Perception, Part 2
Gleitman *et al*. (2011), Chapter 5

Mike D'Zmura
Department of Cognitive Sciences, UCI

Psych 9A / Psy Beh 11A
February 27, 2014

Visual Reconstruction of a *Three-Dimensional* Scene

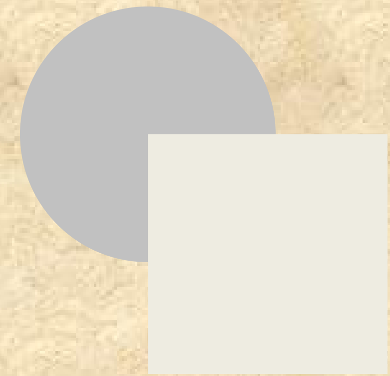
- Retinal images are two-dimensional

- The *depth* or distance from the viewer must be recovered: the third dimension

- **Depth Cues**
    - Pictorial or static cues (found in a single monocular image)
    - Physiological cues (weak)
    - Stereo disparity (used by many but not all people when viewing a scene with two eyes)
    - Motion cues (available from a sequence of monocular images)
        - Optic flow (caused by motion of the viewer)
        - Independent object motion

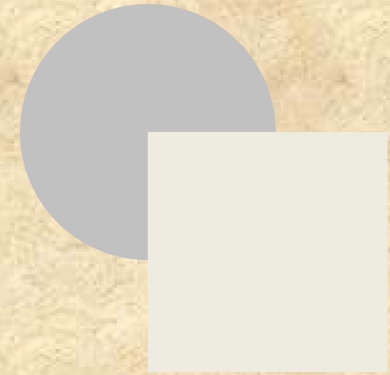
Pictorial Depth Cues

Interposition or Occlusion



Pictorial Depth Cues

Interposition or Occlusion



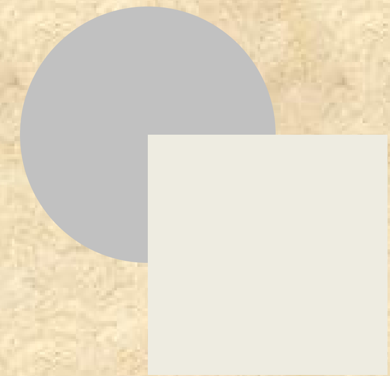
How do we know that the white square lies in front of the gray disk?

Perhaps the gray disk is a pacman eating the white square.

Perceptual grouping (closure and *convexity*) leads us to the standard interpretation: the white square occludes the gray disk.

Pictorial Depth Cues

Interposition or Occlusion

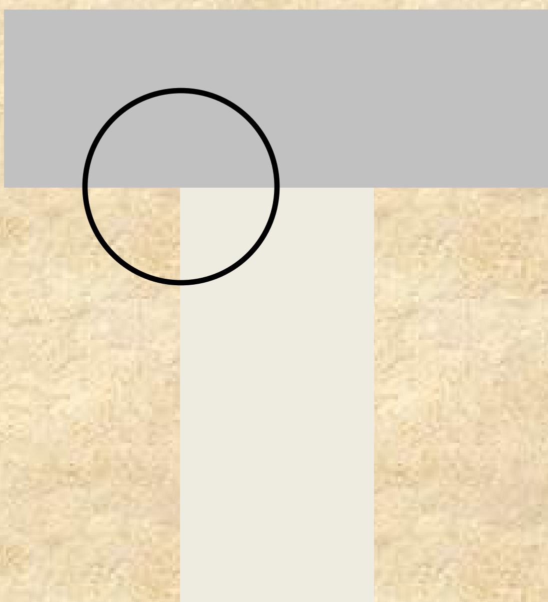


Any occlusion in this picture?

