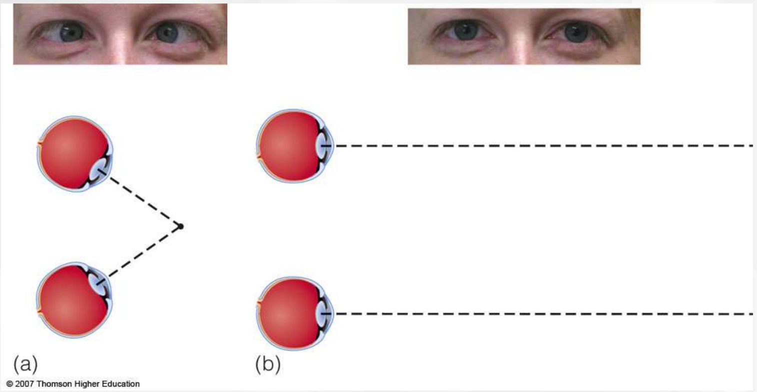
Chapter 8: Perceiving Depth and Size

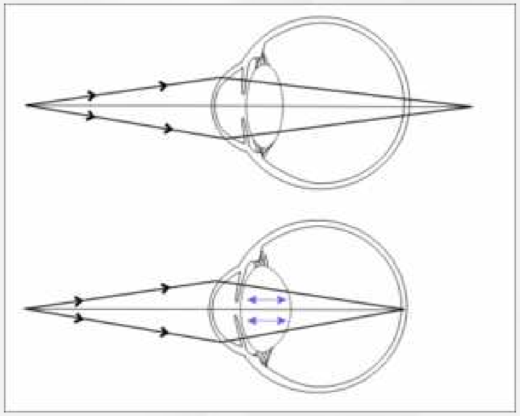
Cues to Depth Perception

- **Oculomotor** - cues based on sensing the position of the eyes and muscle tension

1. **Convergence** – knowing the inward movement of the eyes when we focus on nearby objects



2. **Accommodation** – feedback from changing the focus of lens.



Cues to Depth Perception

- **Monocular** - cues that come from one eye. Two categories:

  1. **Pictorial cues** - sources of depth information that come from 2-D images, such as pictures

  2. **Movement-produced cues**

Pictorial Cues

Occlusion - when one object partially covers another
Relative height - objects that are higher in the field of vision are more distant

Pictorial Cues

- **Relative size** - when objects are equal size, the closer one will take up more of your visual field
- **Perspective convergence** - parallel lines appear to come together in the distance
- **Familiar size** - distance information based on our knowledge of object size

Pictorial Cues

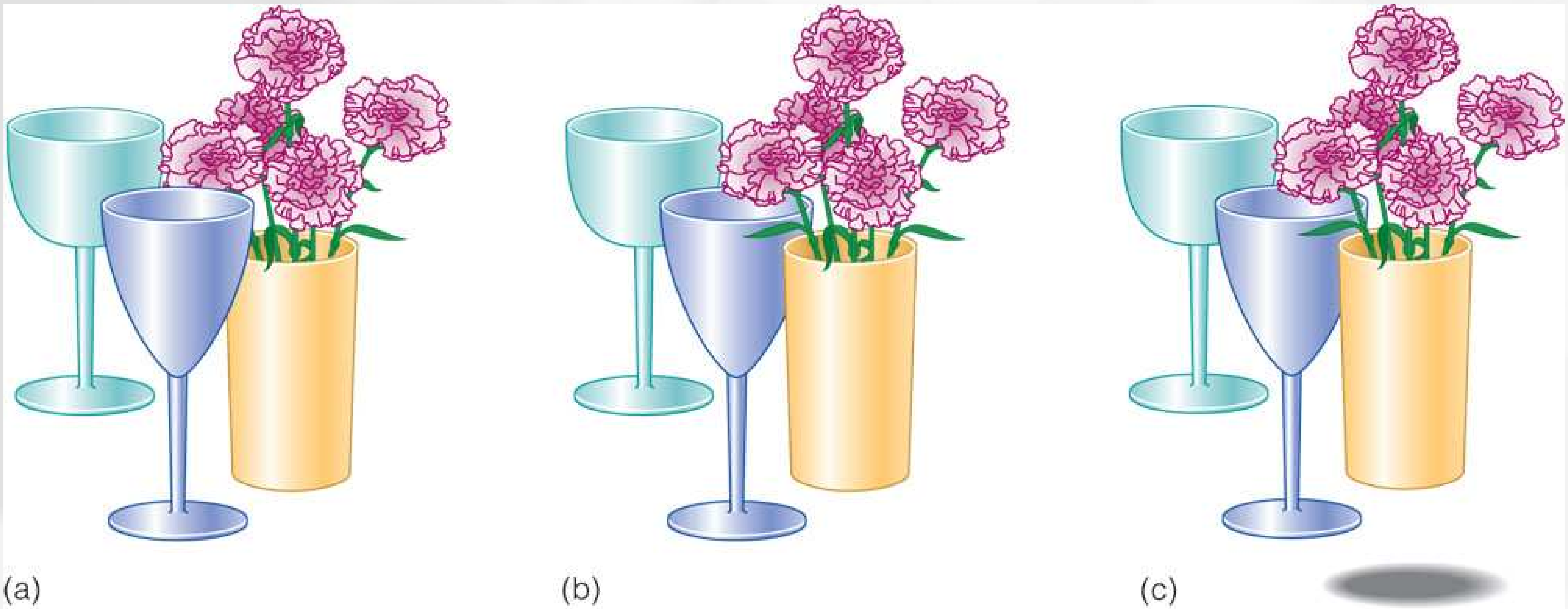
- **Atmospheric perspective** - distance objects are fuzzy and have a blue tint

Pictorial Cues

Texture gradient - equally spaced elements are more closely packed as distance increases

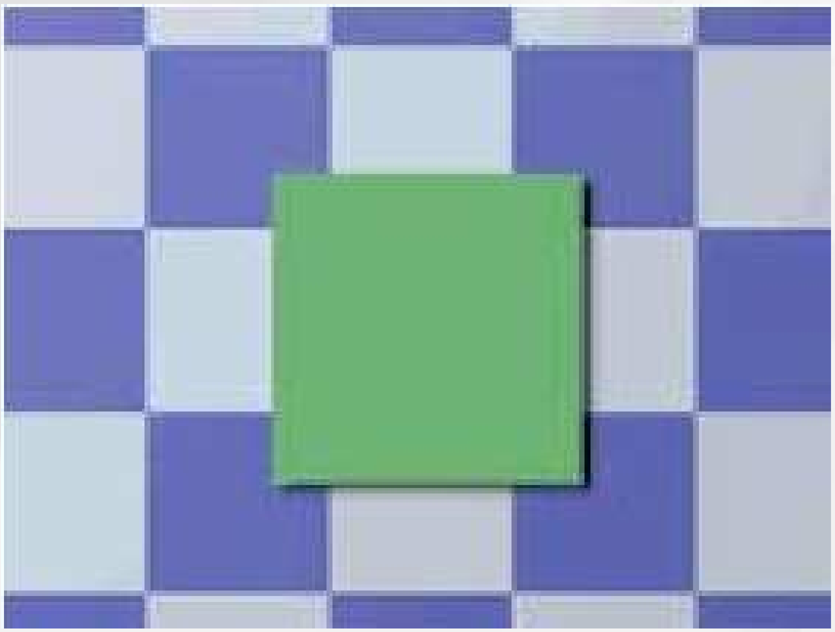
Pictorial Cues

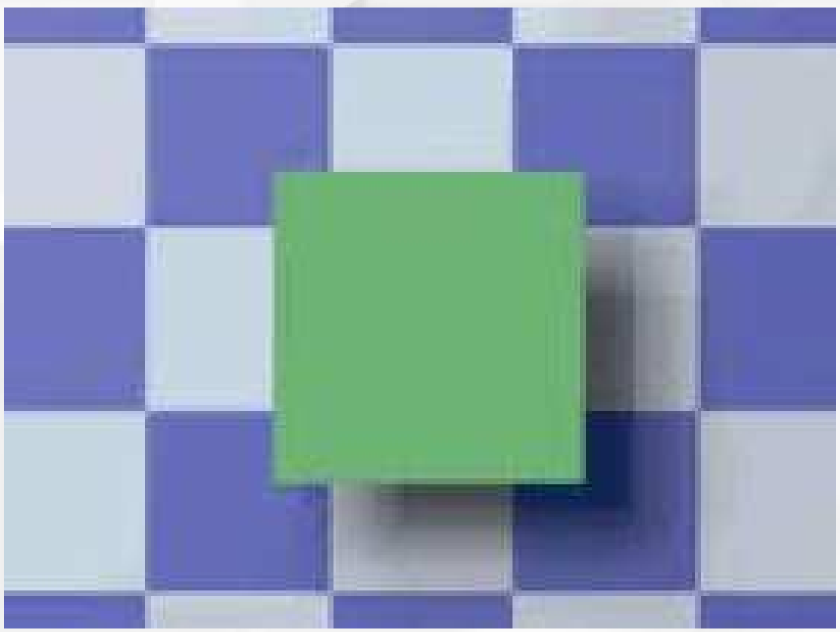
Shadows – can help indicate distance



Pictorial Cues

Shadows – can help indicate distance





Name the pictorial cues in this scene

atmospheric perspective
texture gradient
shadows

Name the pictorial cues in this scene

Cestello Annunciation by Sandro Botticelli, circa 1489-1490.

