

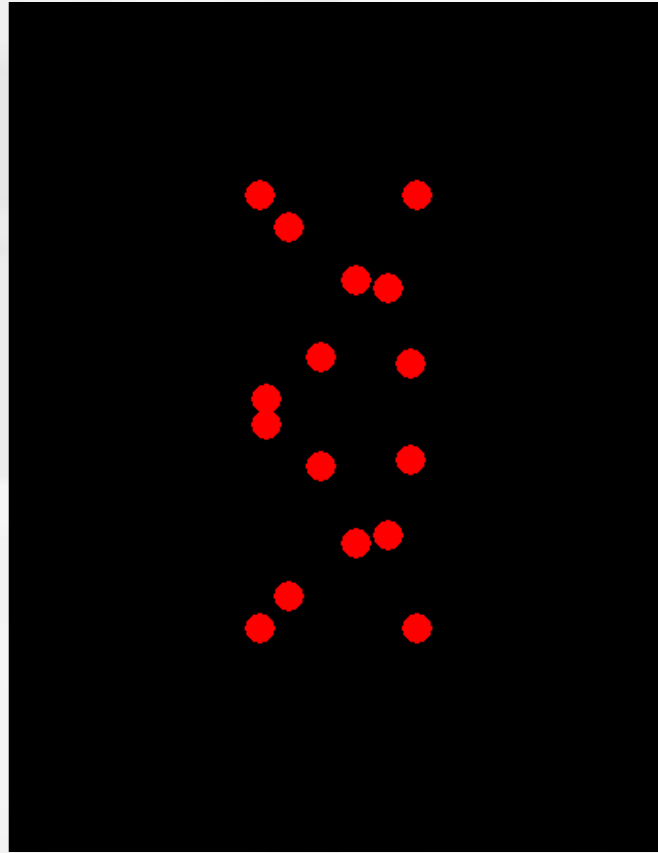
Chapter 9: Perceiving Movement

- Why do some animals freeze in place when they sense danger?
- How do films create movement from still pictures?
- When we scan a room, the image of the room moves across the retina, but we perceive the room and the objects as remaining stationary. Why does this occur?



Four Ways to Perceive Movement

1. **Retinal motion** – an object is physically moving on the retina



The 'Kinetic Depth Effect' (KDE)

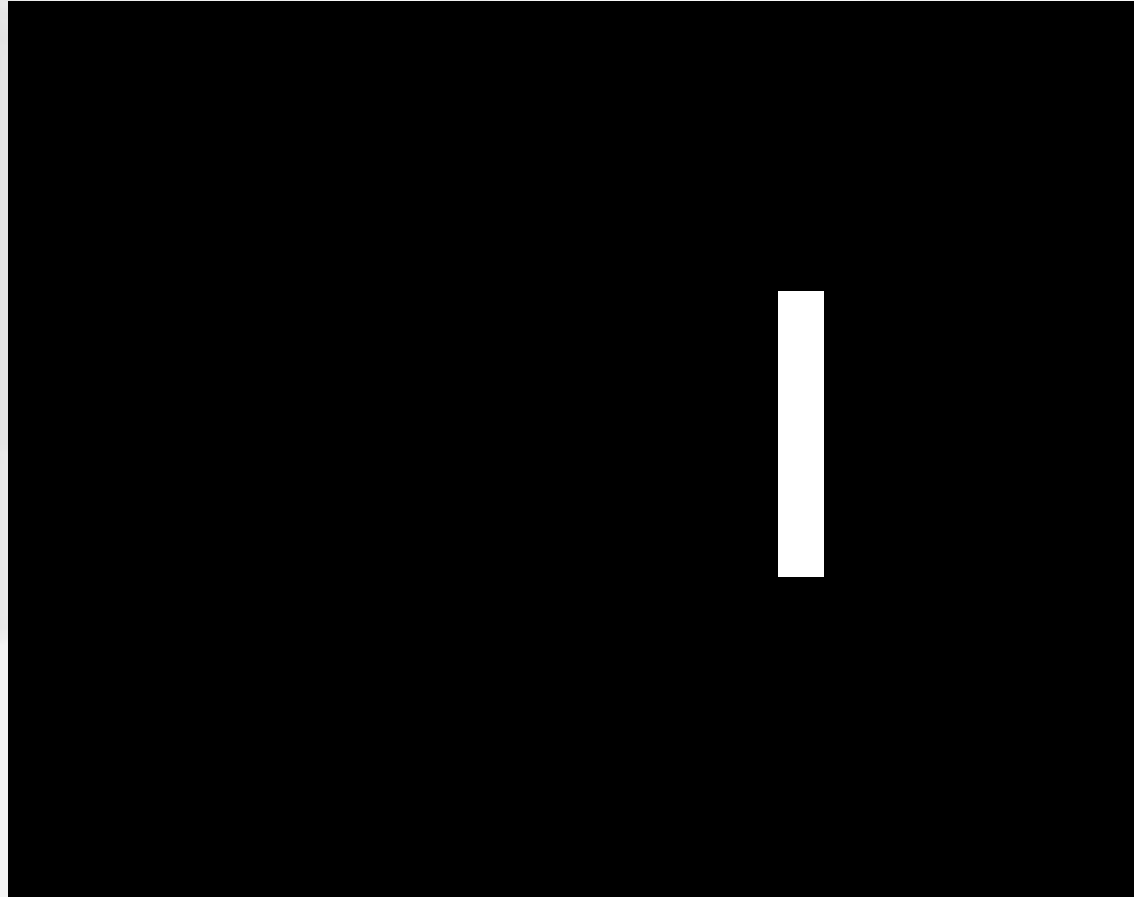
Four Ways to Perceive Movement

2. **Apparent movement** - stationary stimuli are presented in slightly different locations



Four Ways to Perceive Movement

2. **Apparent movement** - stationary stimuli are presented in slightly different locations



Four Ways to Perceive Movement

3. **Induced movement** - movement of one object results in the perception of movement in another object



