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.

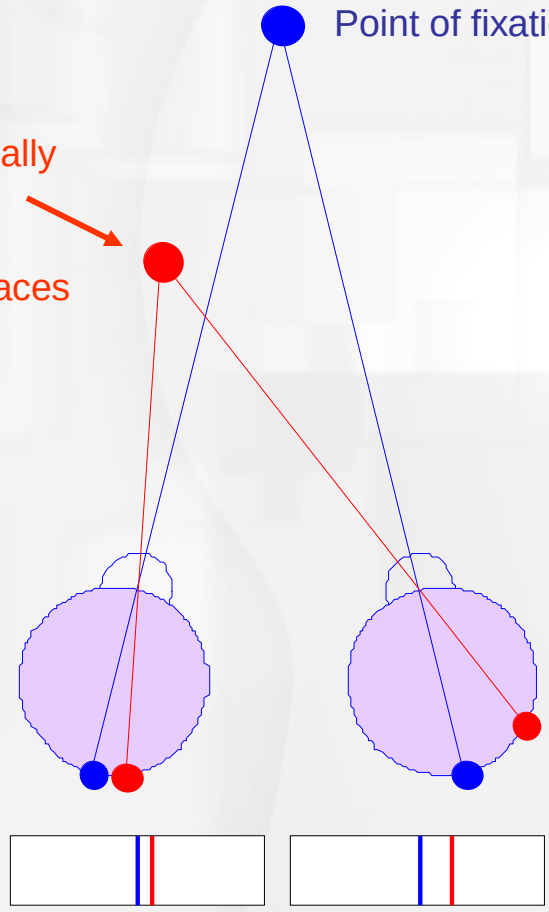
Binocular Depth Information

Binocular Depth Information

- Binocular disparity - difference in images between the two eyes

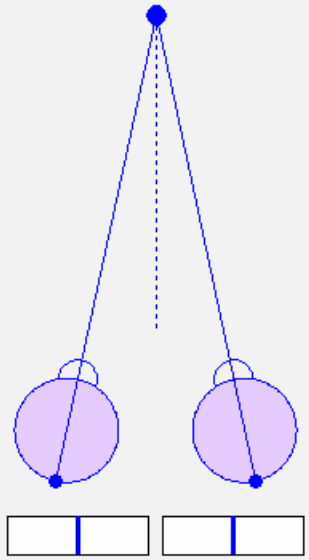
Points away from fixation will usually have **binocular disparity**:

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

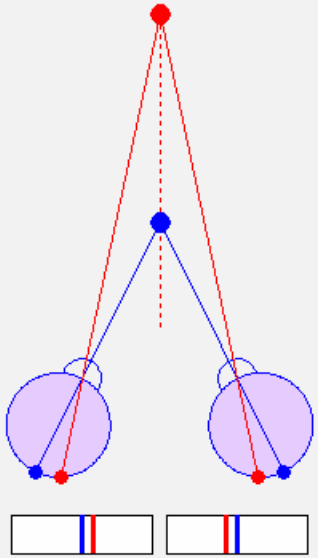


In this example, the disparity in the left eye is smaller than the disparity in the right eye.

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.

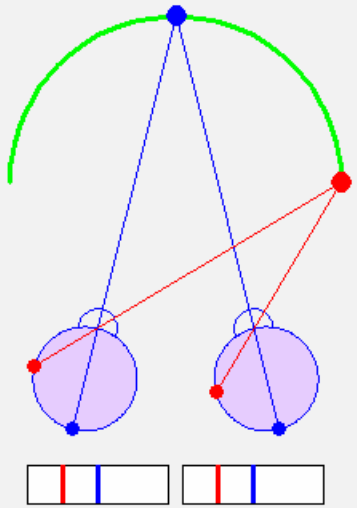


Binocular disparity

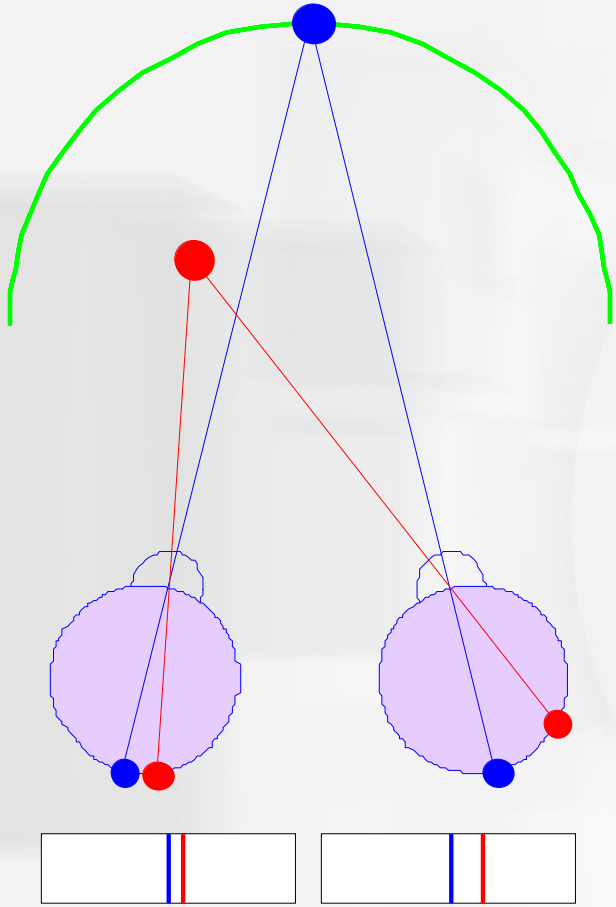
For objects straight in front of you,
if it's in front of fixation: **crossed disparity**
behind fixation: **uncrossed disparity**

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 produce equal disparity in the two eyes.

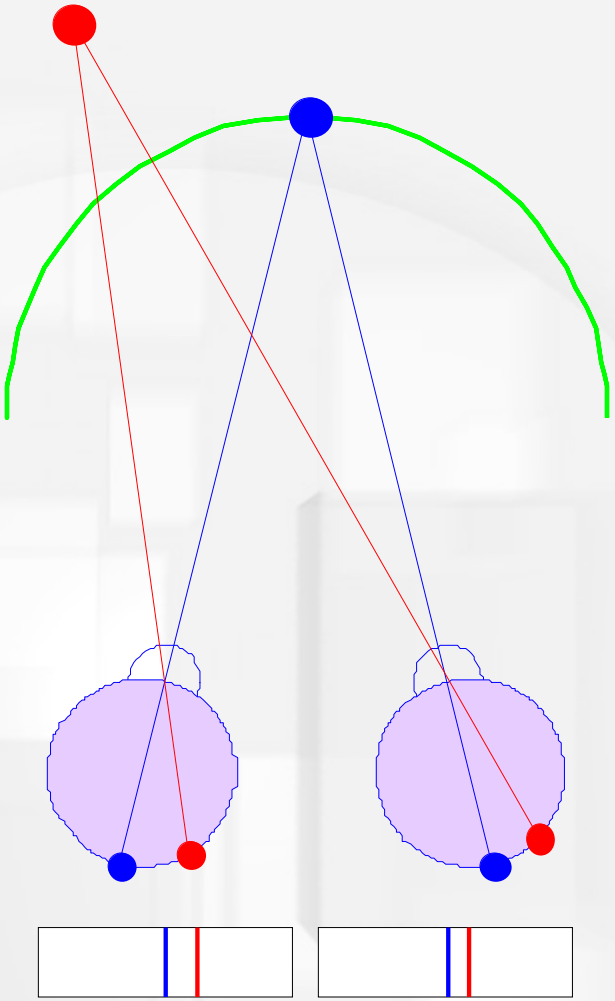


All objects on the horoptor have neither crossed, nor uncrossed disparity



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.