1. Occlusion
2. Relative height
3. Relative size (familiar size)
4. Cast shadows
5. Atmospheric perspective
6. Perspective convergence
7. Texture gradient

Motion-Produced Cues

- **Motion parallax** - close objects in direction of movement glide rapidly past but objects in the distance appear to move slowly
- **Deletion and accretion** - objects are covered or uncovered as we move relative to them
  - Also called occlusion-in-motion

Table 8.1 ▮ *Range of effectiveness of different depth cues*

Depth Information	0–2 Meters	2–20 Meters	Above 30 Meters
Occlusion	✓	✓	✓
Relative size	✓	✓	✓
Accommodation and convergence	✓		
Movement	✓	✓	
Relative height		✓	✓
Atmospheric perspective			✓

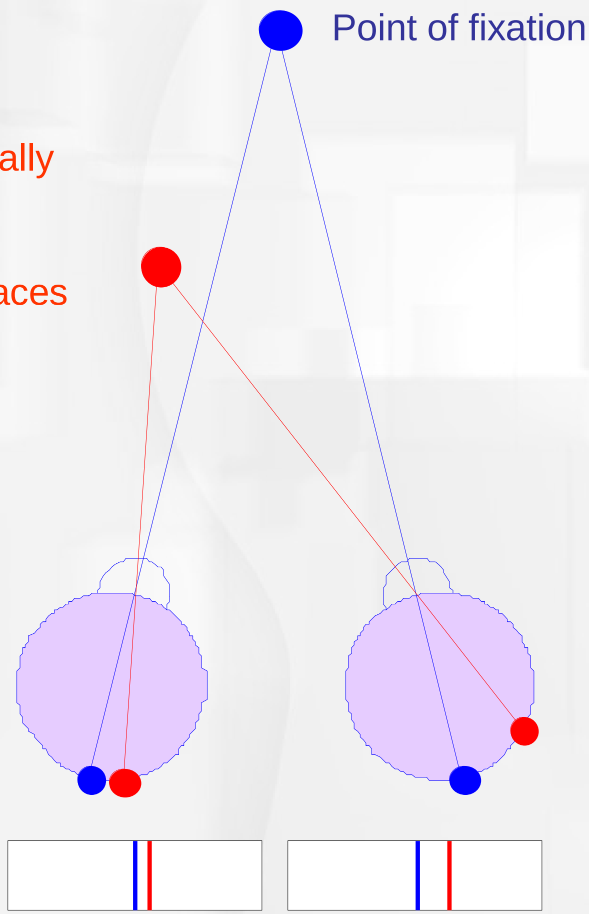
Source: Based on Cutting & Vishton, 1995.

Binocular Depth Information

- Binocular disparity - difference in images between the two eyes

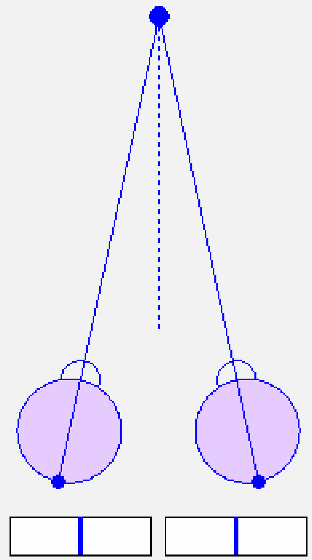
Points away from fixation will usually have **binocular disparity**:

the point will project to different places on the two retinas.

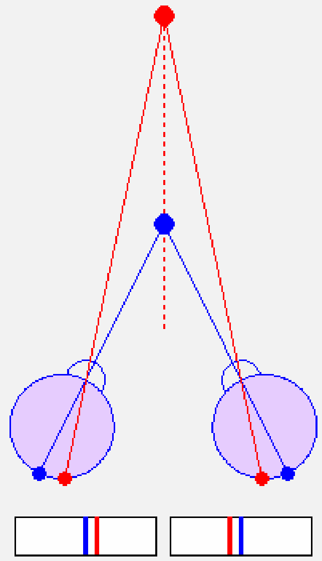


In this example, the disparity on the left is smaller than the disparity on the right.

We make **vergence movements**
to keep an object at fixation on the fovea of both eyes.



Once you're fixating, the relative positions of other locations on the two retinas can serve as a cue to depth.

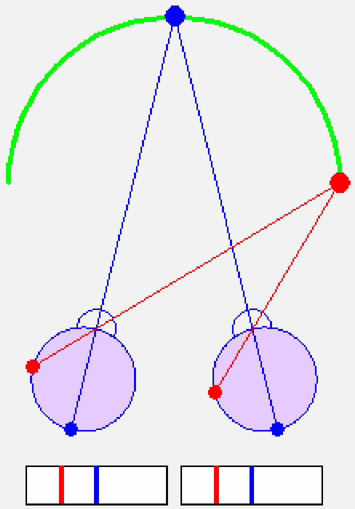


Binocular disparity

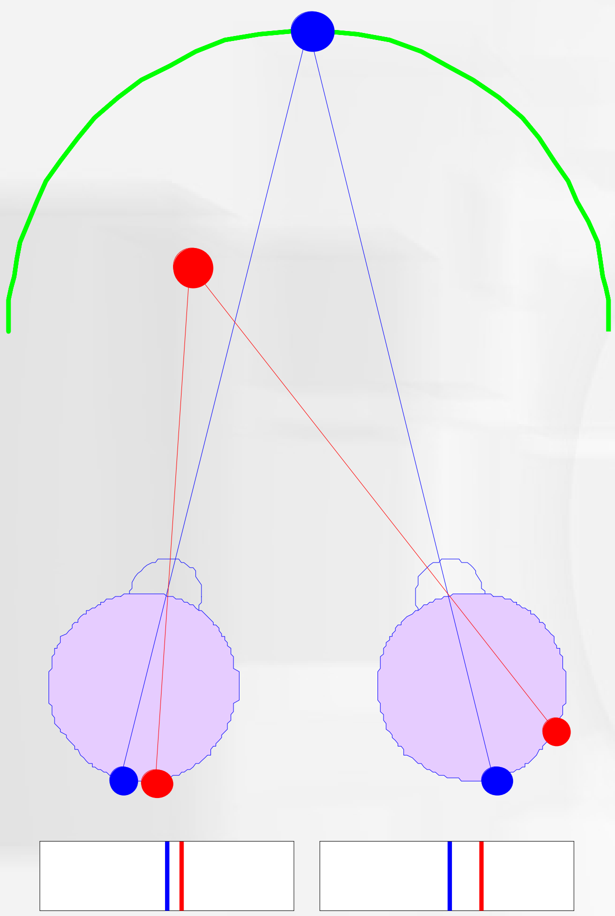
For objects straight in front of you,
if it's in front of fixation: **crossed disparity**
behind fixation: **uncrossed disparity**

It's a little more complicated for objects that aren't directly in front of you.

The horopter - imaginary circle that passes through the point of focus. Objects on the horopter fall on corresponding points on the retina

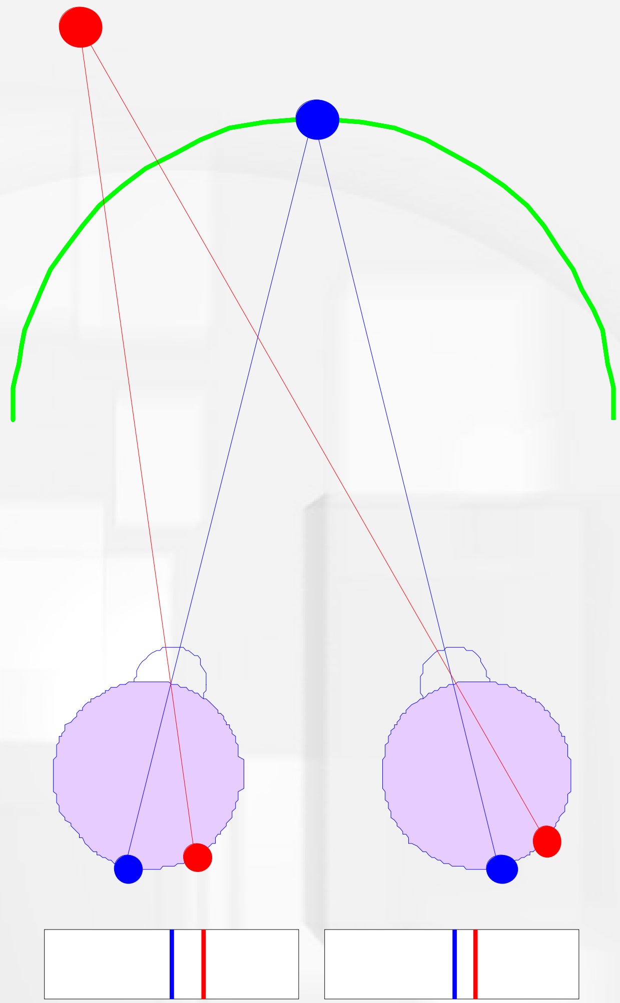


All objects on the horoptor have neither crossed, nor uncrossed disparity



Objects inside the horoptor have
crossed disparity:

Inside the horoptor, objects in the
near eye have less disparity.



Objects outside the horoptor
have uncrossed disparity

Outside the horoptor, objects in
the near eye have more disparity.