Four Ways to Perceive Movement

4. Motion aftereffect



Four Ways to Perceive Movement

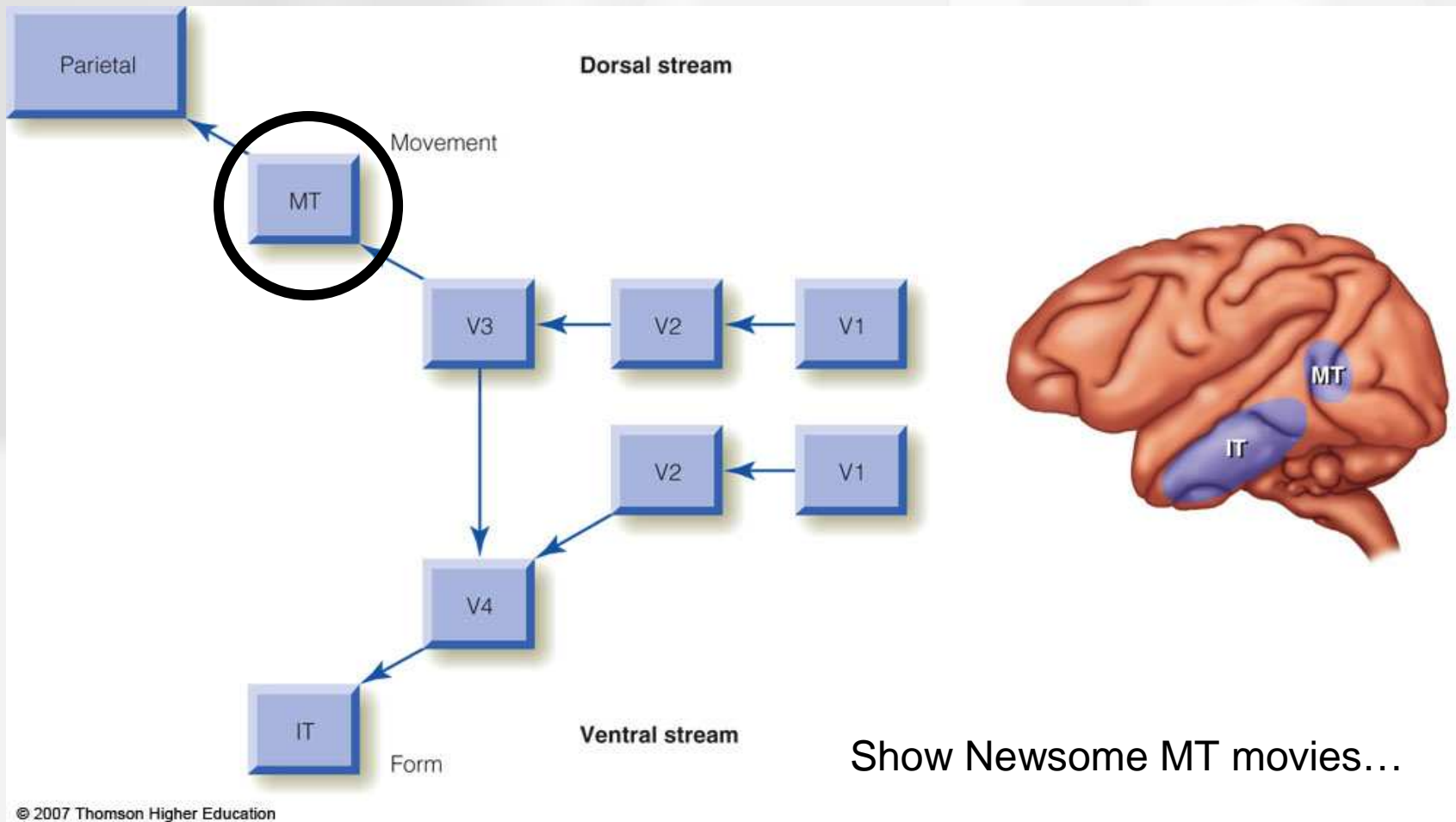
4. Motion aftereffect



Like face adaptation, the motion aftereffect is evidence of direction selective neurons. Adapting to one direction changes the balance in the response to a stationary stimulus, causing the perception of motion in the opposite direction.

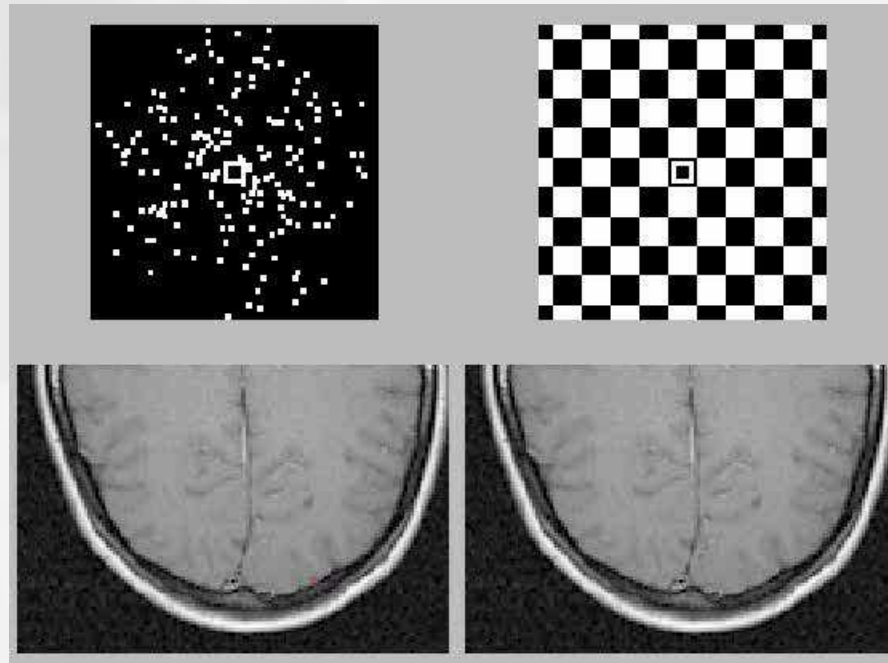
Physiological basis of retinal motion perception

Hubel and Wiesel discovered direction selective cells in the cat.
Almost all neurons in area MT of the monkey are direction selective.