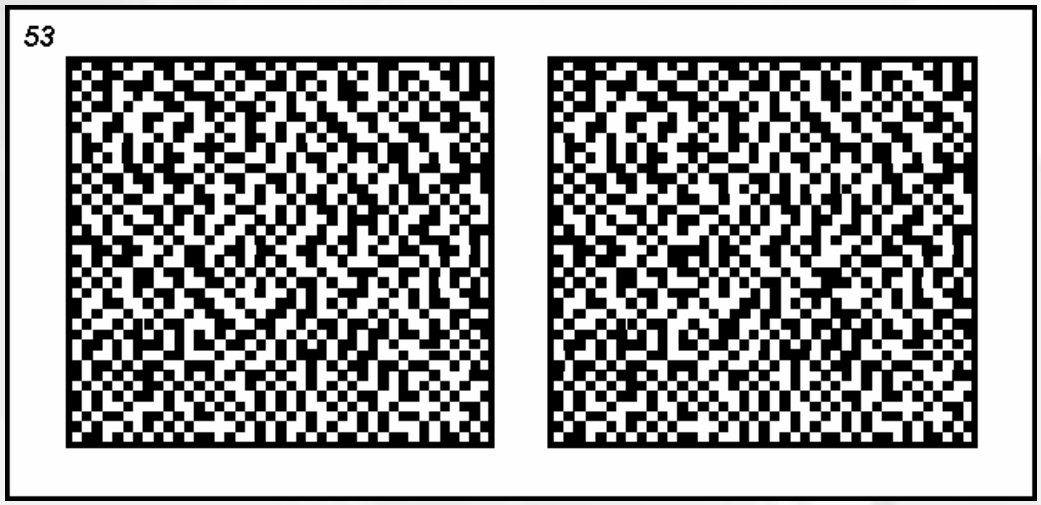
- **Stereopsis** - depth information provided by binocular disparity
  - Stereoscope uses two pictures from slightly different viewpoints
  - 3-D movies use the same principle and viewers wear glasses to see the effect

(a) Left eye image

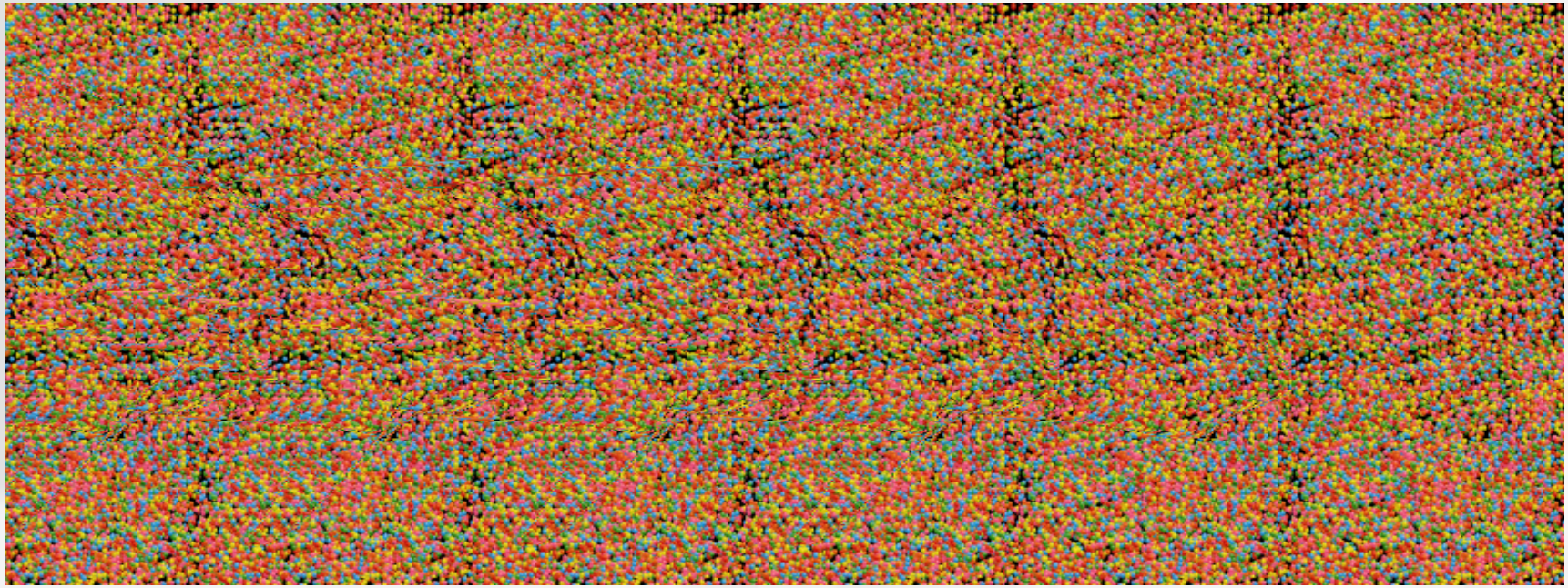
(b) Right eye image

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.

A “random-dot” stereogram has two identical patterns with part of one shifted to the right to produce disparity

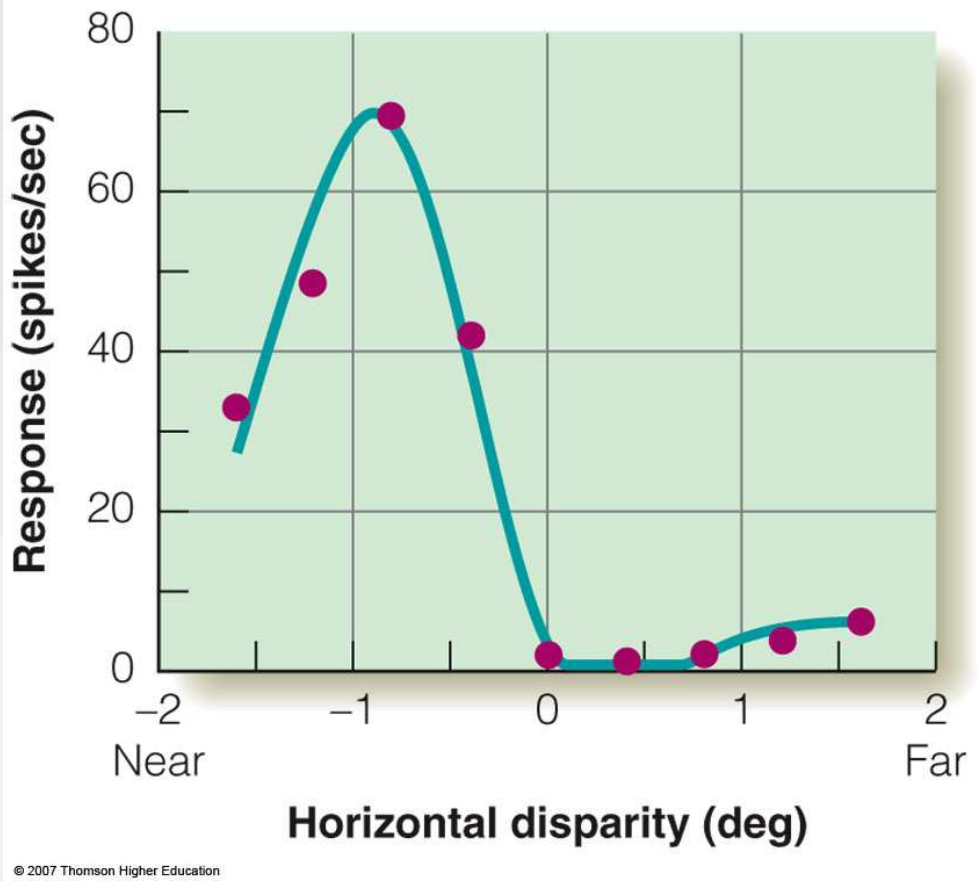


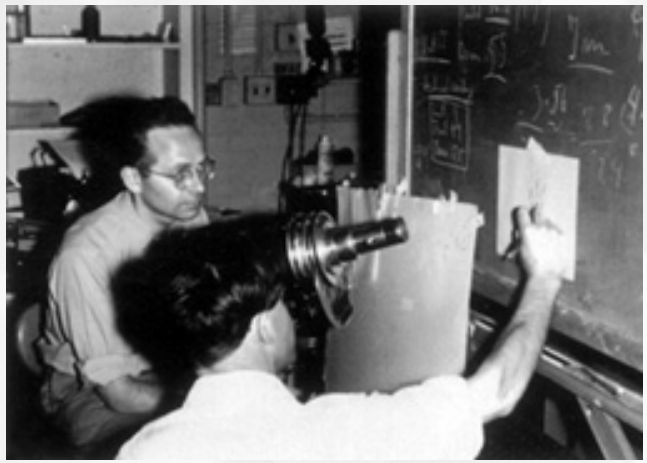
‘Auto stereograms’ work on the same principle.



