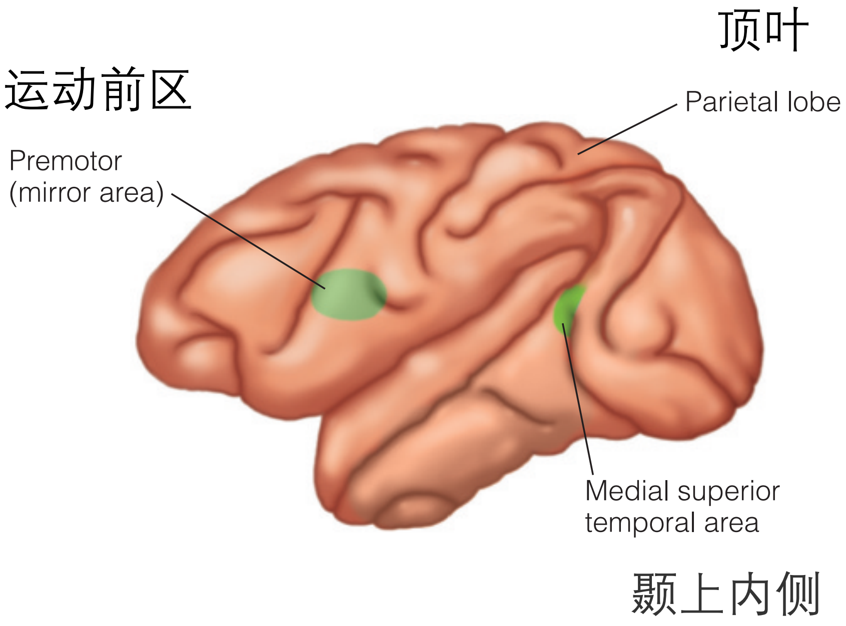
8 Event Perception

- When look out at a scene, individual objects arranged relative to each other in space. This is the result of perceptual organization and perceptual segmentation.
- What does this have to do with perceiving movement?
  - We can segment ongoing behavior into a sequence of events, where an **event** is defined as a segment of time at a particular location that is perceived by observers to have a beginning and an ending.
  - Our everyday life is a cascade of events.
- Measured the connection between events and motion perception
  - Having subjects watch films of common activities, and asking them to press a button when they believe one unit of meaningful activity ends and another begins.
  - Compared event boundaries to the actor's body movements measured with a motion tracking system, found that event boundaries were more likely to occur when there was *a change in the speed or acceleration of the actor's hands*.
  - Concluded that the perception of movement plays an important role in separating activities into meaningful events.
- Events, which are often defined by motion, follow one after the other to create our understanding of what is happening.

Summary

- Part 1: Taking Action
  - The Ecological Approach to Perception
  - Navigating Through The Environment
  - Acting on Objects
  - Observing Other People's Actions
  - Action-Based Accounts of Perception
- Part 2: Perceiving Motion
  - Functions of Motion Perception
  - Studying Motion Perception
  - Motion Perception and the Brain
  - Motion and the Human Body
  - Representational Momentum
  - Event Perception





1、空间地图：客体、身体位置与导航
2、affordance：客体属性、范畴与用途
3、运动检测机制
The Reichardt Detector→Corollary discharge theory→aperture problem
4、动作控制/避障：
1）腹侧通路(知觉)与背侧通路(运动)的协同
2）多模态融合
5、肢体运动感知：与肢体运动关联
手的动作感知与运动神经元: the parietal reach region
6、动作序列
1）镜像神经元：语境中动作链、预测和意图
2）apparent motion：手臂绕头受到物理约束
3）spotlight知觉: superior temporal sulcus
4）表示动量：动作链(MST);
7、视觉场景分析 vs. 基于运动的事件分割

Thanks