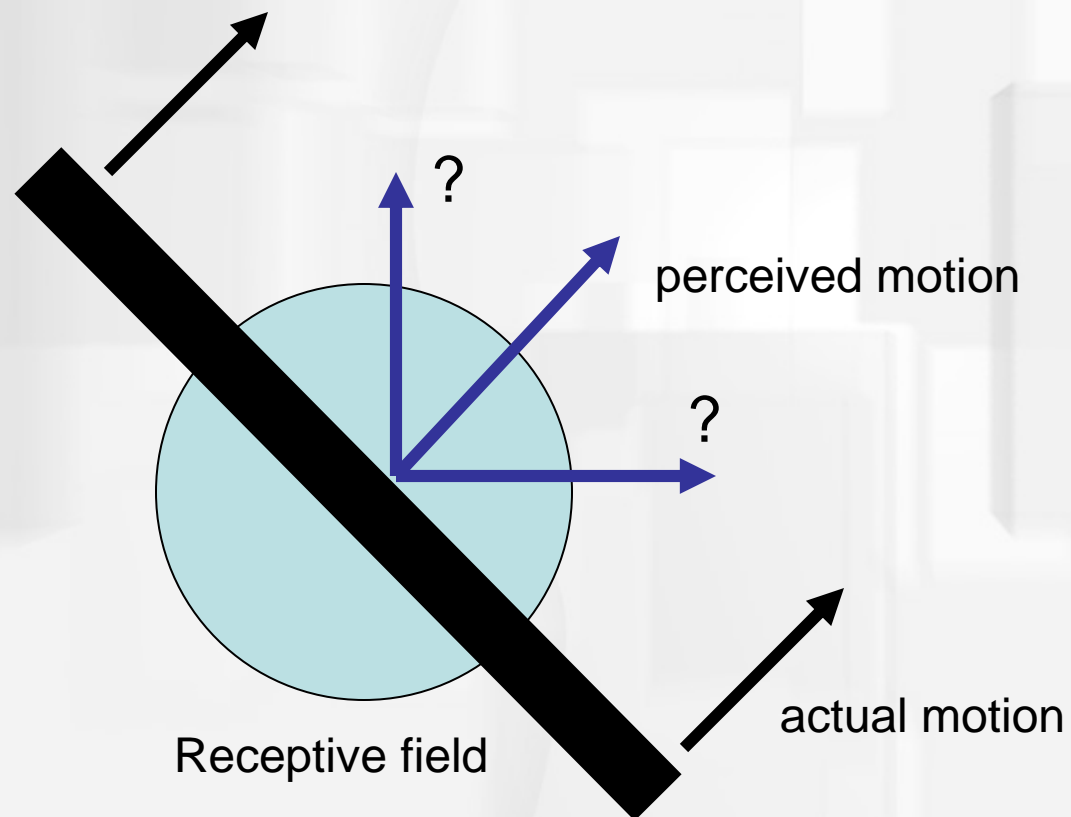


Physiological basis of retinal motion perception

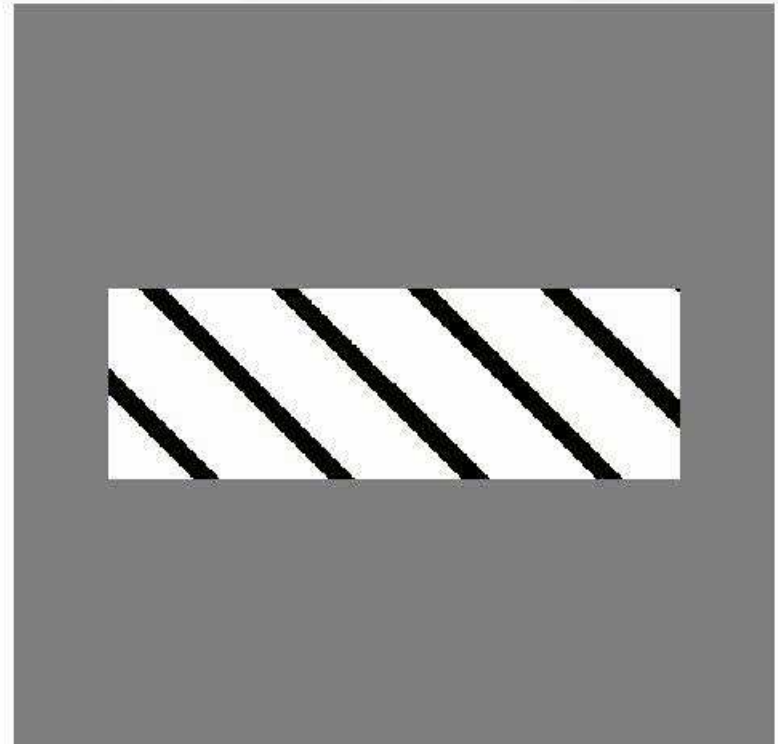
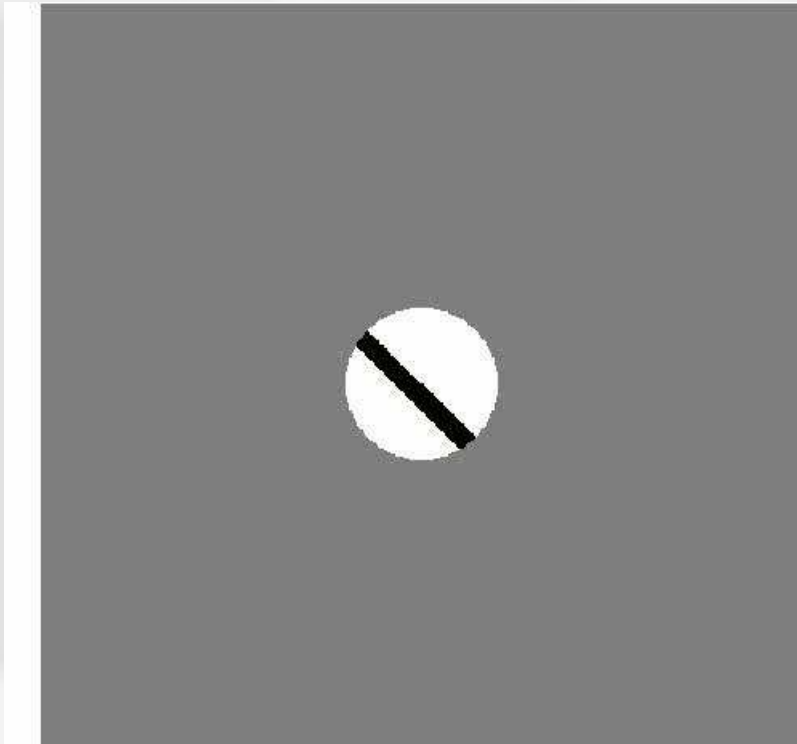
Humans have a homologous area, called 'MT*'



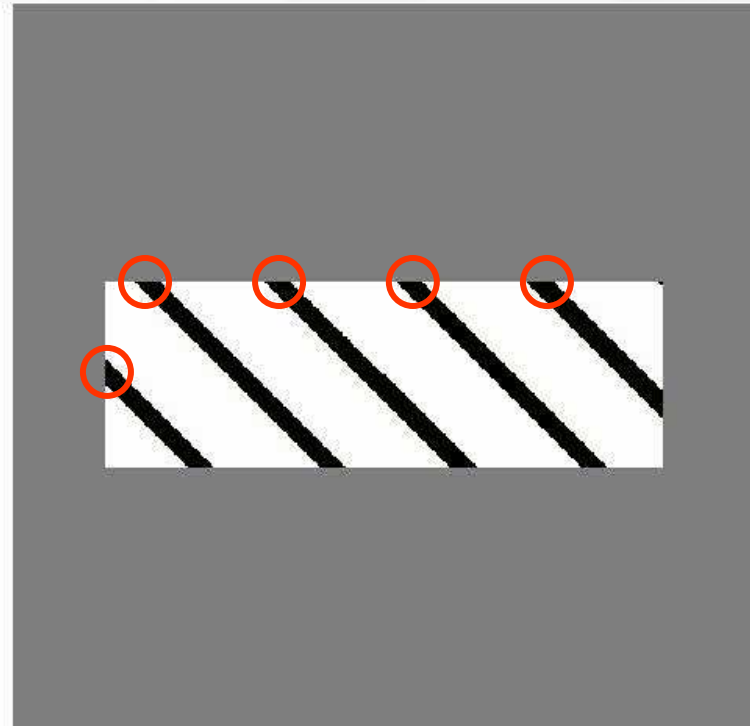
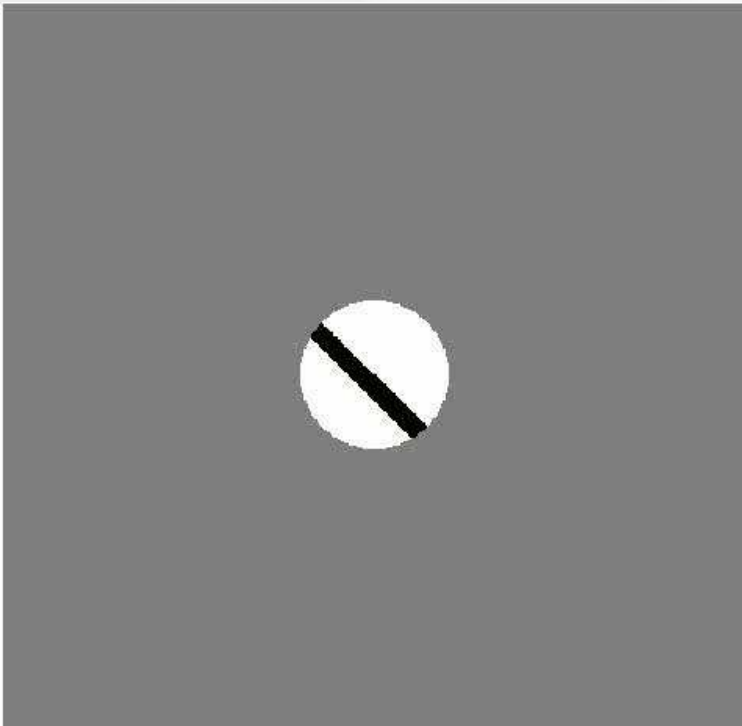
The 'aperture problem': the direction of a moving bar through an aperture (like a receptive field) is ambiguous



The 'aperture problem'



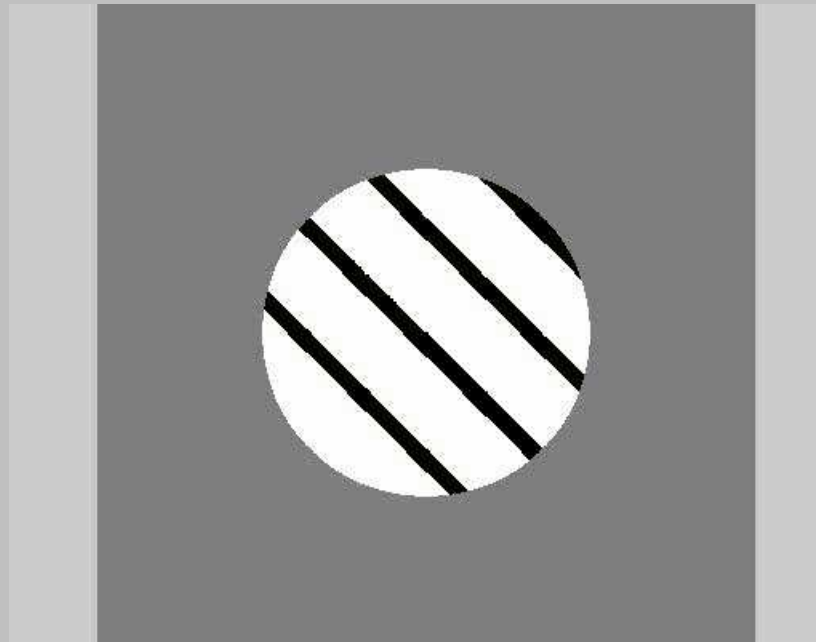
The 'aperture problem'



Why does this look like horizontal motion?

The edge of the stimulus contains 'terminators' that serve as a cue to the direction of motion.

The 'aperture problem'

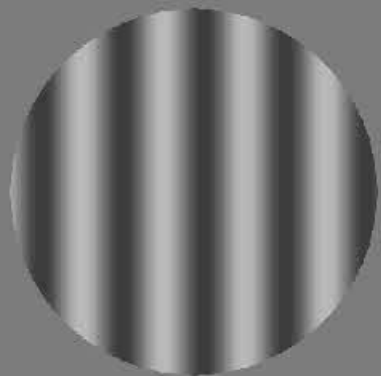


The overall average of the 'terminators' determines the overall direction of motion.