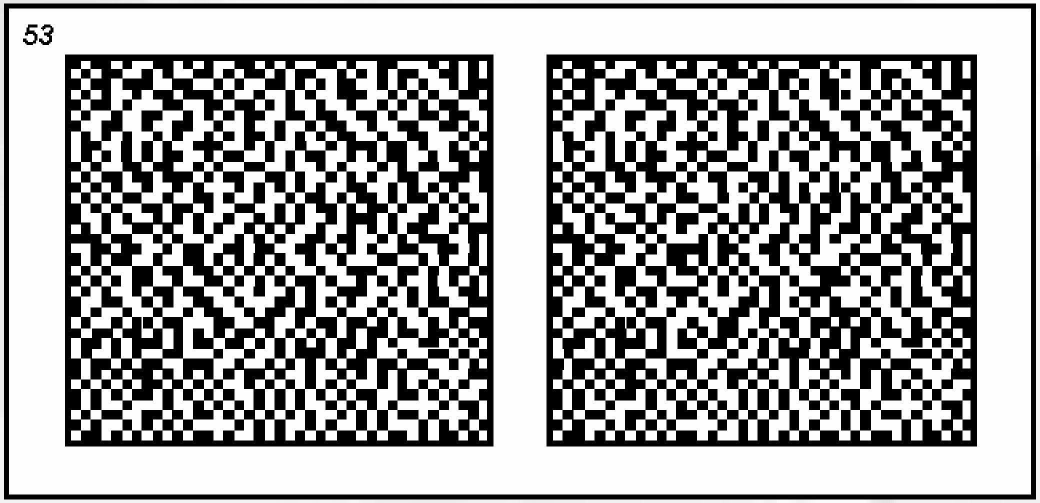
- **Stereopsis** - depth information provided by binocular disparity
  - Stereoscope uses two pictures from slightly different viewpoints
  - 3-D movies use the same principle and viewers wear glasses to see the effect

(a) Left eye image

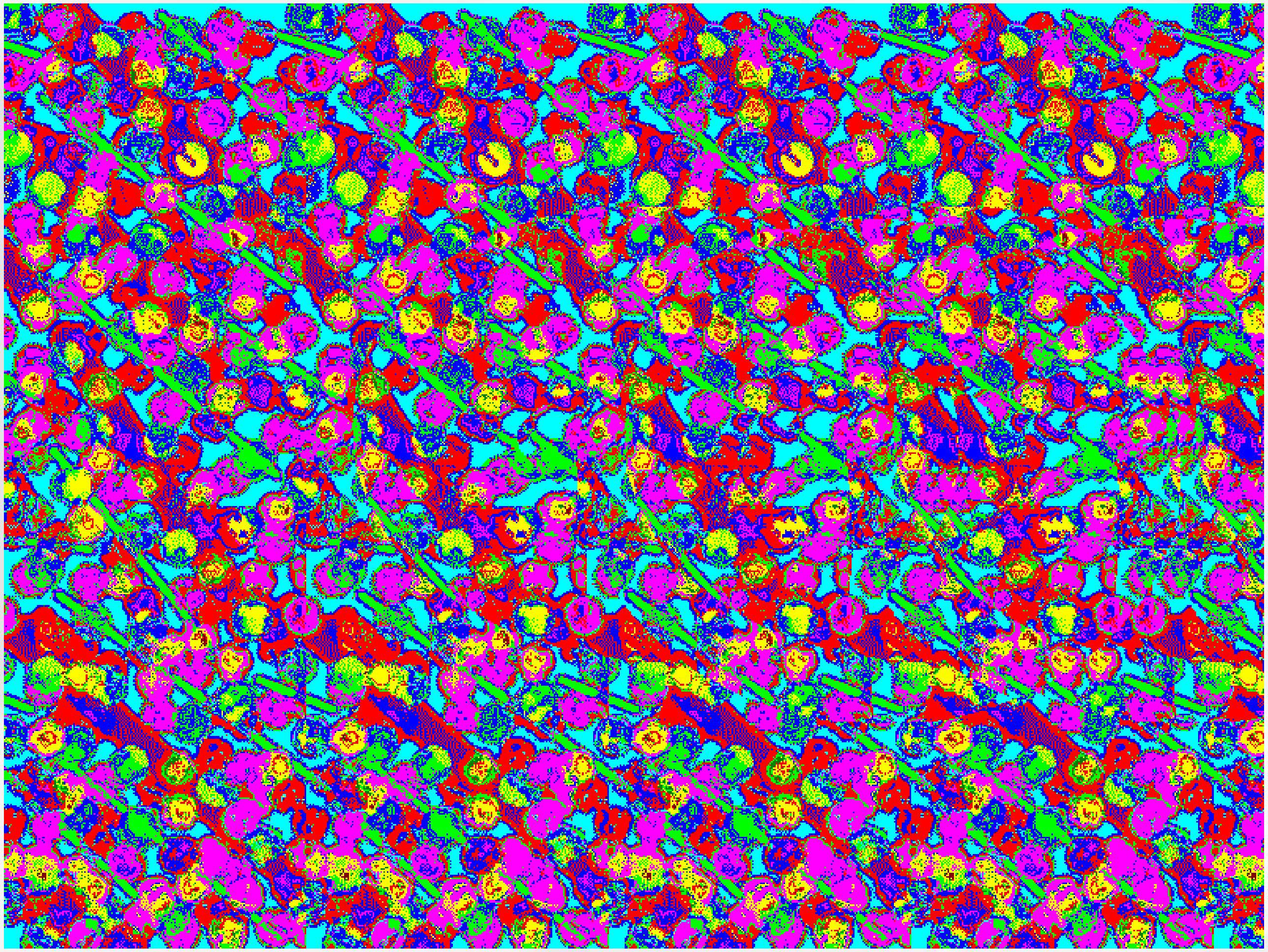
(b) Right eye image

Two images of a stereoscopic photograph. The difference between the two images, such as the distances between the front cactus and the window in the two views, creates retinal disparity. This creates a perception of depth when (a) the left image is viewed by the left eye and (b) the right image is viewed by the right eye.

Random-dot stereogram has two identical patterns with one shifted to the right

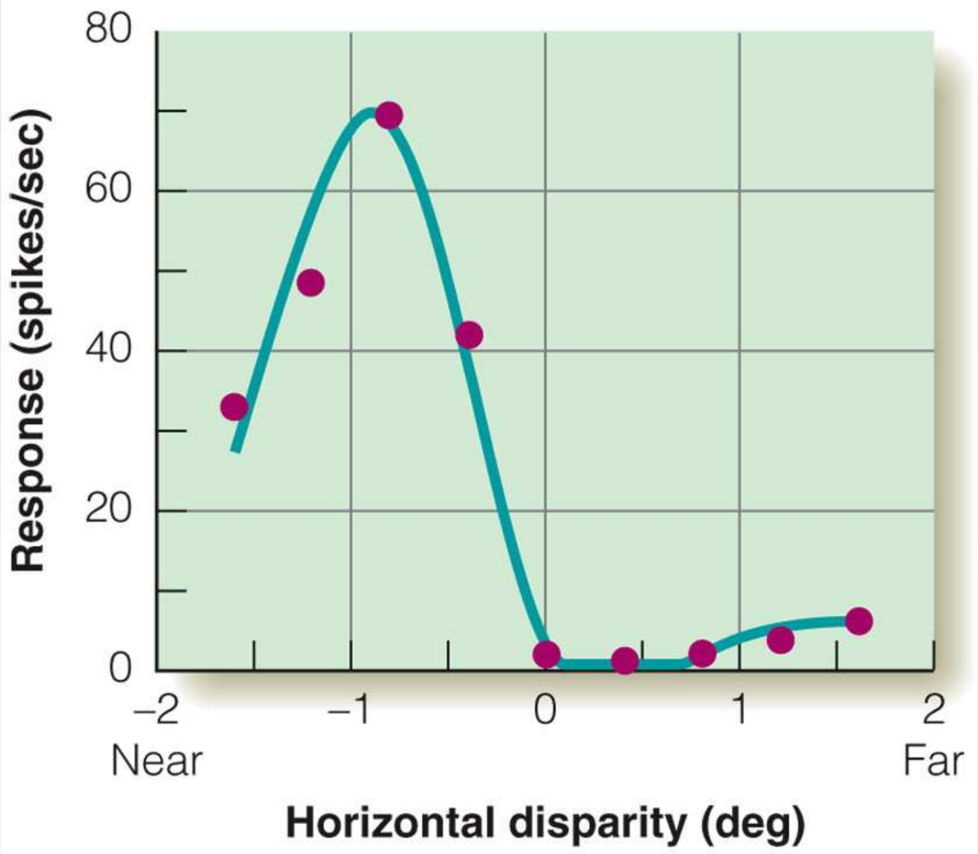


‘Auto stereograms’ work on the same principle.



Physiology of Depth Perception

- Neurons have been found that respond best to binocular disparity
  - Called binocular depth cells or disparity selective cells
    - These cells respond best to a specific *degree* of disparity between images on the right and left retinas



(Show Hubel and Wiesel's binocular neuron movie)

Connecting Binocular Disparity and Depth Perception

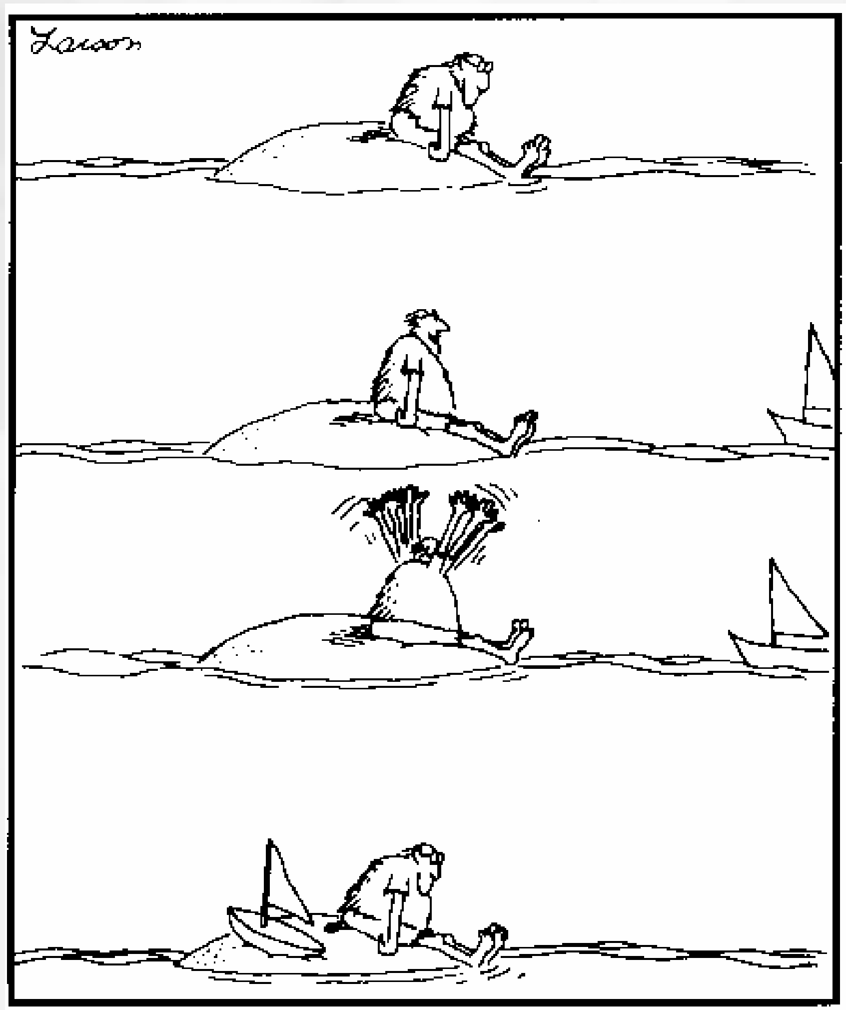
- Experiment by Blake and Hirsch
  - Cats were reared by alternating vision between two eyes
  - Results showed that they:
    - Had few binocular neurons
    - Were unable to use binocular disparity to perceive depth

Around 10% of human adults cannot use stereopsis for depth perception. They are ‘stereoblind’.