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

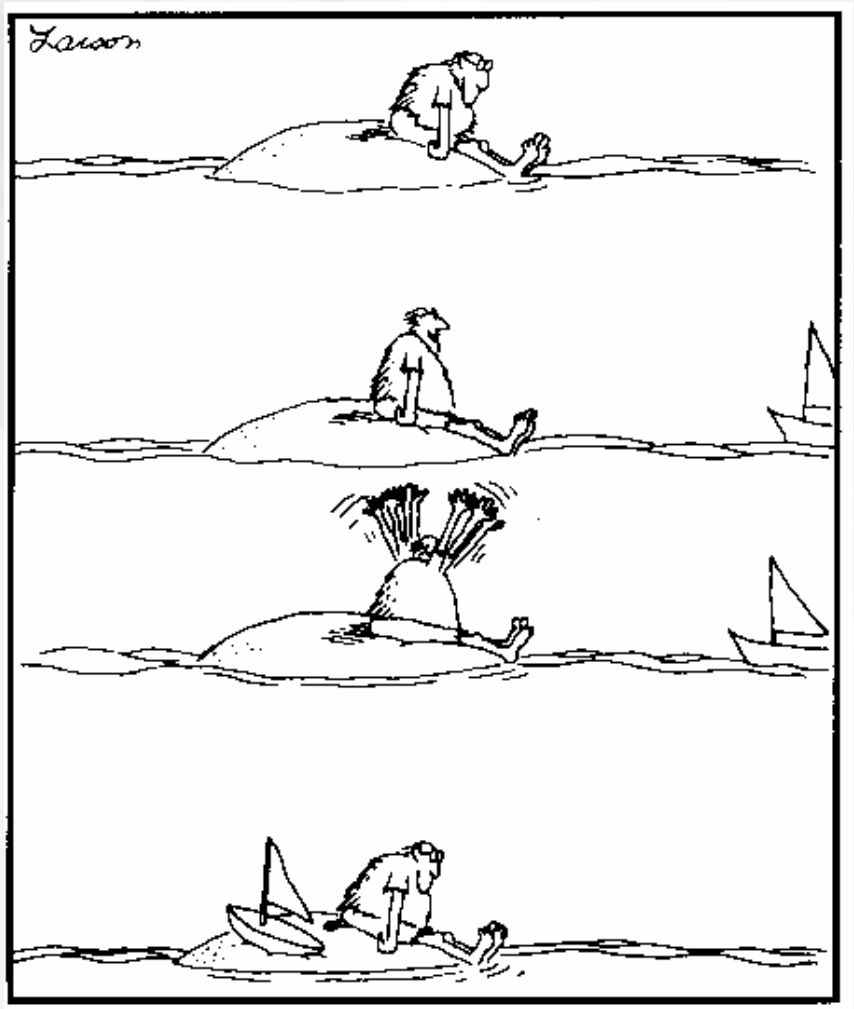
- Experiment by Blake and Hirsch
  - Cats were reared by alternating vision between two eyes
  - Results showed that they:
    - Had few binocular neurons
    - Were unable to use binocular disparity to perceive depth

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

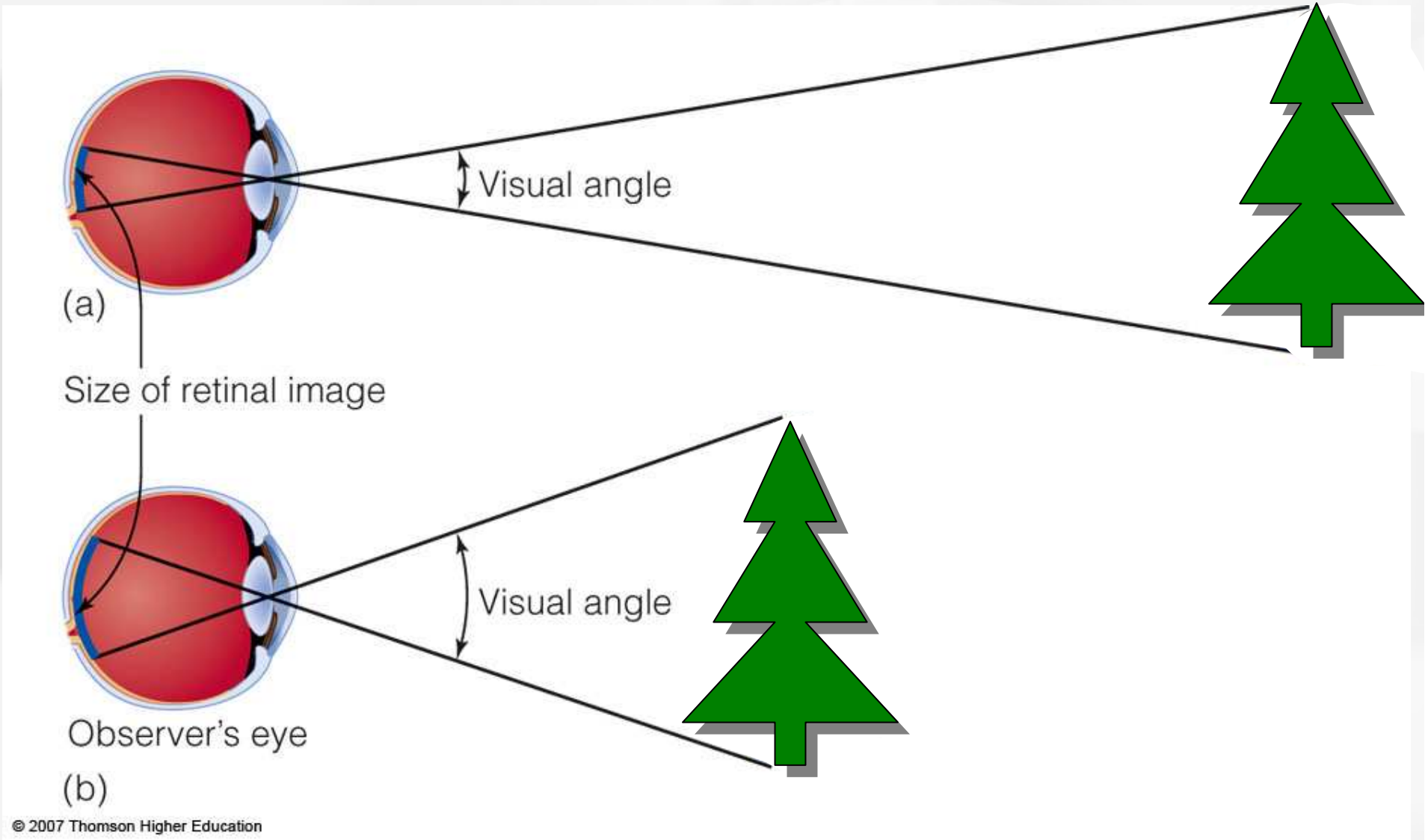
Stereopsis isn’t helpful for distances beyond about 6 feet anyway.