Gratings and Plaids



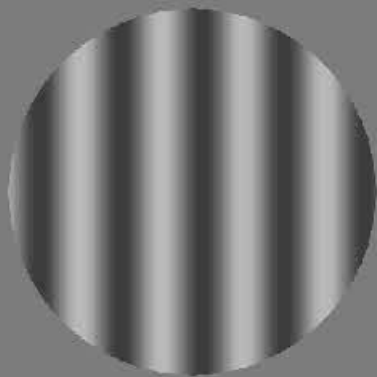
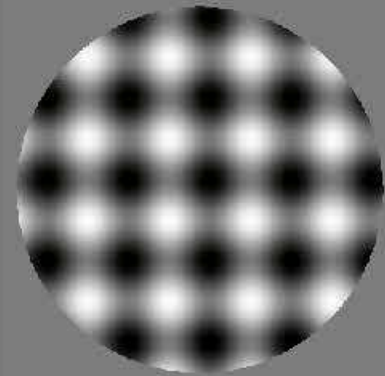
Gratings and Plaids



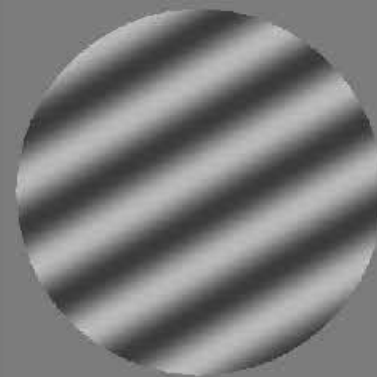
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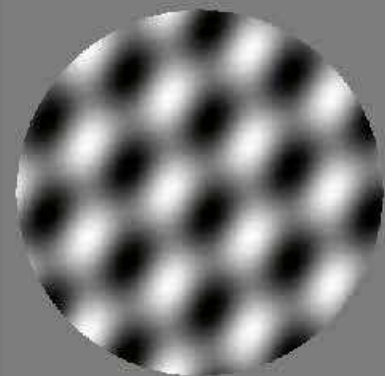
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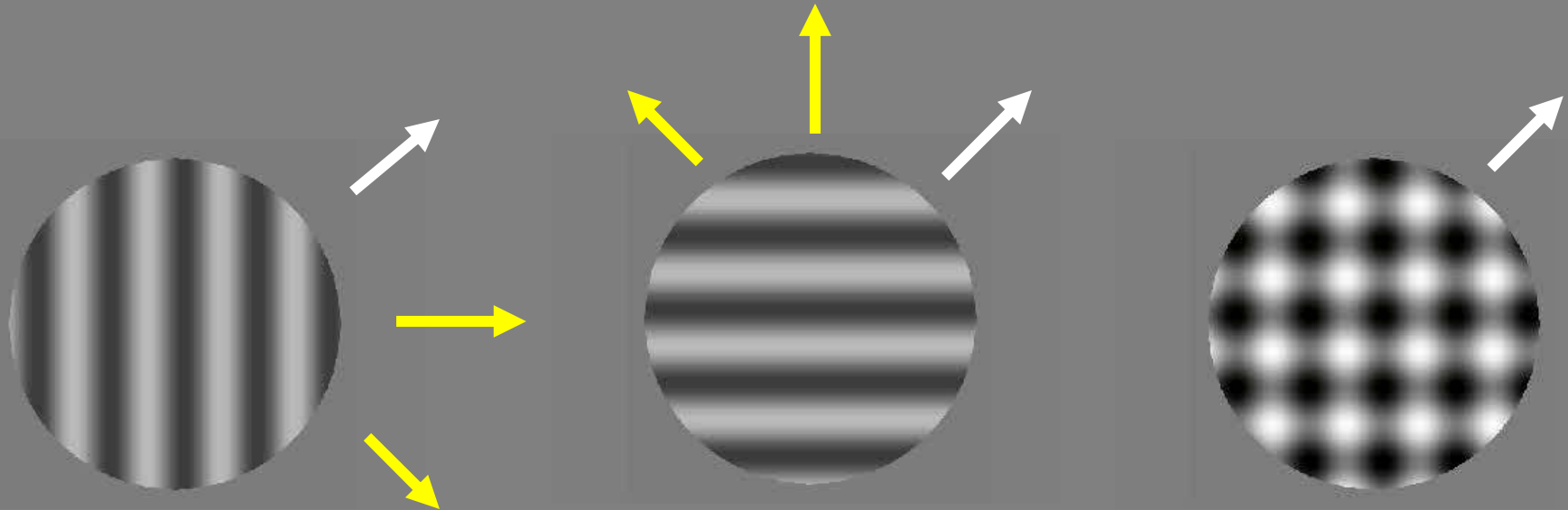


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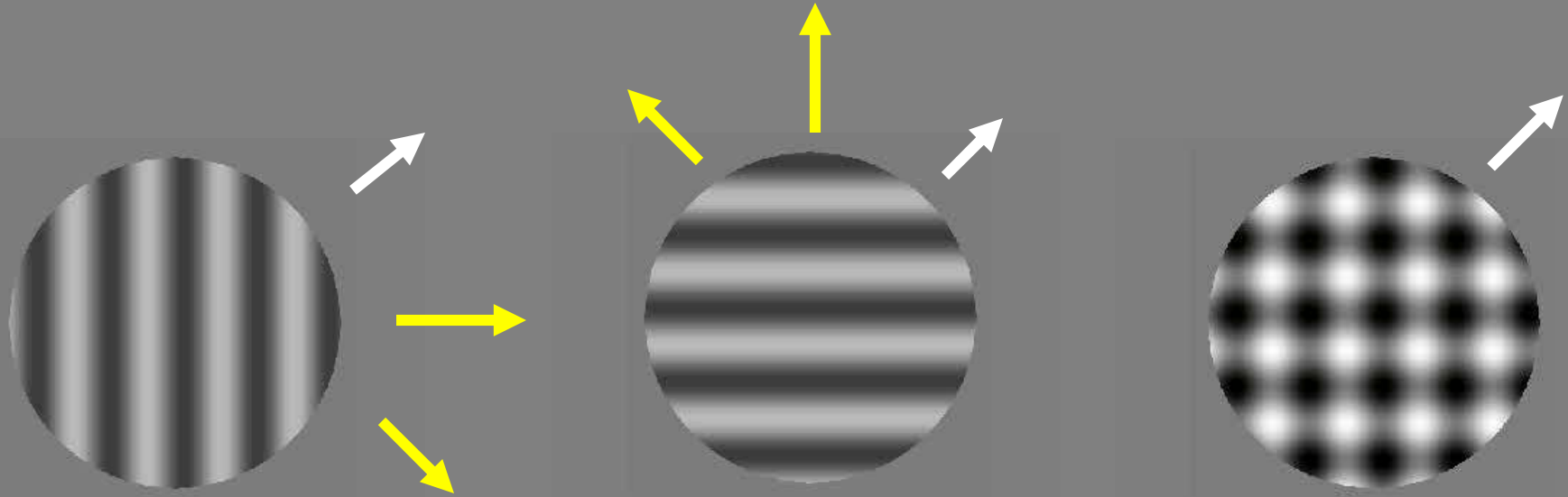


Which direction does the plaid go?

'intersection of constraints'



How will a direction-selective neuron respond to a plaid stimulus?



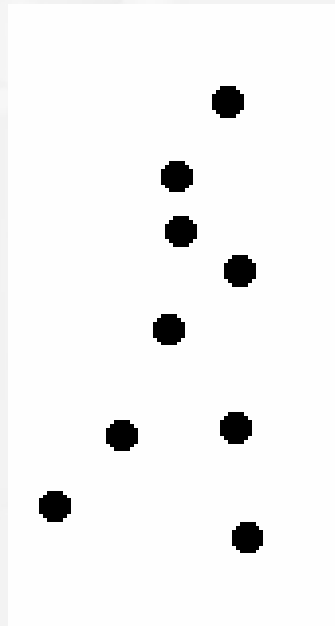
If you show a plaid stimulus to a V1 and some MT neurons, it responds best when **one** of its components is in the neuron's preferred direction. These are called '**component cells**'

But other MT cells will respond when the **whole pattern** moves in the preferred direction of the neuron. These are called '**pattern cells**'.

It is believed that component cells connect together to produce the properties of pattern cells.