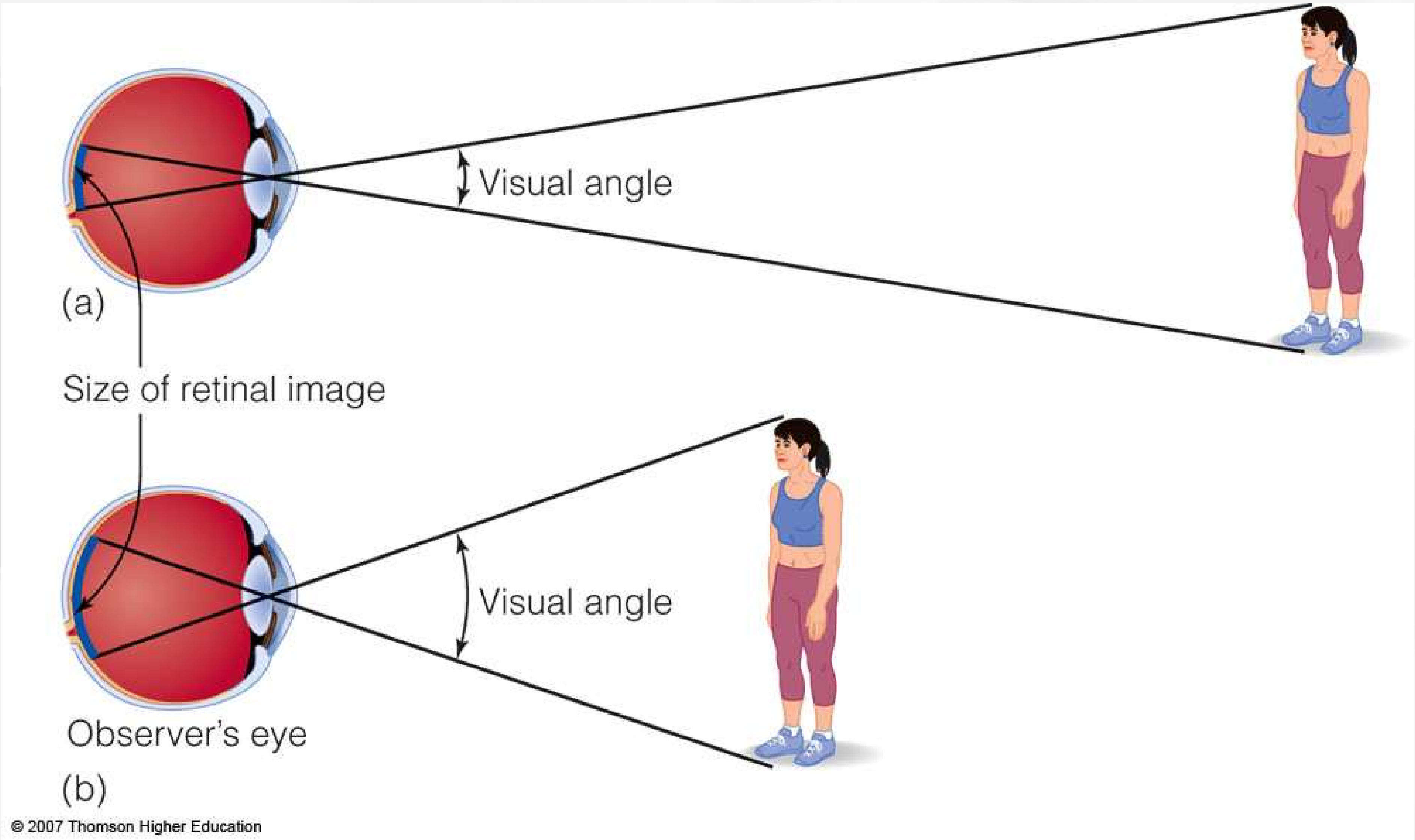
Stereopsis isn’t helpful for distances beyond about 6 feet anyway.

Size Perception

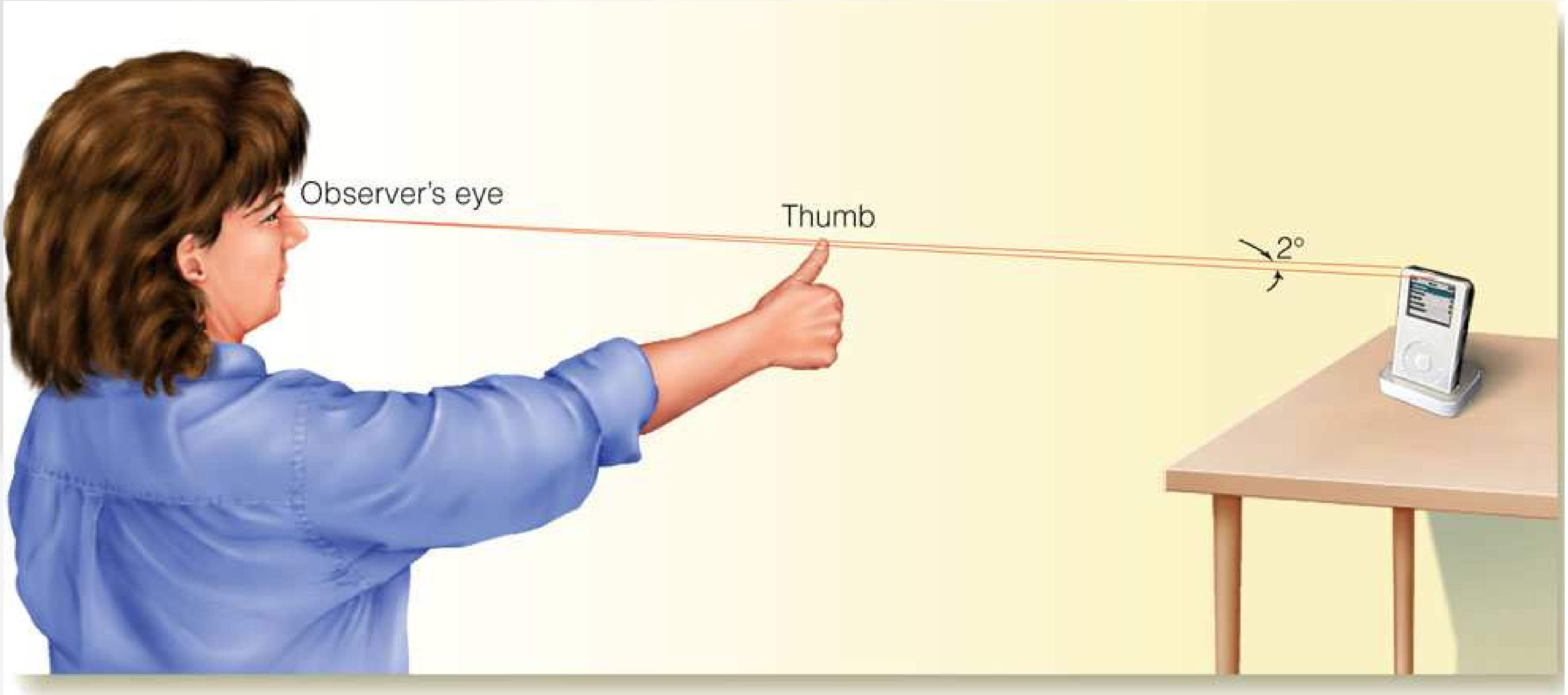
Distance and size perception are interrelated



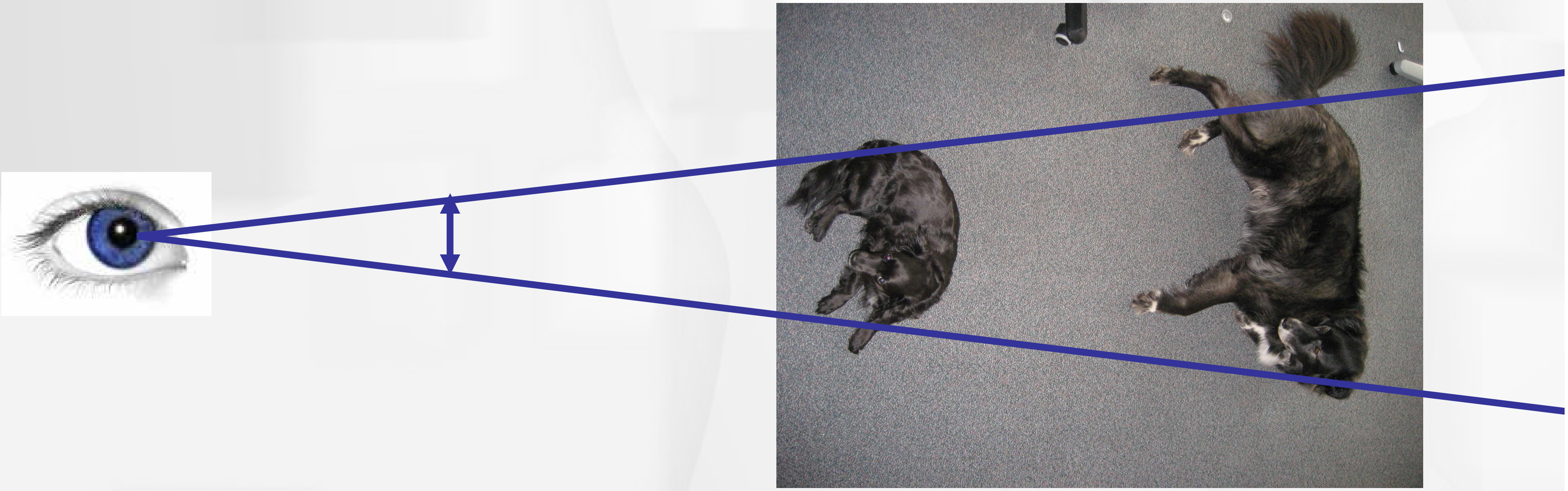
The *Visual angle* depends on both the size of the object and the distance from the observer