Size Perception

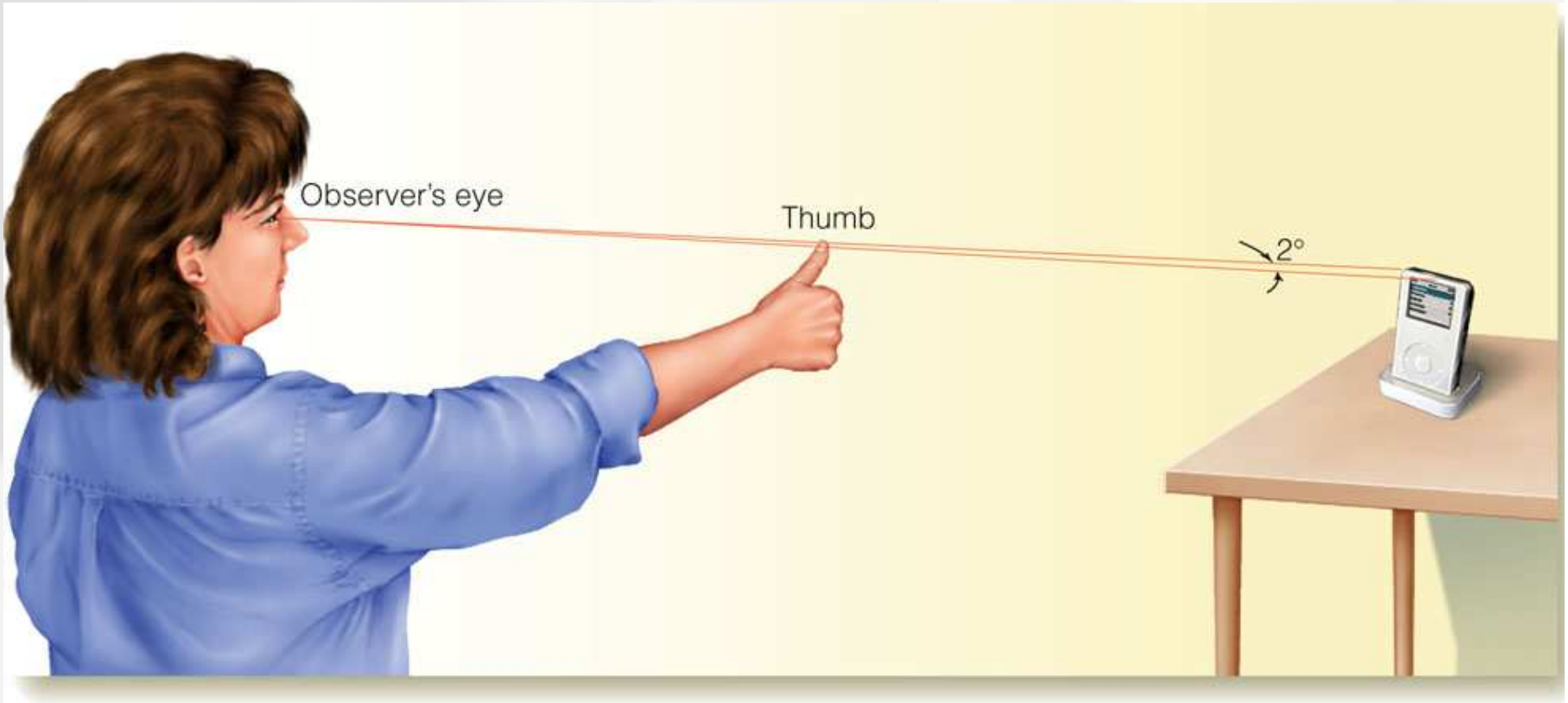
Distance and size perception are interrelated



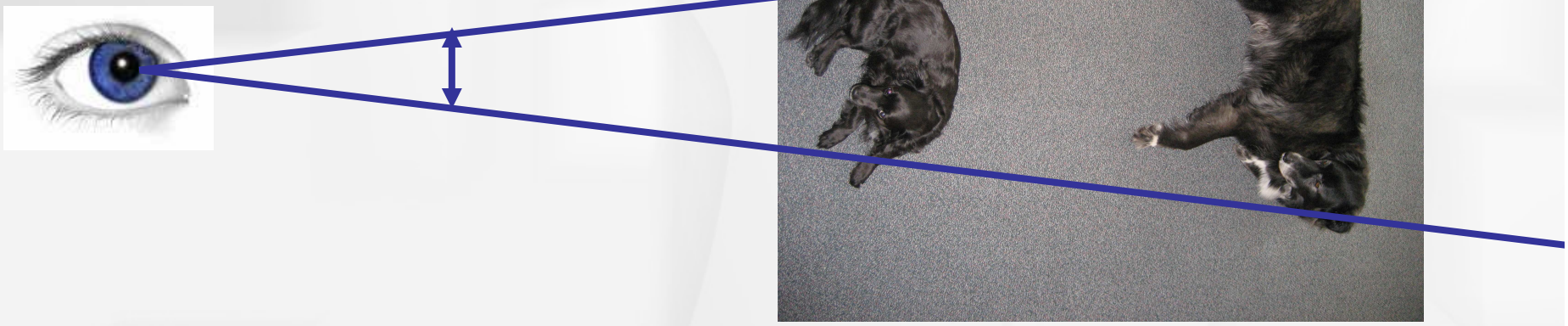
The *Visual angle* depends on both the size of the object and the distance from the observer

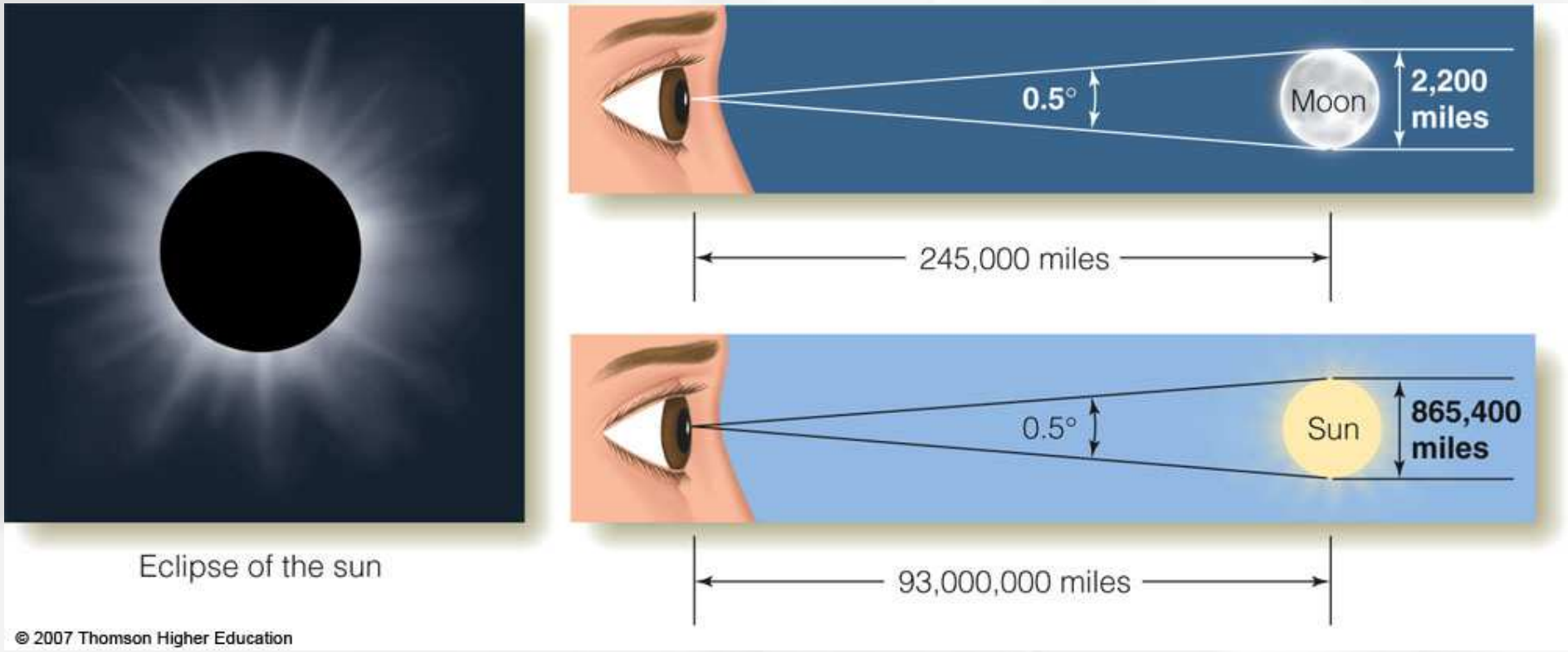


The moon and sun subtend about 0.5 degrees of visual angle, your thumb subtends about two degrees, and your average computer monitor subtends about 30 degrees (assuming you are viewing it from two feet away).



These two dogs subtend approximately the same visual angle despite their different physical sizes.