Other kinds of motion stimuli

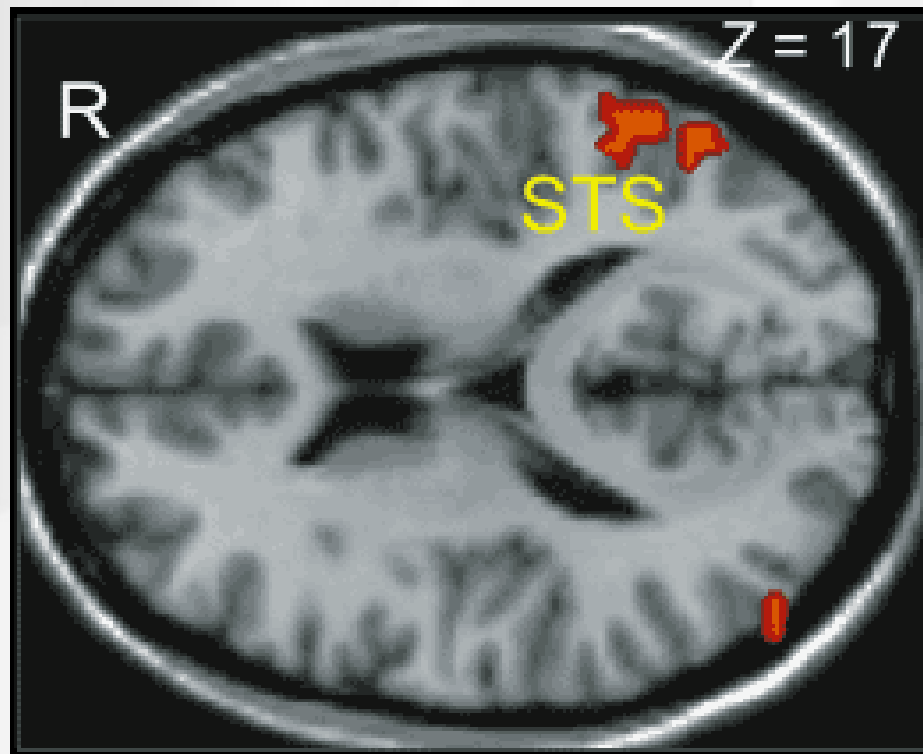
‘Biological Motion’ is another example of the kinetic depth effect.



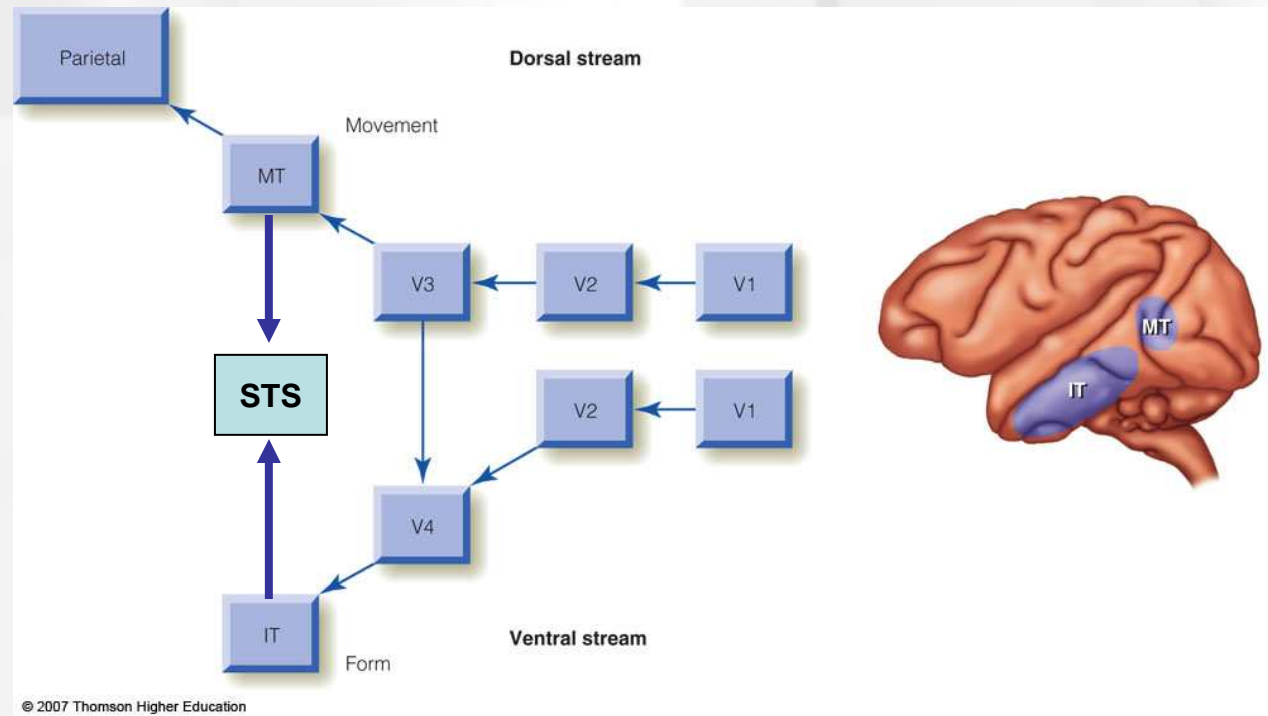
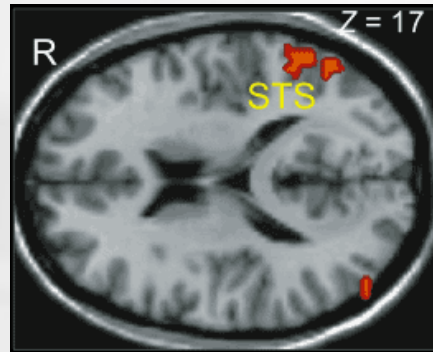
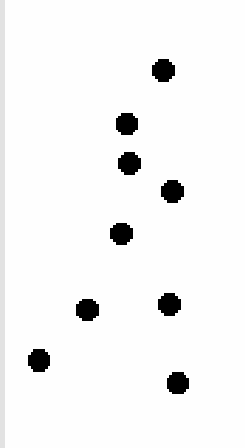
‘point light walker’

<http://www.biomotionlab.ca/Demos/BMLwalker.html>

fMRI studies show biological motion is processed in the superior temporal sulcus (STS)



The superior temporal sulcus (STS) receives projections from the Dorsal and the Ventral streams



If motion is perceived when an image moves on the retina,
then why don't we see motion when we move our eyes
from A to B?

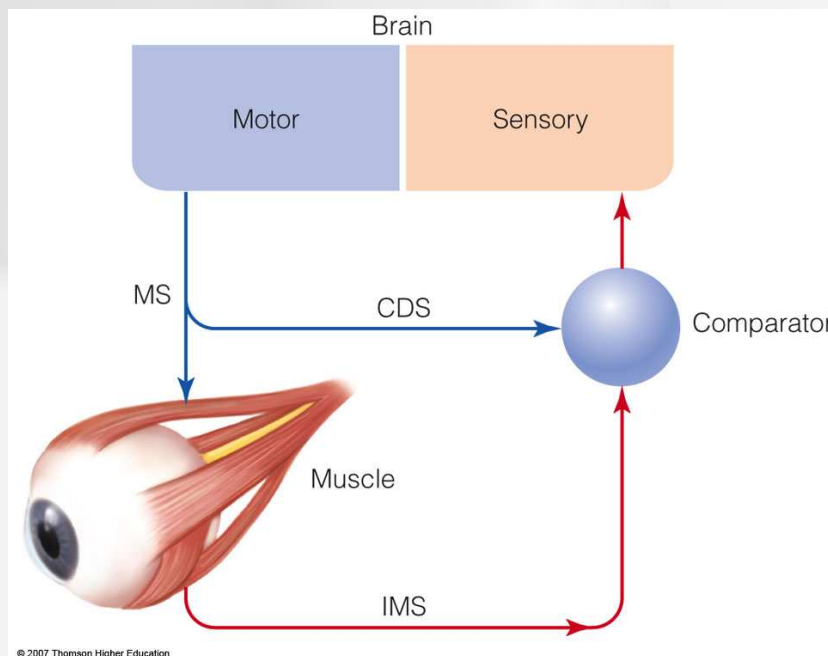


- Somehow, the visual system subtracts the perception of motion during an eye movement.