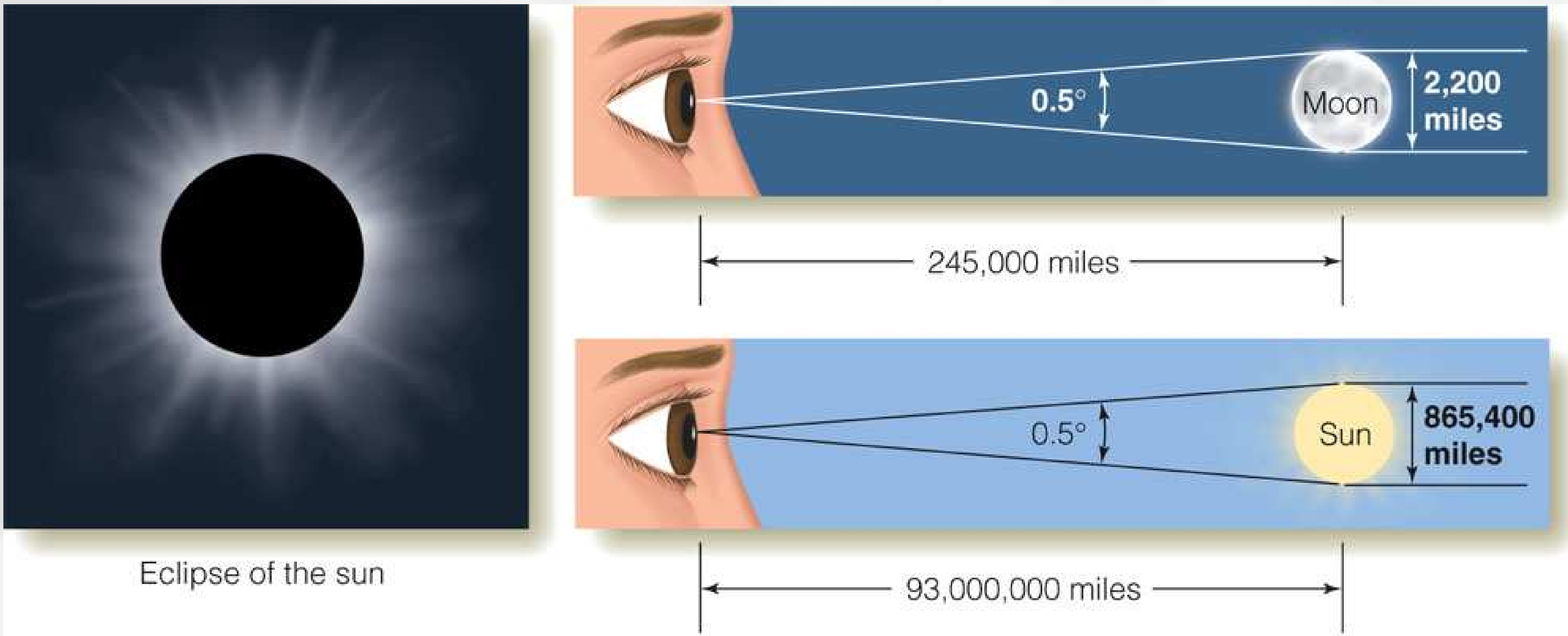


The moon and sun subtend about 0.5 degrees of visual angle, your thumb subtends about two degrees, and your average computer monitor subtends about 30 degrees (assuming you are viewing it from two feet away).



These two dogs subtend approximately the same visual angle.





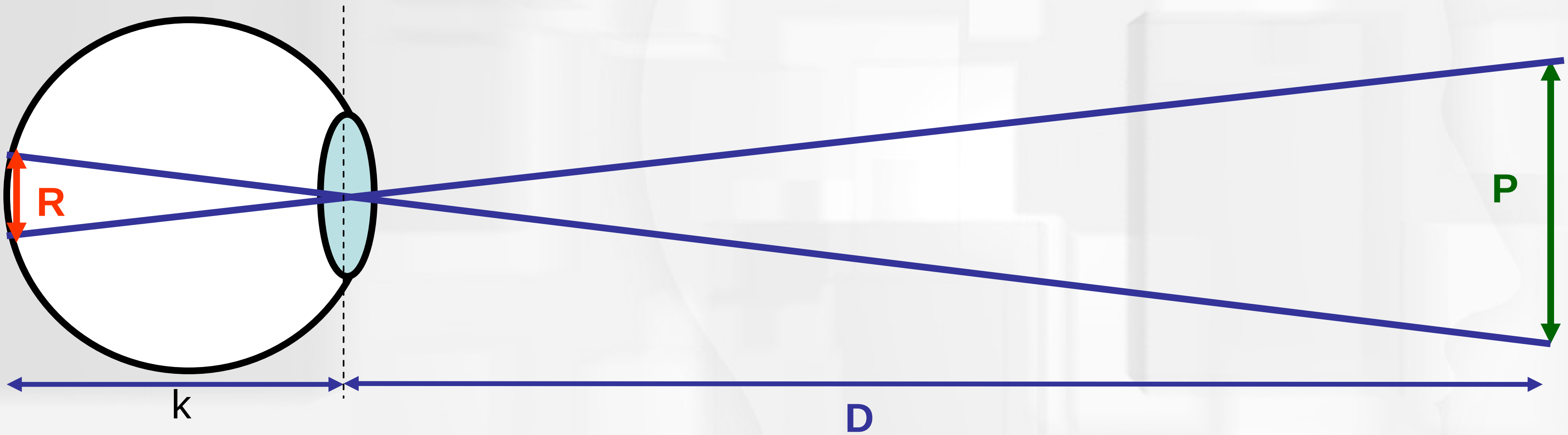
The moon’s disk almost exactly covers the sun during an eclipse because the sun and the moon have the same visual angles.

Size Constancy

- Perception of an object's size remains relatively constant
- This effect remains even if the size of the object on the retina changes

Size-distance scaling equation:

Perceived size (P) ~ retinal image size (R) X perceived distance (D)