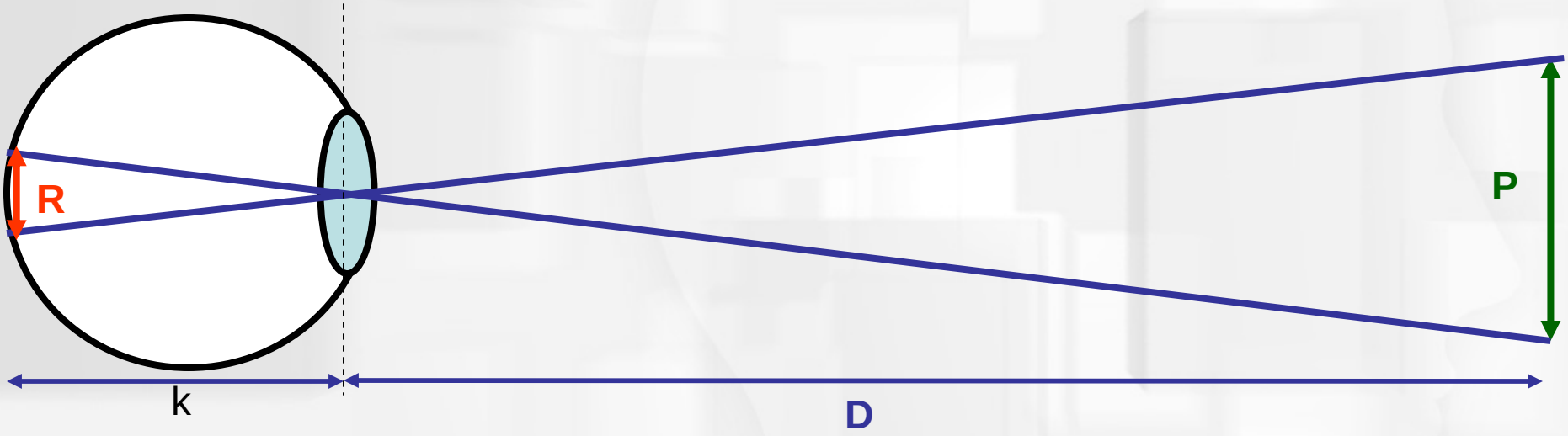
The moon's disk almost exactly covers the sun during a solar eclipse because the sun and the moon have the same visual angles.

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)

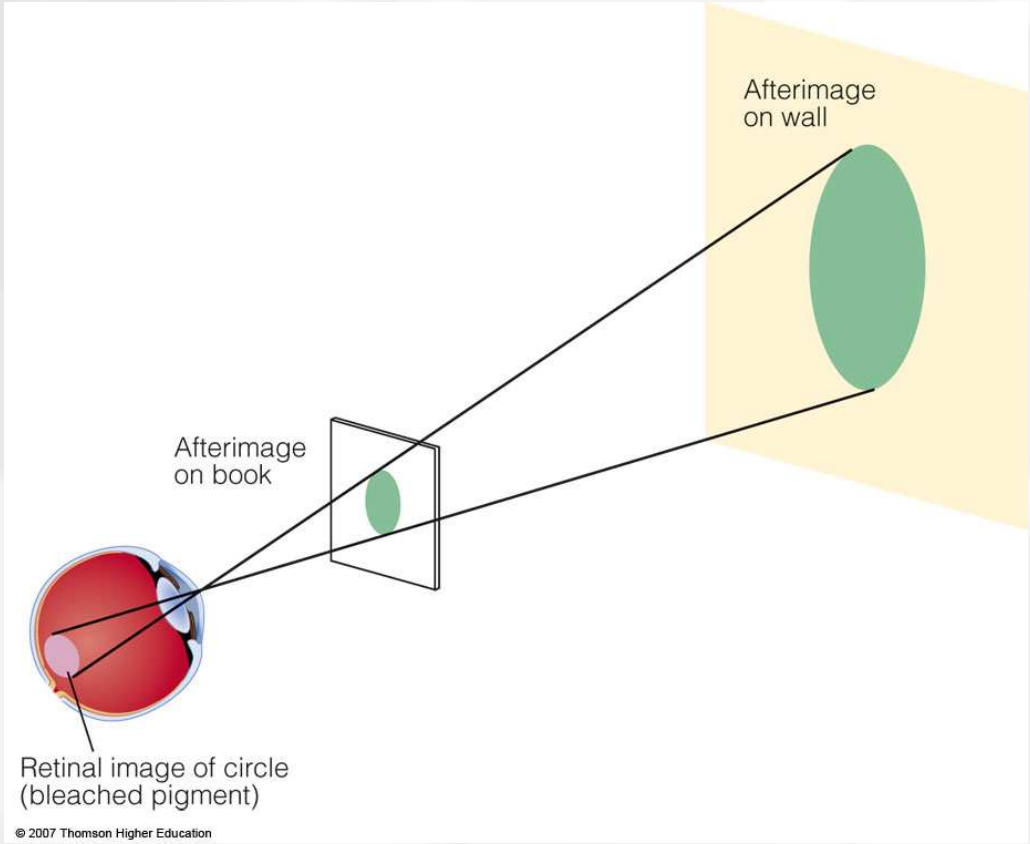


$$\frac{P}{D} = \frac{R}{k} \qquad P = \frac{R\,D}{k} \qquad P \sim R\,D$$

Size-Distance Scaling

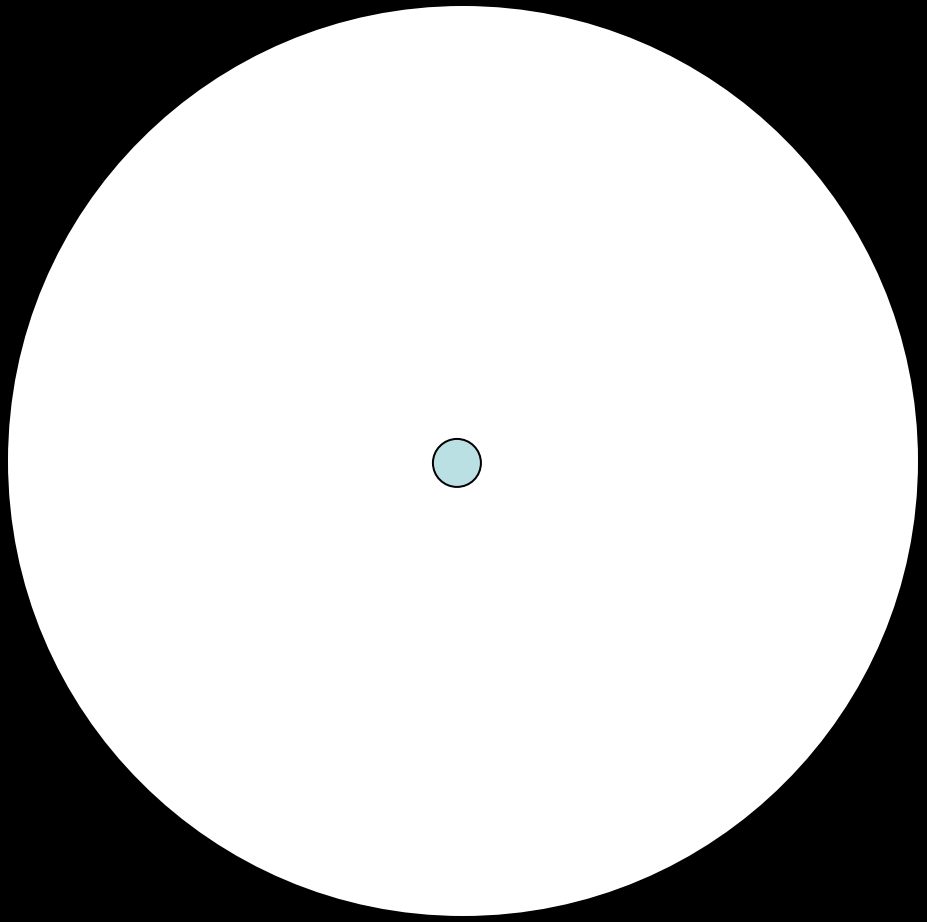
Perceived size (P) ~ retinal image size (R) X perceived distance (D)

- 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.



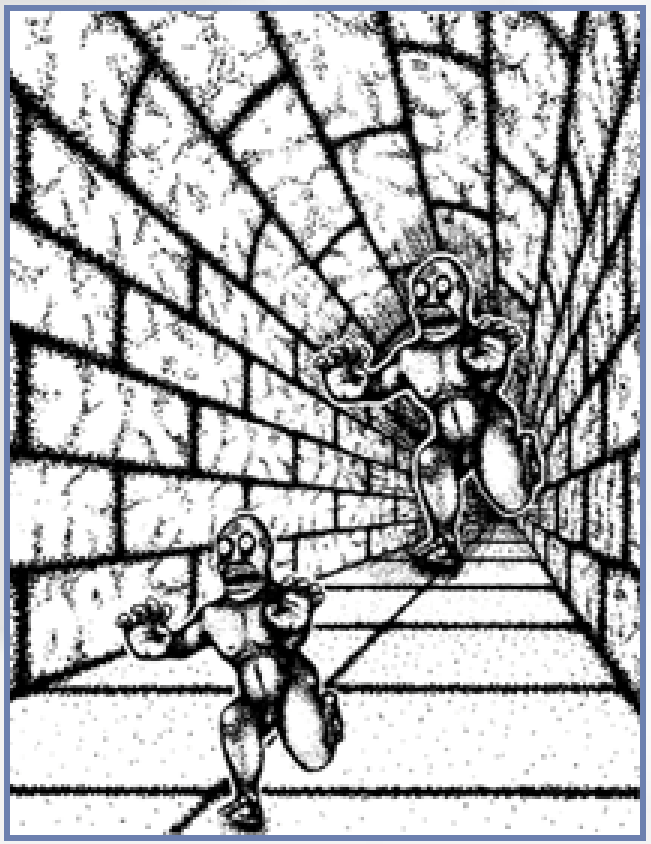
Emmert’s law:

Objects that generate retinal images of the same size will look different in physical size if they appear to be located at different distances.