Corollary discharge theory

Movement perception depends on three signals:

1. Image movement signal (IMS) - movement of image stimulating receptors across the retina
2. Motor signal (MS) - signal sent to eyes to move eye muscles
3. Corollary discharge signal (CDS) - copy of the motor signal



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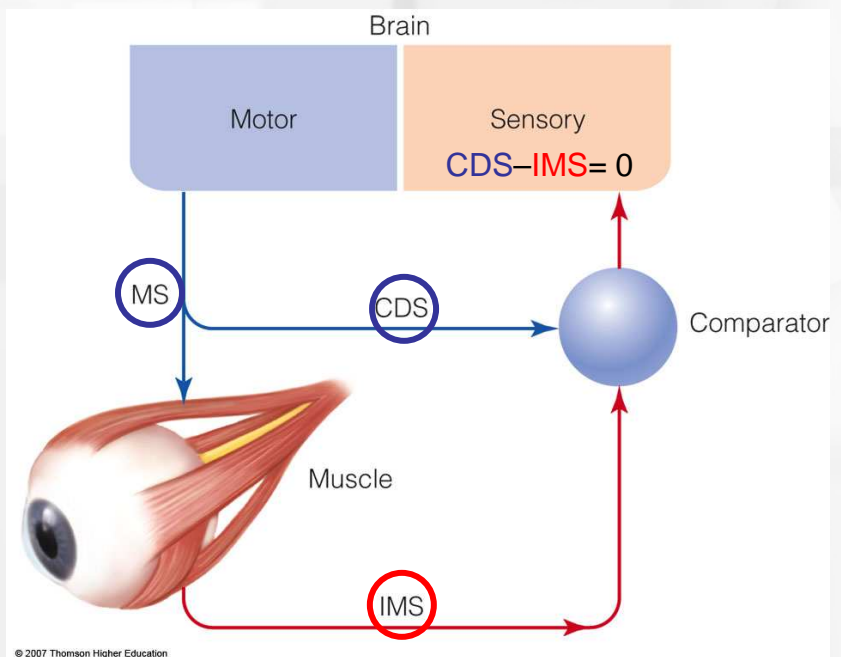
When you send a command to move your eyes, a copy of the motor signal is sent to the 'comparator'.

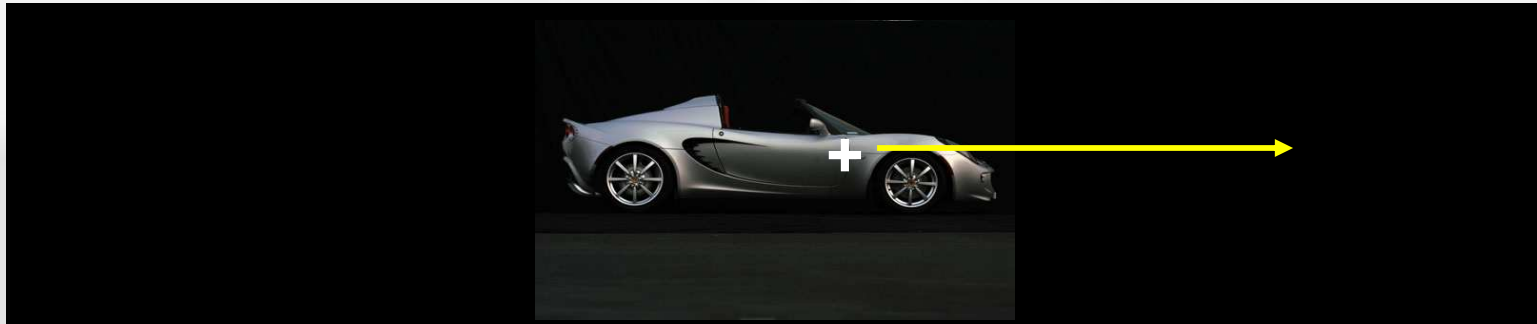
The image motion signal (IMS) is subtracted from the CDS to calculate the amount of 'real' motion in the world.



When you make a saccade from left to right:

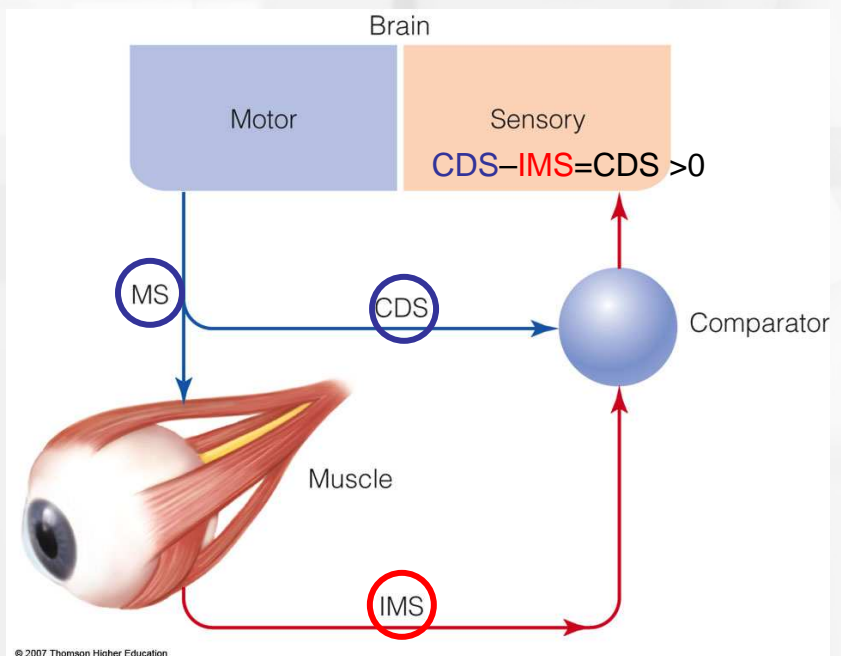
- 1) A motor signal is initiated (MS) which moves the eyes rightward.
- 2) A copy of this rightward signal is sent to the 'comparator' (CDS)
- 3) Leftward image motion (IMS) occurs on the retina.
- 4) The comparator subtracts the IMS from the CDS, telling the sensory system that there was no 'real' motion.





When you **track** an object that's moving rightward:

- 1) A motor signal is initiated (MS) which moves the eyes rightward.
- 2) A copy of this rightward signal is sent to the 'comparator' (CDS)
- 3) No image motion (IMS) occurs on the retina (because you're tracking the object).
- 4) The comparator subtracts the IMS (which is zero) from the CDS, giving telling the sensory system that **was** 'real' motion.



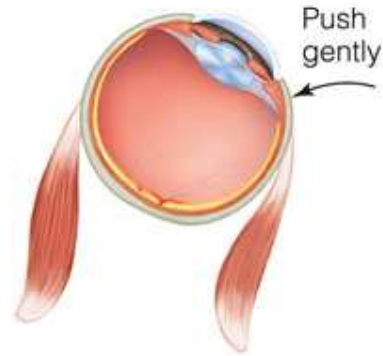
There are four ways to experience the effects of corollary discharge.
Three of them you can try at home.

Eye moves in dark

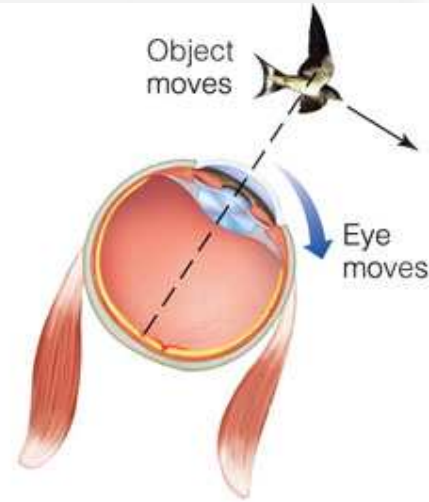


(a) Bleached patch stays stationary on retina as eye moves

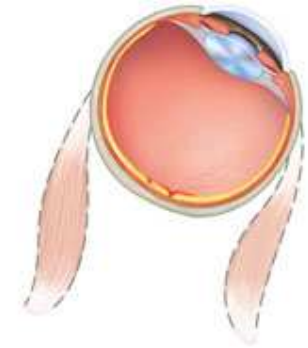
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(b) Push on eyeball; eye stationary



(c) Eye moves to follow target



(d) Eye muscles paralyzed; eye remains stationary when observer tries to move eye