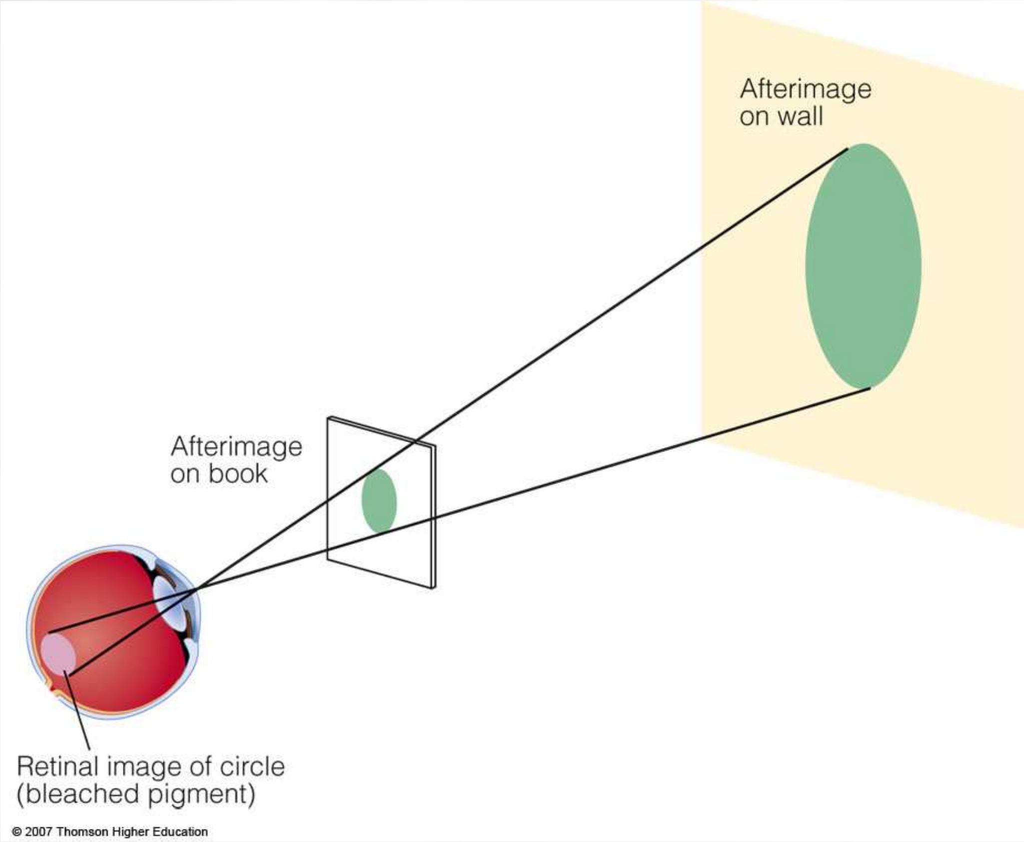


$$\frac{P}{D} = \frac{R}{k} \qquad P = \frac{RD}{k} \qquad P \sim RD$$

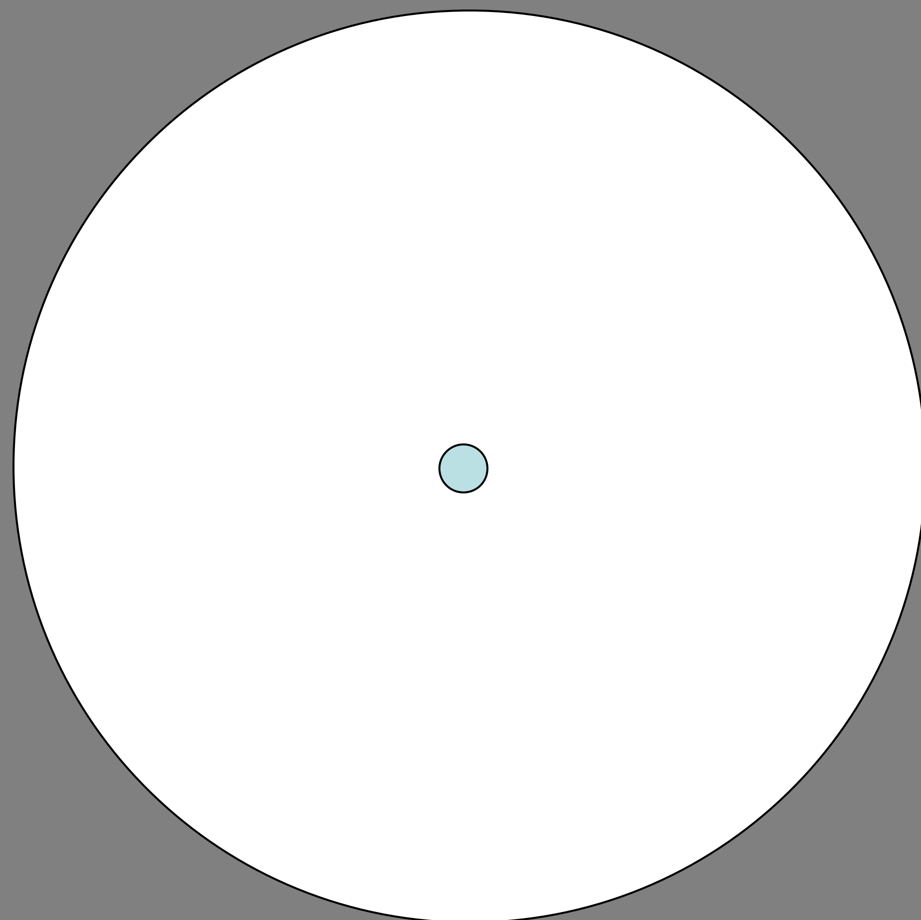
Size-Distance Scaling

Perceived size (P) ~ retinal image size (R) X perceived distance (D)

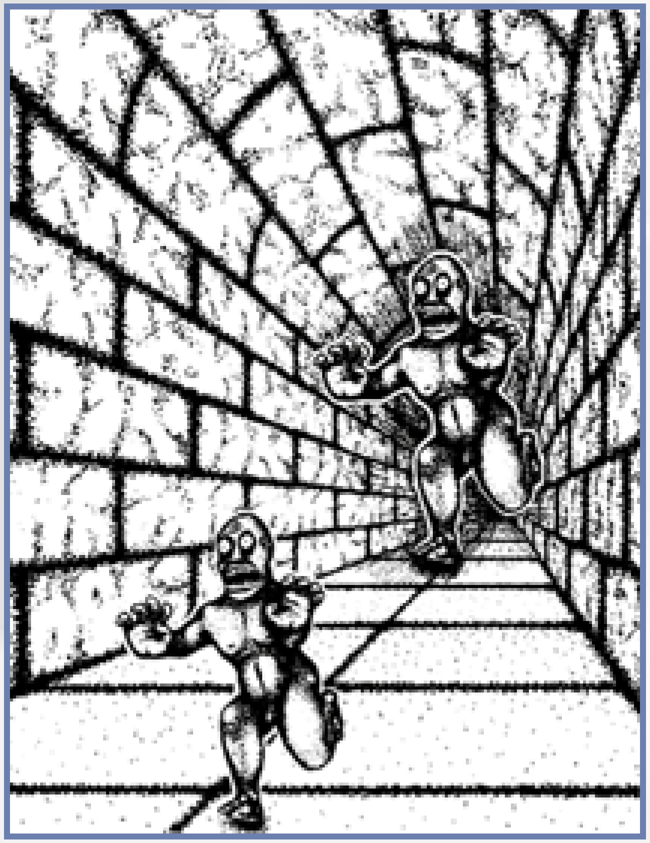
- Emmert's law: use an afterimage to keep retinal image size constant.
  - If you keep the retinal image size constant, changing the perceived distance should change the perceived size.

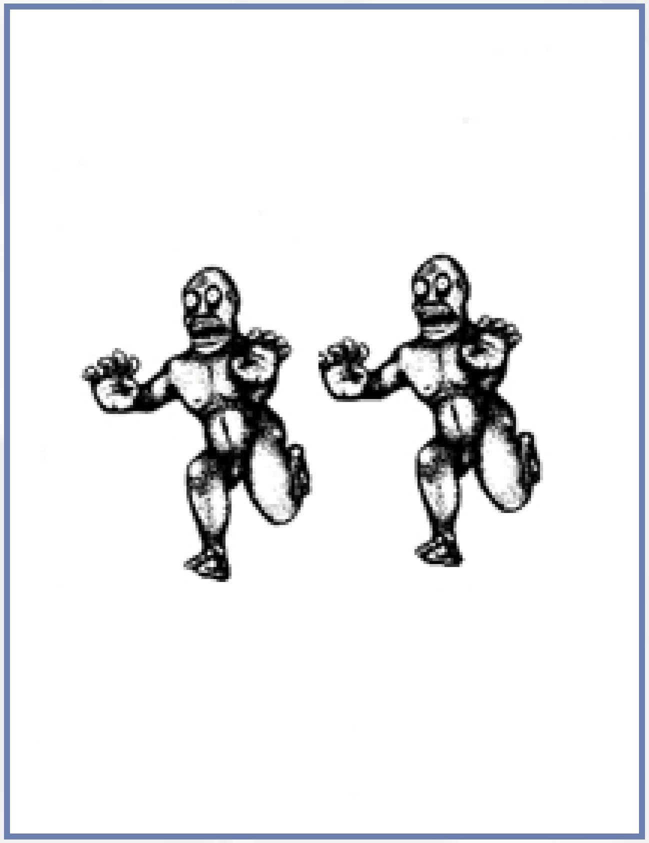


Emmert’s law:



Many visual Illusions are caused by manipulations of size constancy.





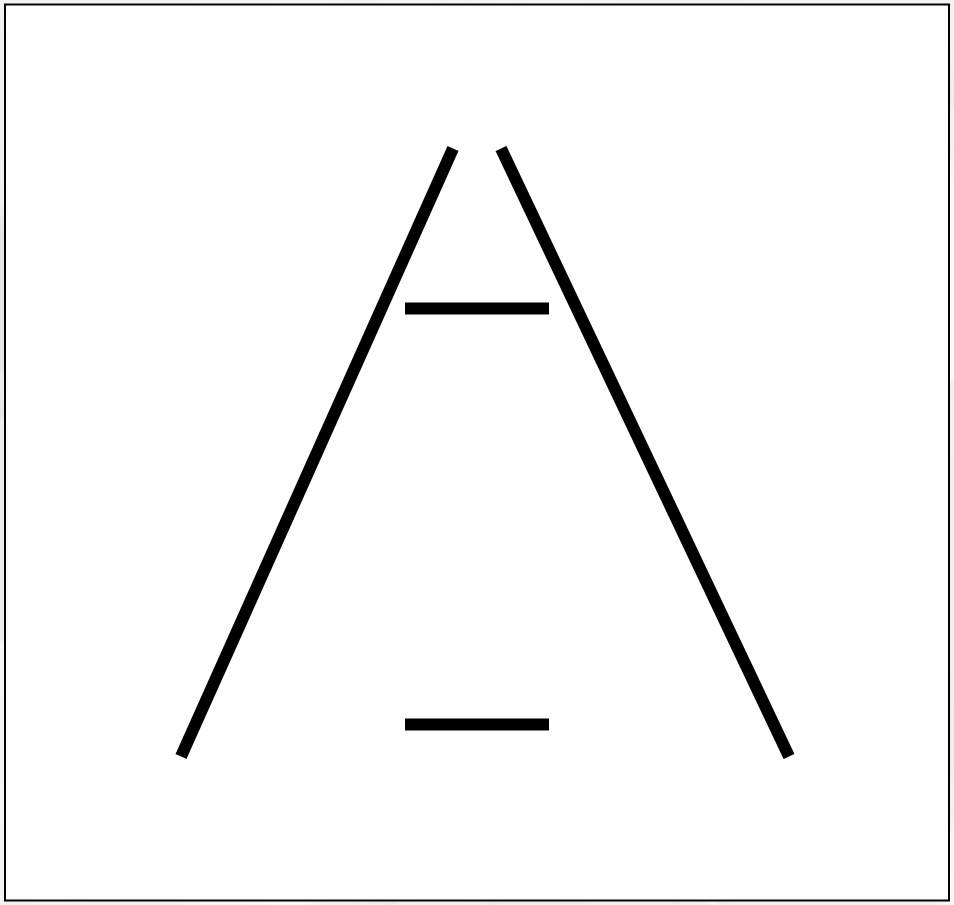
What's going on here?

perceived size = retinal size X perceived distance

Monocular cues to depth: relative height, ~~perspective convergence, texture gradient~~

perceived size = retinal size X perceived distance

Now we understand the ‘Ponzo Illusion’.