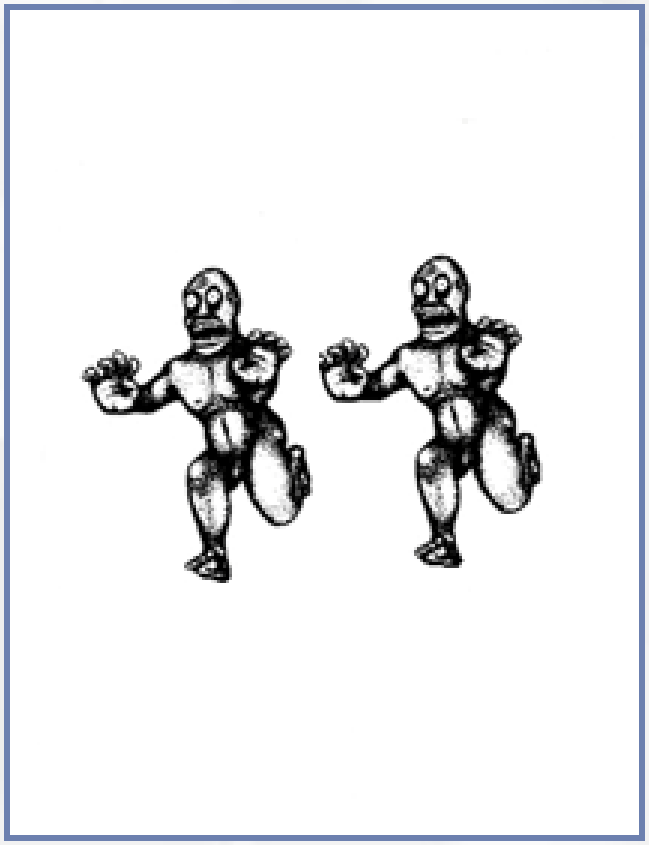


Adapt to this image, and then look at a piece of paper in front of you.

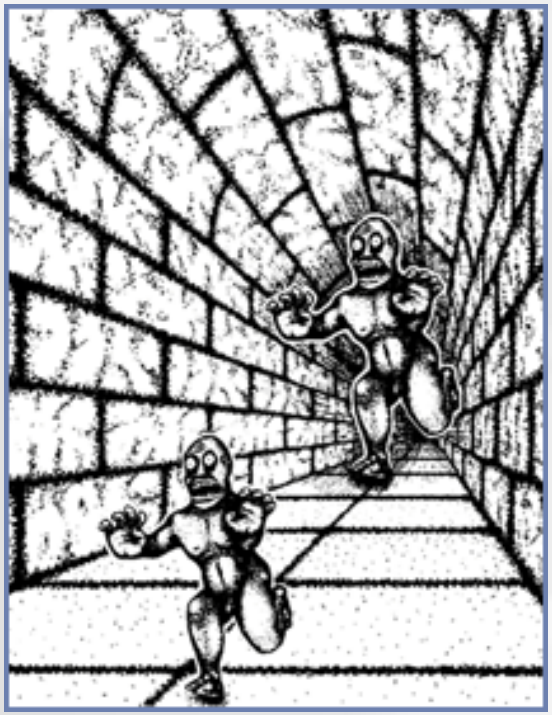
Many visual Illusions are caused by manipulations of size constancy.

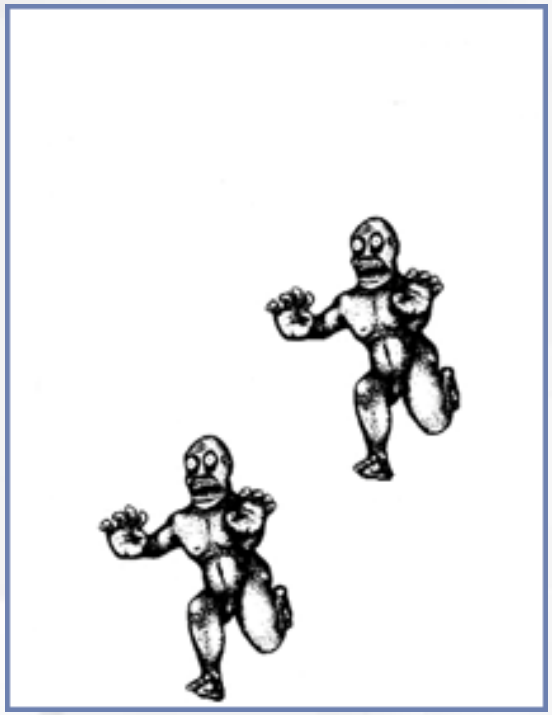


©1990 RM Shepard



What's going on here?