$CDS > 0$

$IMS = 0$

Motion seen

$CDS = 0$

$IMS > 0$

Motion seen

$CDS > 0$

$IMS = 0$

Motion seen

$CDS > 0$

$IMS = 0$

Motion seen

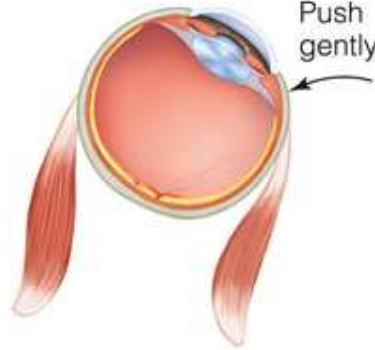
Eye moves in dark



(a) Bleached patch stays stationary on retina as eye moves

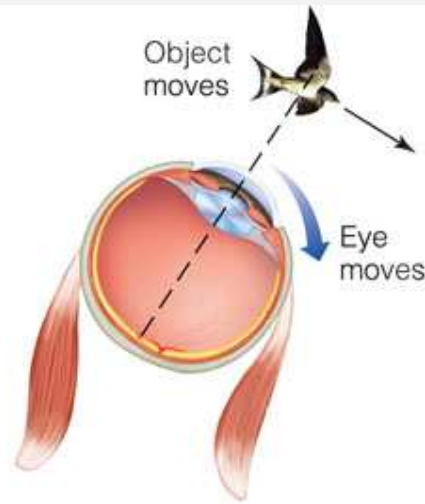
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Push gently

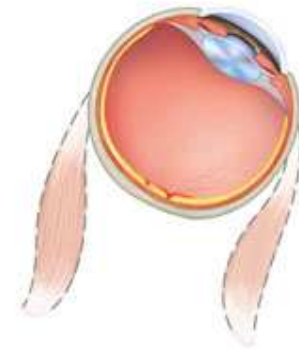


(b) Push on eyeball; eye stationary

Object moves



(c) Eye moves to follow target



(d) Eye muscles paralyzed; eye remains stationary when observer tries to move eye

Table 9.1 ■ Four ways corollary discharge can cause the perception of movement when there is no movement on the retina

Condition	Image Movement Signal?	Corollary Discharge Signal?	Perceive Movement?
1. Move eyes while viewing afterimage in the dark (Figure 9.9a).	NO, afterimage always stays on same place in retina.	YES, signal is sent to the eye muscles to move eyes.	YES
2. Push on eyeball while looking at a spot to keep eyes stationary (Figure 9.9b).	YES, moving the eyeball causes motion on the retina	NO, there was no command to Move the eyeball.	YES
3. Move eyes to follow a target (Figure 9.9c).	NO, the target stays on fovea at all times.	YES, signal sent to eye muscles to move eye.	YES
4. Paralyze eye muscles and try to move eye (Figure 9.9d).	NO, the eye doesn't move because it is paralyzed.	YES, signal sent to eye muscles to attempt to move eye.	YES

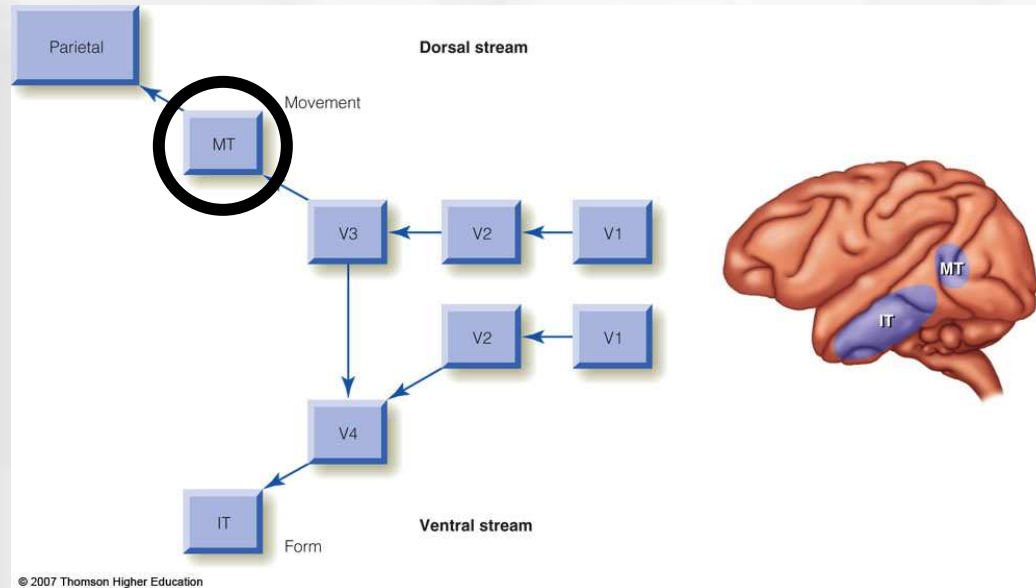
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Physiological Evidence for Corollary Discharge Theory

- Damage to the medial superior temporal area in humans leads to perception of movement of a stationary environment with the eyes move.
- Real-movement neurons found in monkeys (area MST) that respond only when a stimulus moves and do not respond when eyes move

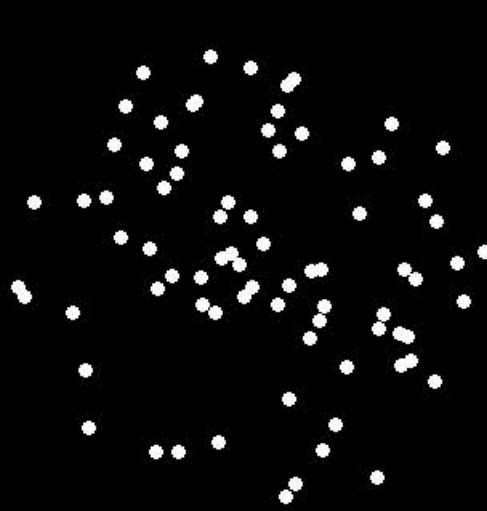
Nearly all neurons in MT are direction selective.

But how can we be sure that MT is involved in motion perception?

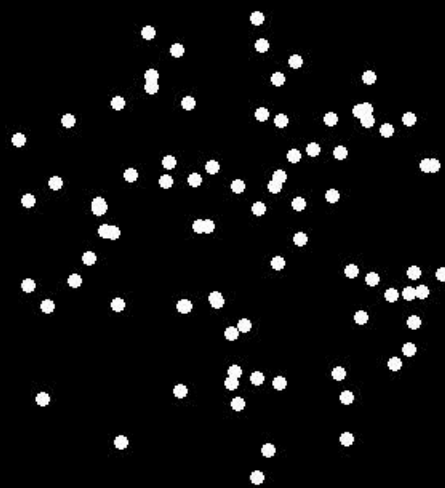


A series of experiments by Bill Newsome and colleagues established the link between MT and motion perception.