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Monocular cues to depth: relative height, perspective convergence

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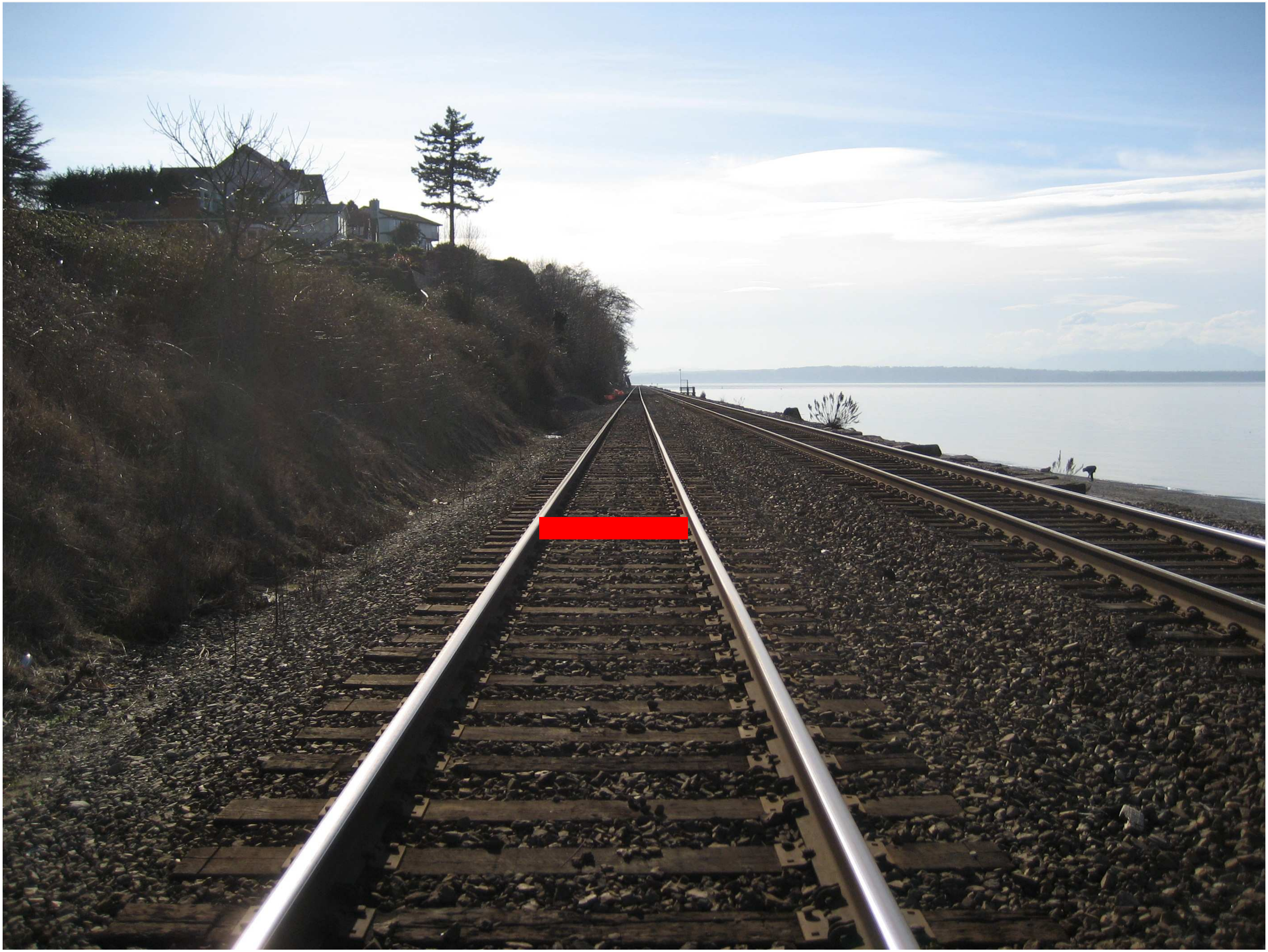
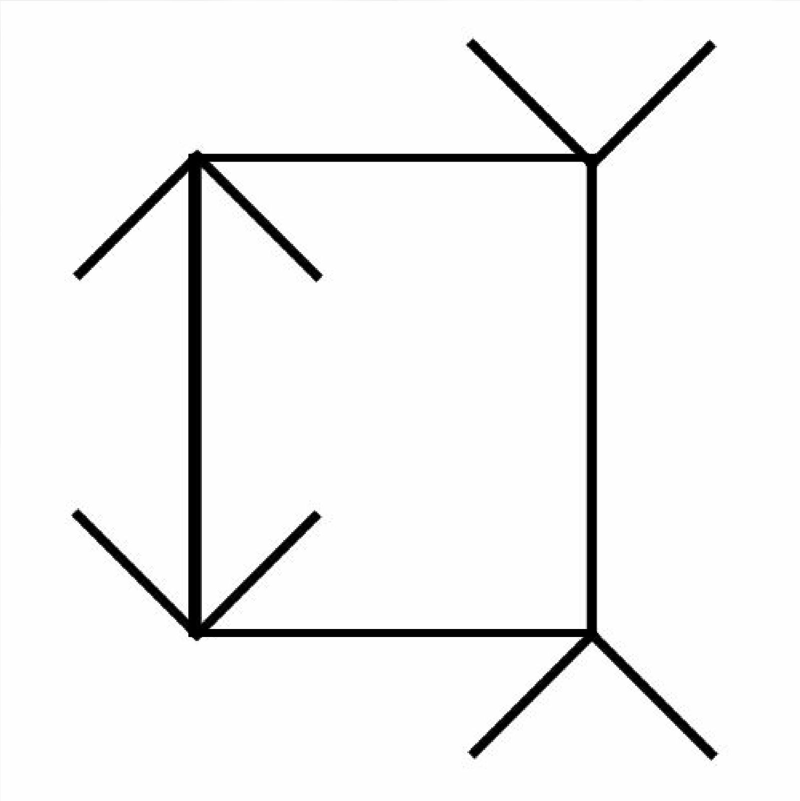
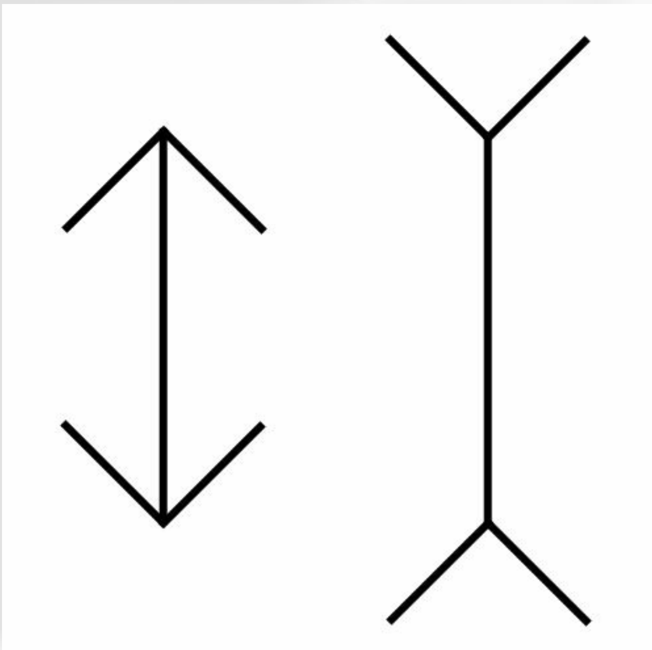


Who’s bigger now?

The Muller-Lyer Illusion

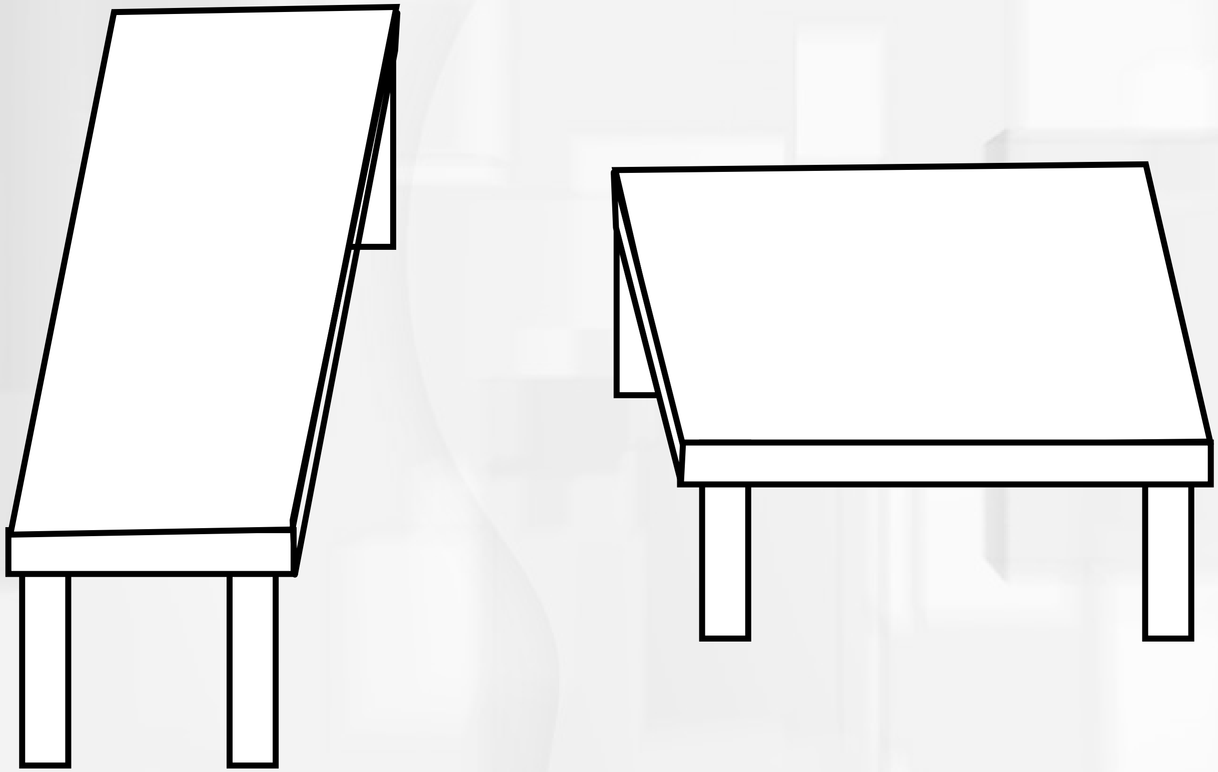


The Muller-Lyer Illusion



Perspective cues to depth make the vertical bar on the right appear farther away, which makes it look smaller.