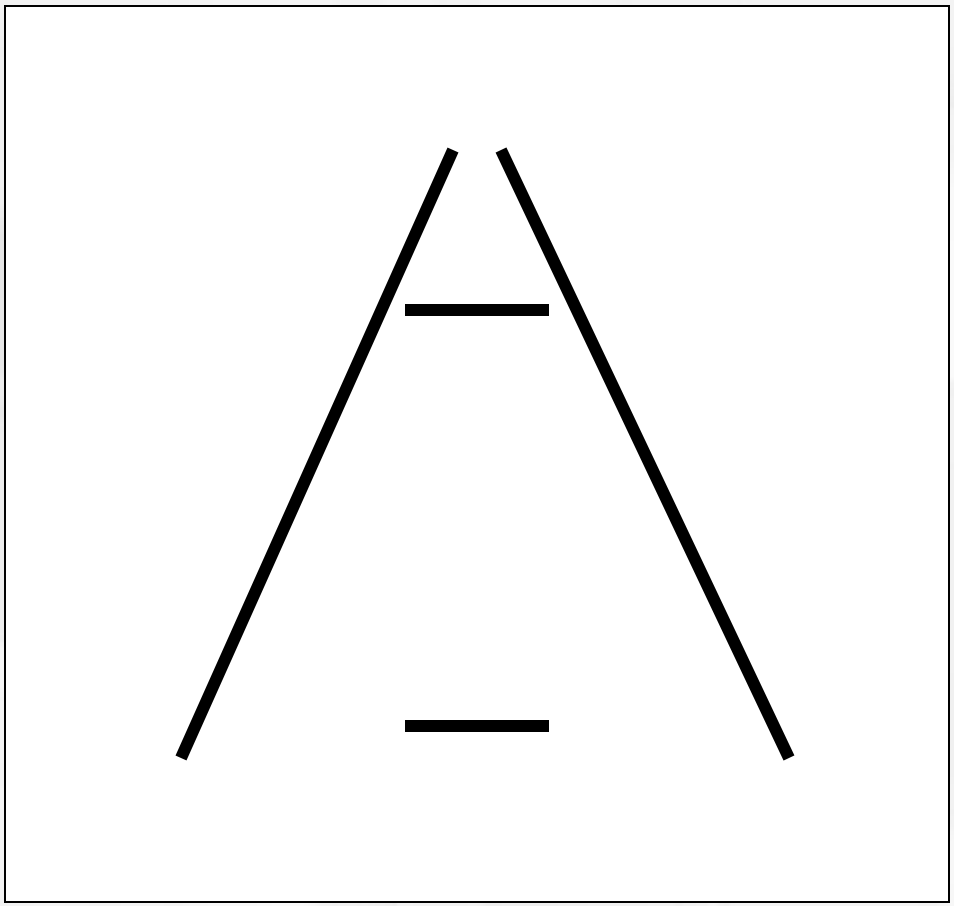


perceived size = retinal size X perceived distance

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

perceived size = retinal size X perceived distance

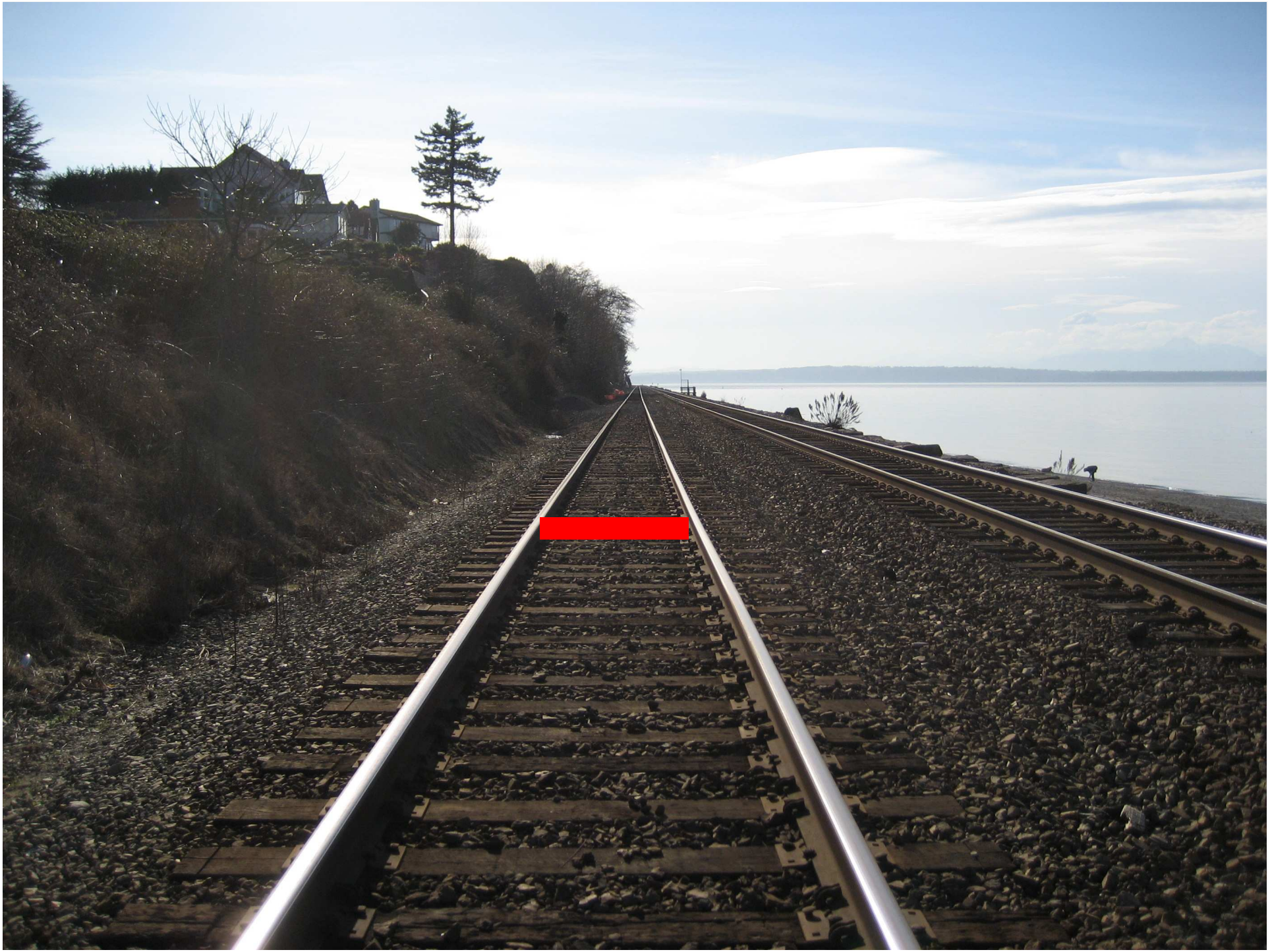
Now we understand the ‘Ponzo Illusion’.

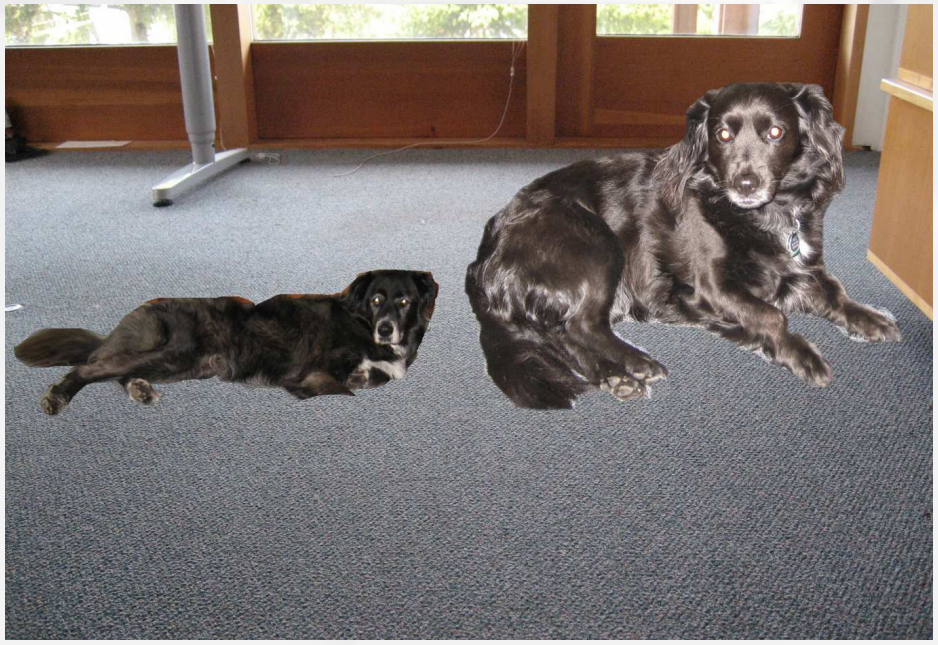


perceived size = retinal size X perceived distance

Monocular cues to depth: relative height, perspective convergence

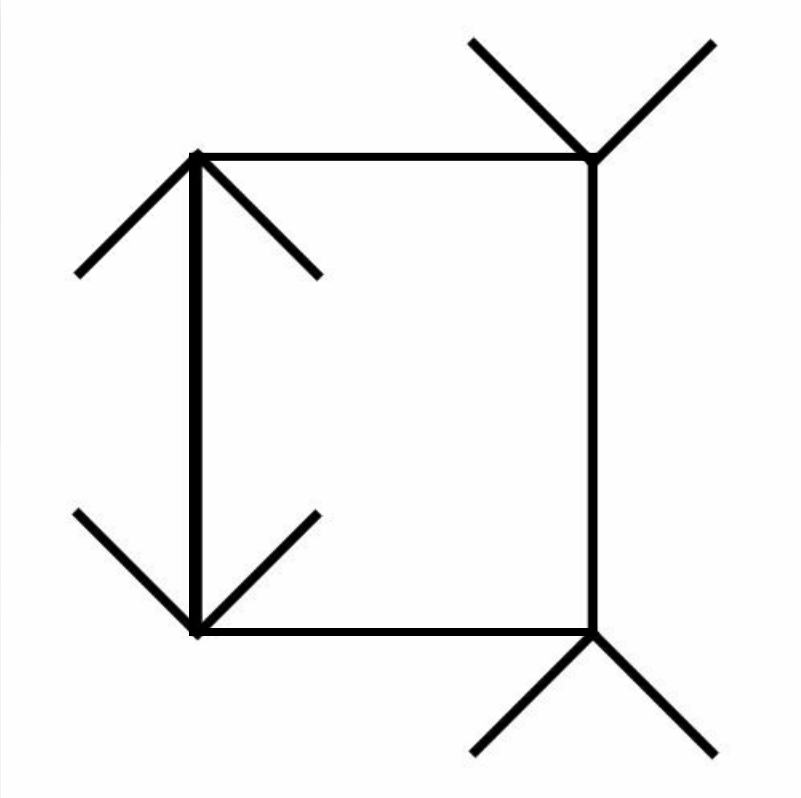
perceived size = retinal size X perceived distance