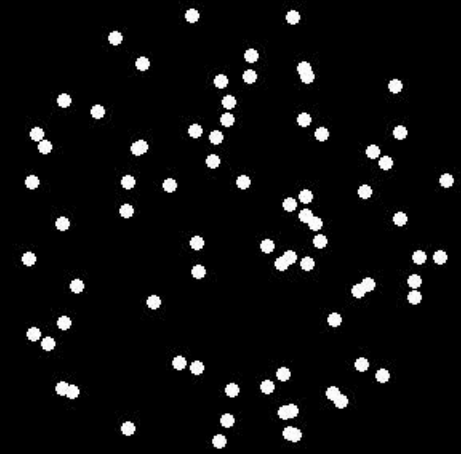
Correlated dot motion stimuli



0%

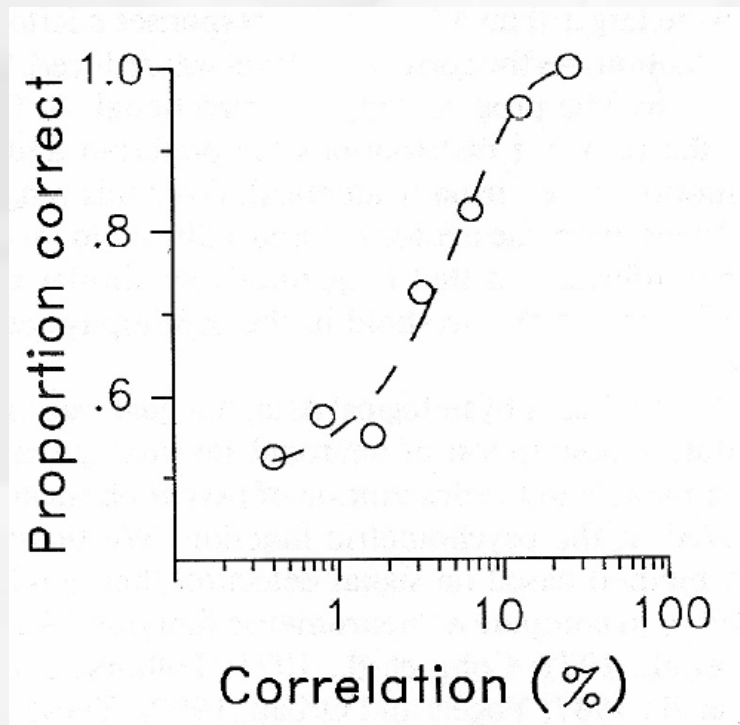


50%



100%

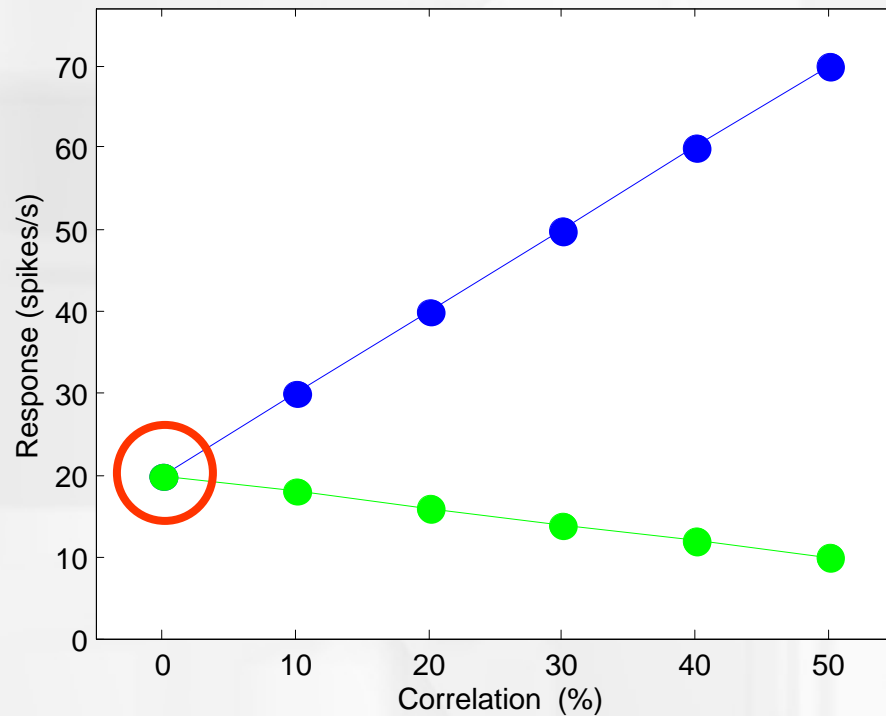
Newsome and colleagues trained monkeys to detect the motion in a correlated dot motion stimulus.



A trained monkey is as good as a human.

They then showed that a lesion in MT impaired motion perception.

MT neurons increase their firing rate with increasing correlation of dots in the neuron's preferred direction.

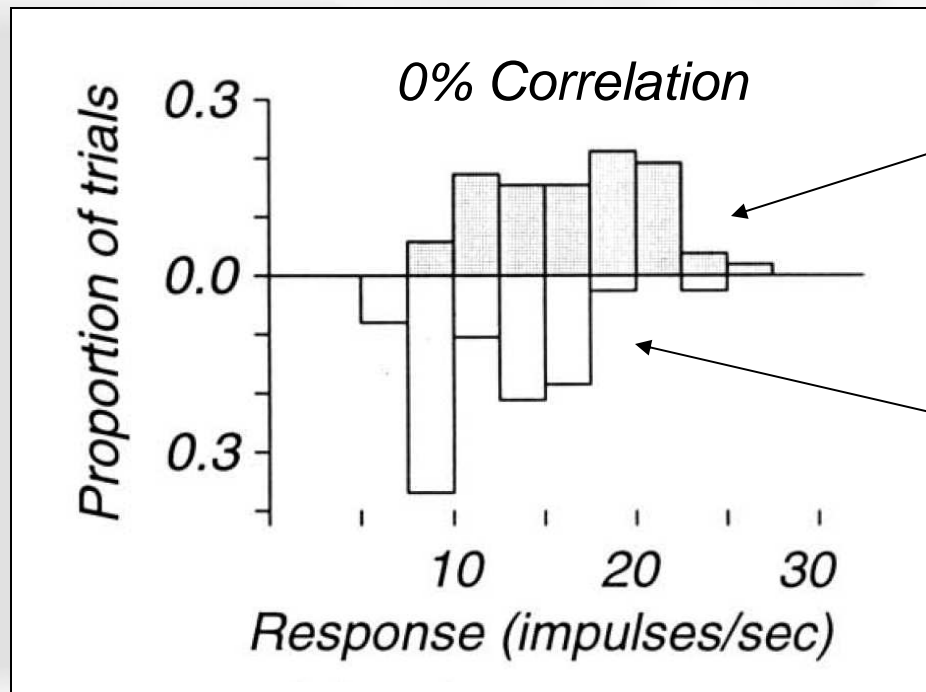


MT neurons decrease their firing rate with increasing correlation of dots in the opposite of the neuron's preferred direction.

Something interesting happens at 0% correlation.

Neurons responses vary slightly on a trial by trial basis.

Newsome et al. divided up the trials of a 0% coherence stimulus



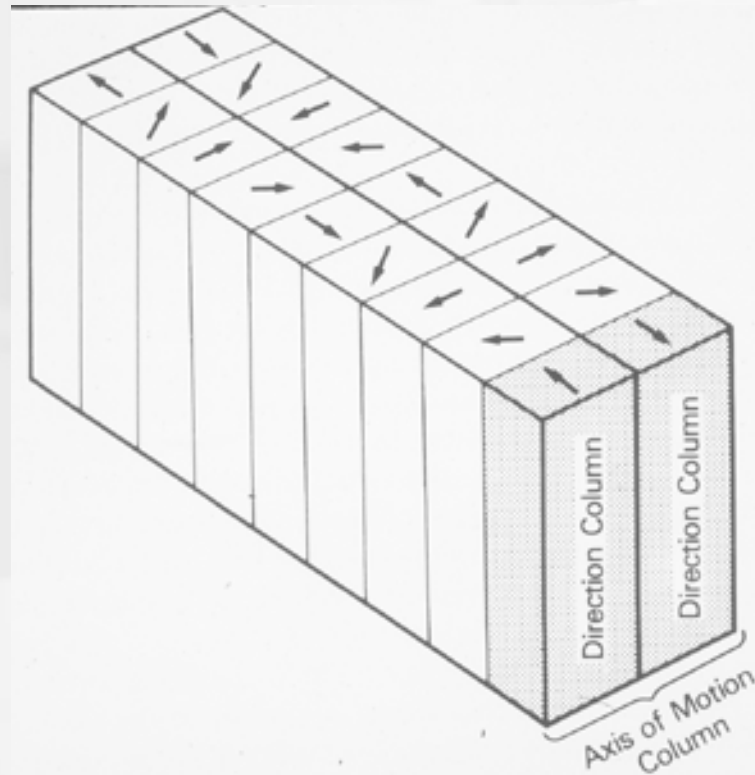
Histogram of firing rates for trials where the monkey thought the motion was in the neuron's preferred direction.

Histogram of firing rates for trials where the monkey thought the motion was in the opposite direction.

Firing rates were slightly higher on average for trials where the monkey guessed that the motion was in the preferred direction of the neuron.

This trial-by-trial variability was reflected in the monkey's perception of motion.

MT has direction-selective columns, much like orientation columns in V1.



Next, Newsome et al. used microstimulation to make MT neurons spike faster.

They found that when they microstimulated an upward selective column, the monkey was more likely to report upward motion.

Summary: Newsome et al. linked area MT with motion perception in 3 ways:

1. A lesion in MT impairs motion perception (similar to akinetopsia in humans).
2. The response of MT neurons to a zero correlation stimulus can predict the monkey's decision.
3. Microstimulation of a direction-selective column biases the monkey's percept of a moving stimulus.