Roger Shepard's "tables illusion"



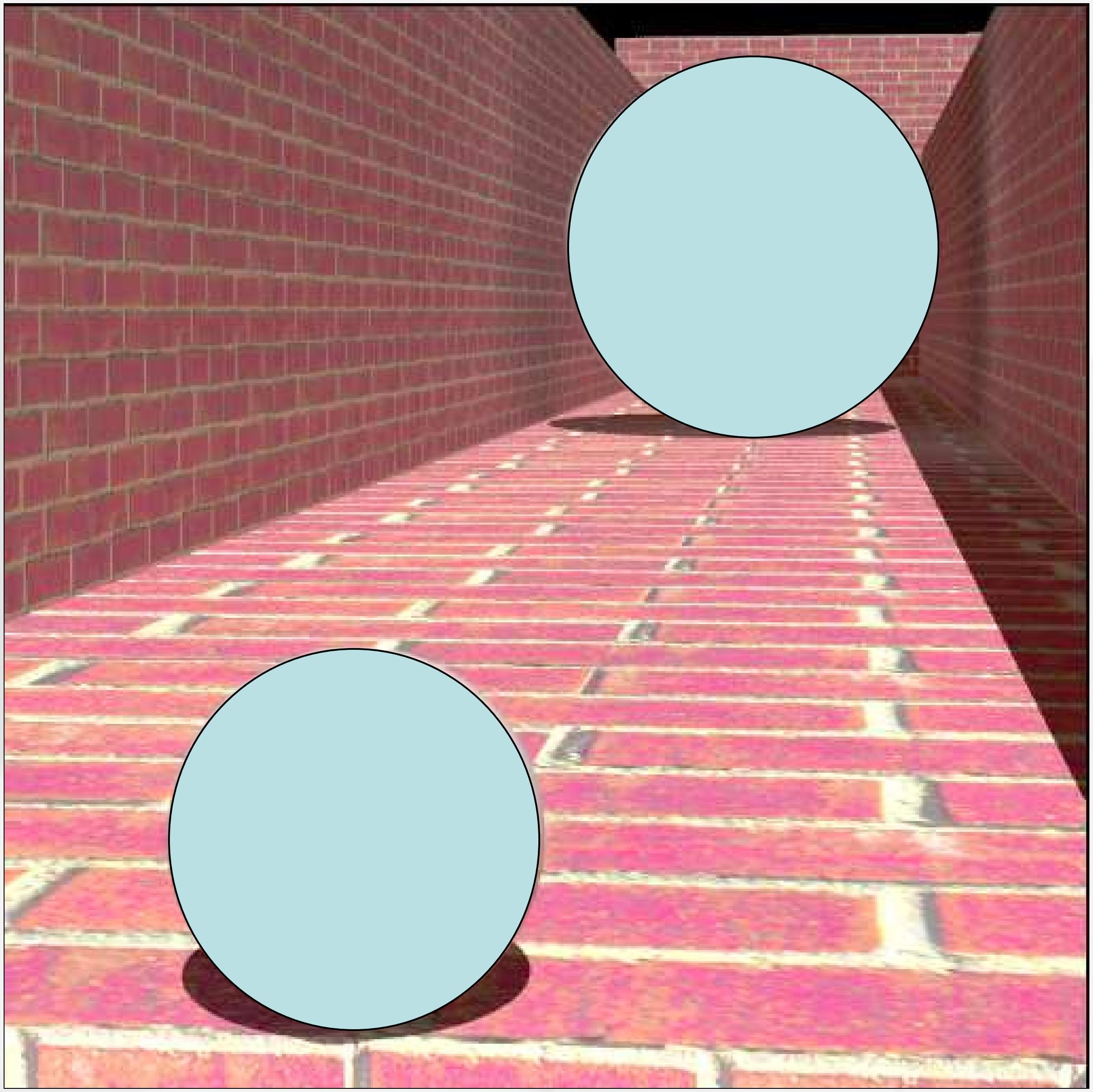
Perceptive cues can strongly alter our perception of size, and therefore shape.

Failures of size constancy is why things look small from an airplane.

We tend to misjudge long distances as being closer.

perceived size = retinal size X perceived distance

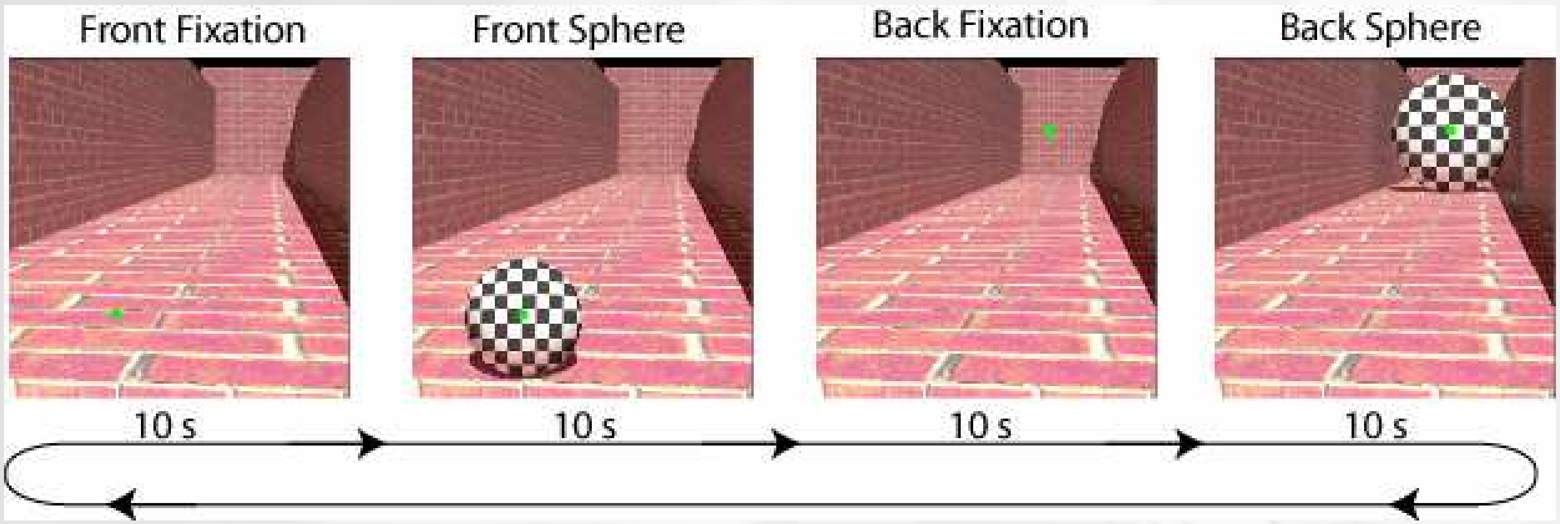
Using psychophysics to measure size constancy illusions.



http://vision.psych.umn.edu/~boyaci/Vision/SizeAppletLarge.html

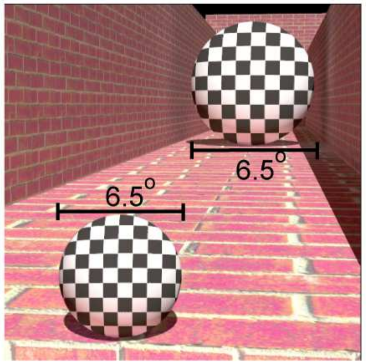
Can effects of size constancy be found in the visual cortex?

fMRI experiment by Murray et al. (2006)

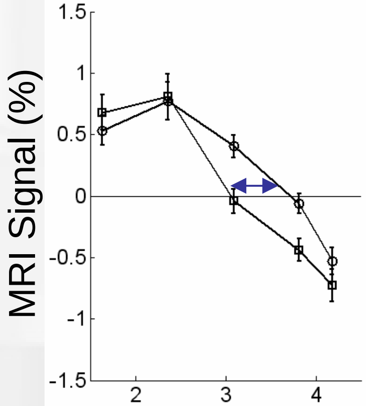


Measure responses in retinotopic area V1

fMRI experiment by Murray et al. (2006)

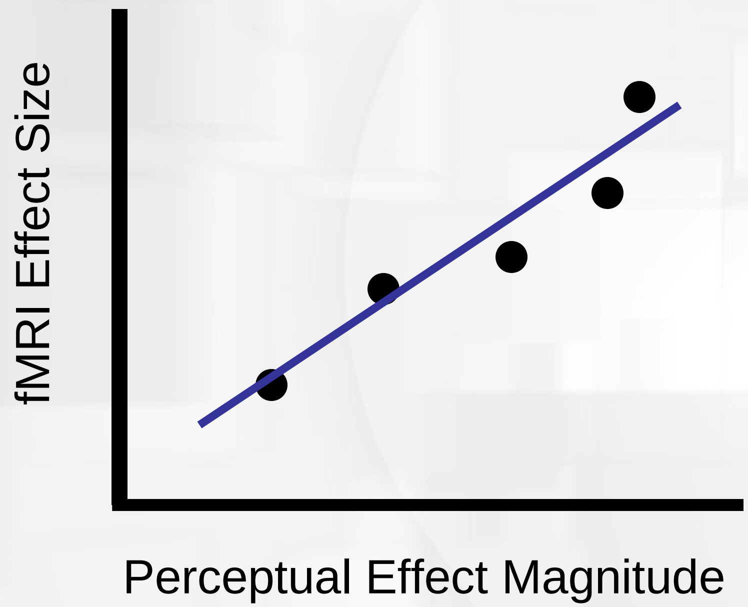


Perceptual difference in size (equal image size)



In V1, the retinotopic representation of the ball increased with the increased perceived size of the ball, even though it was the same size on the retina!

Individual Differences



Subjects who perceived a stronger illusion showed a bigger effect in V1.

Moon Illusion

Moon Illusion

- Moon appears larger on horizon than when it is higher in the sky
- One possible explanation:
  - Apparent-distance theory - horizon moon is surrounded by depth cues while moon higher in the sky has none
  - Horizon is perceived as further away than the sky - called “flattened heavens”

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