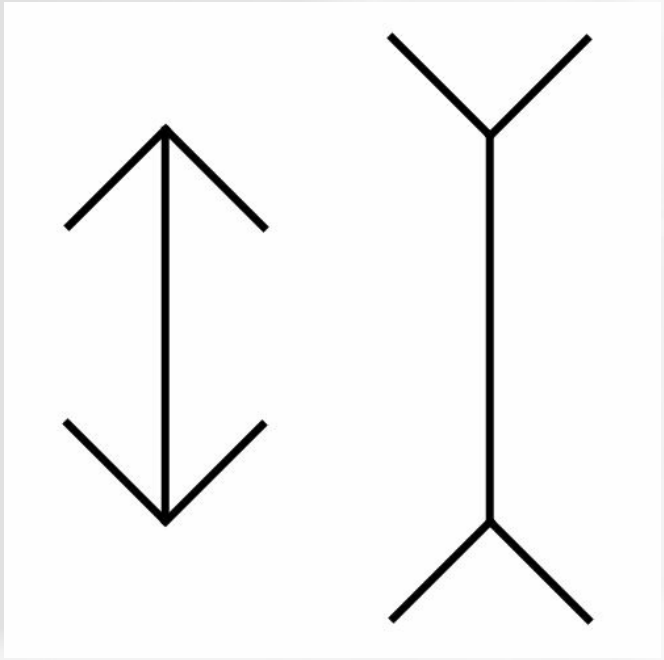


Who’s bigger now?

The Muller-Lyer Illusion

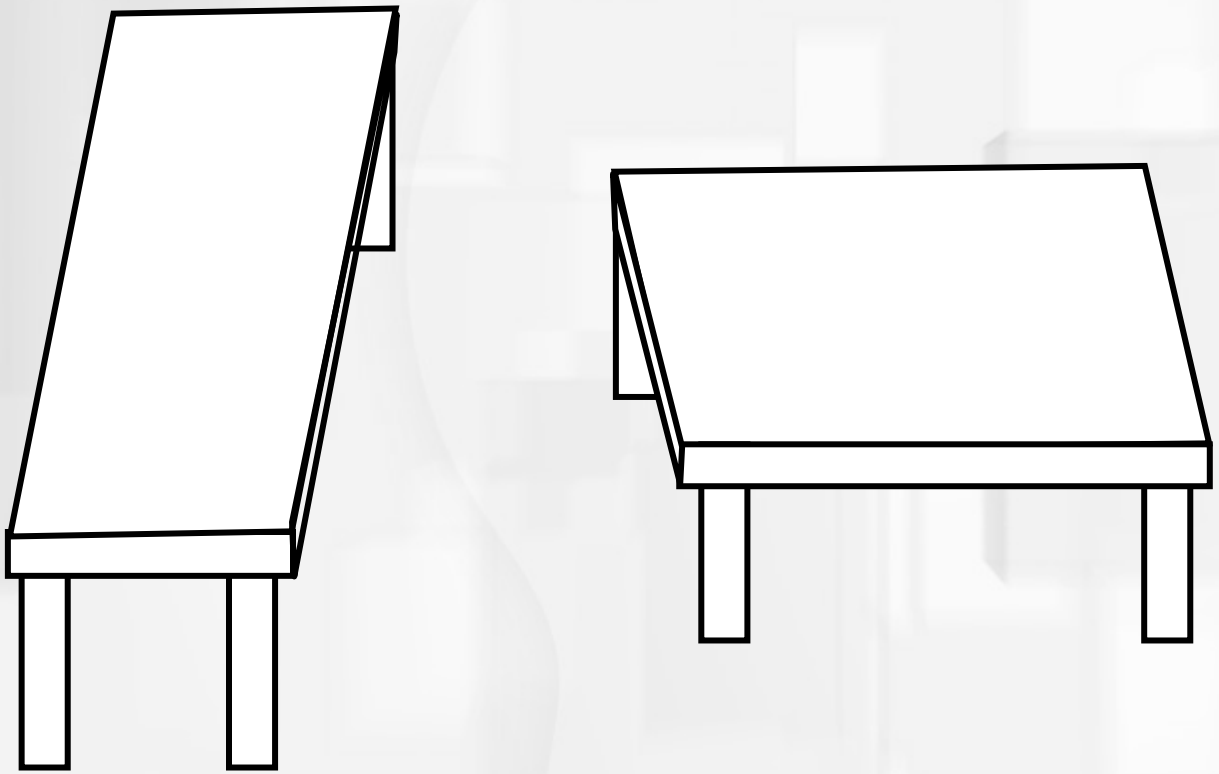


The Muller-Lyer Illusion



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

Roger Shepard’s “tables illusion”



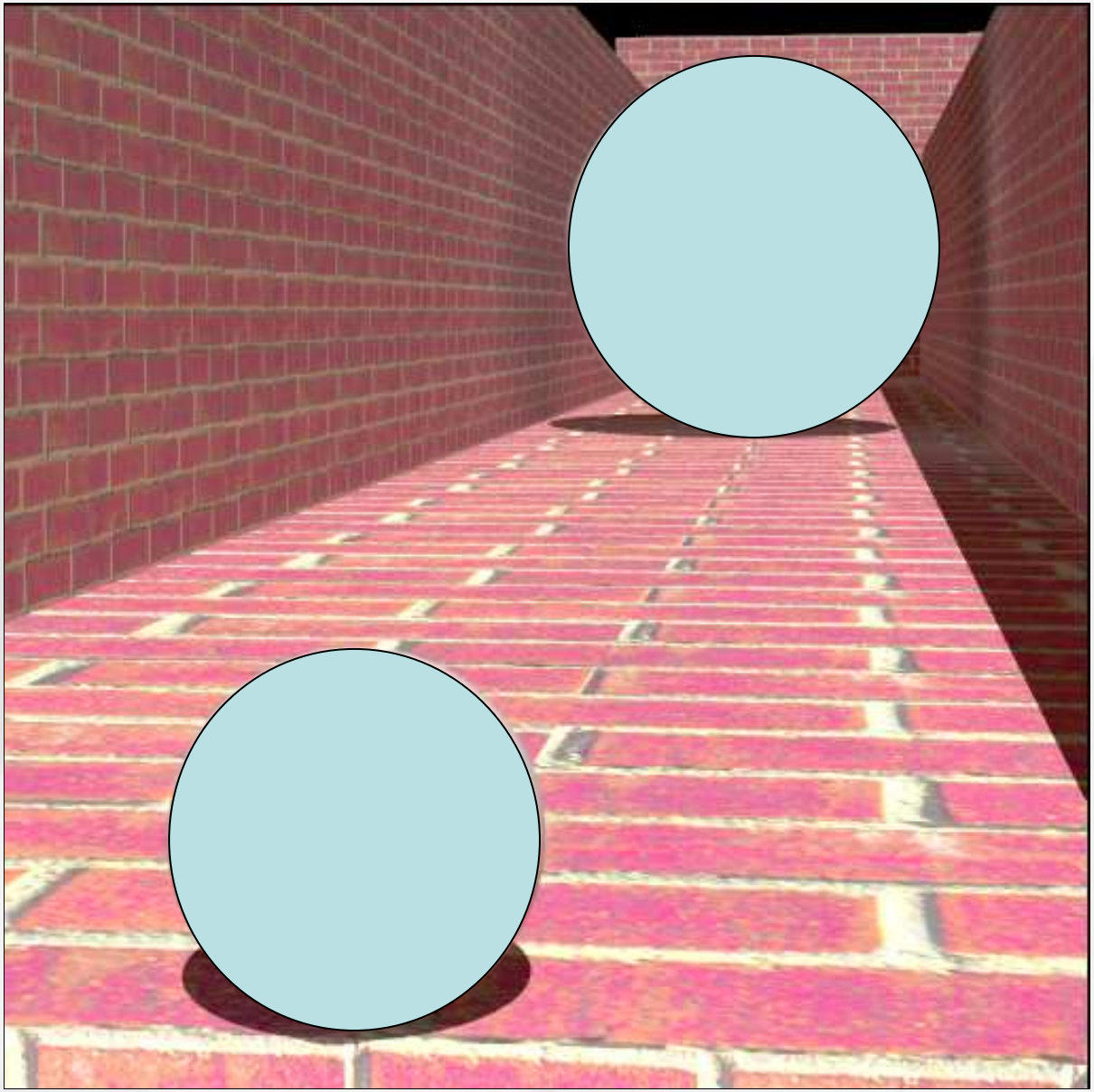
Perceptive cues can strongly alter our perception of size, and therefore shape.

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