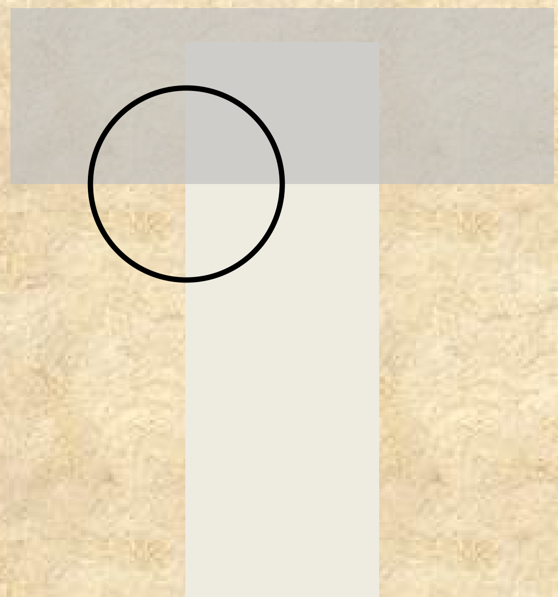
Pictorial Depth Cues

Interposition or Occlusion

T-Junctions



X-Junctions



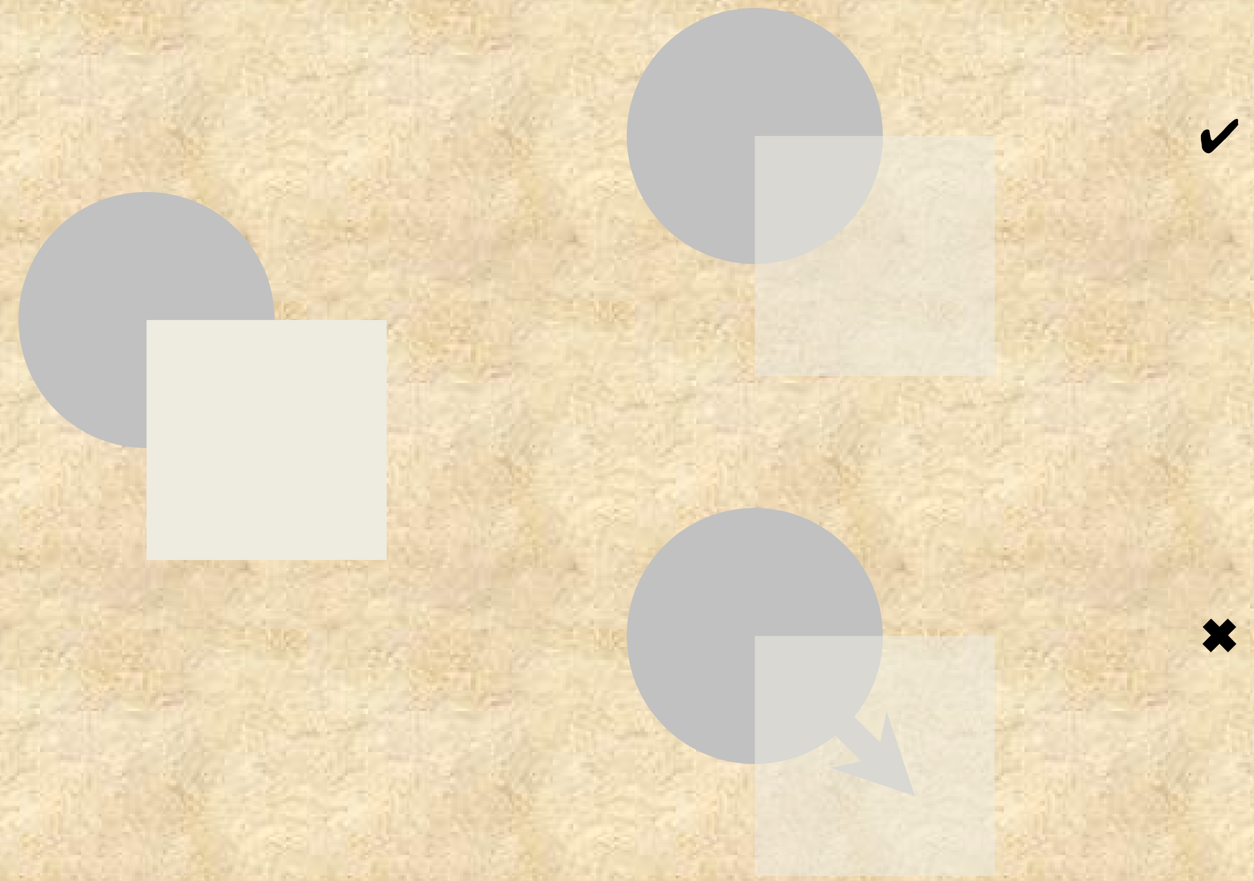
While T-junctions are commonly thought to be an important cue to occlusion,

- detection and interpretation of T-junctions in visual imagery is very tough
- perceptual grouping principles provide the "correct answer" without their use

Pictorial Depth Cues

Interposition or Occlusion

Amodal Completion of the Object Lying Behind the Occluder



try http://www.michaelbach.de/ot/mot_breathingSquare/index.html

Pictorial Depth Cues

Interposition or Occlusion
Shading and **Shadows**

cast shadow

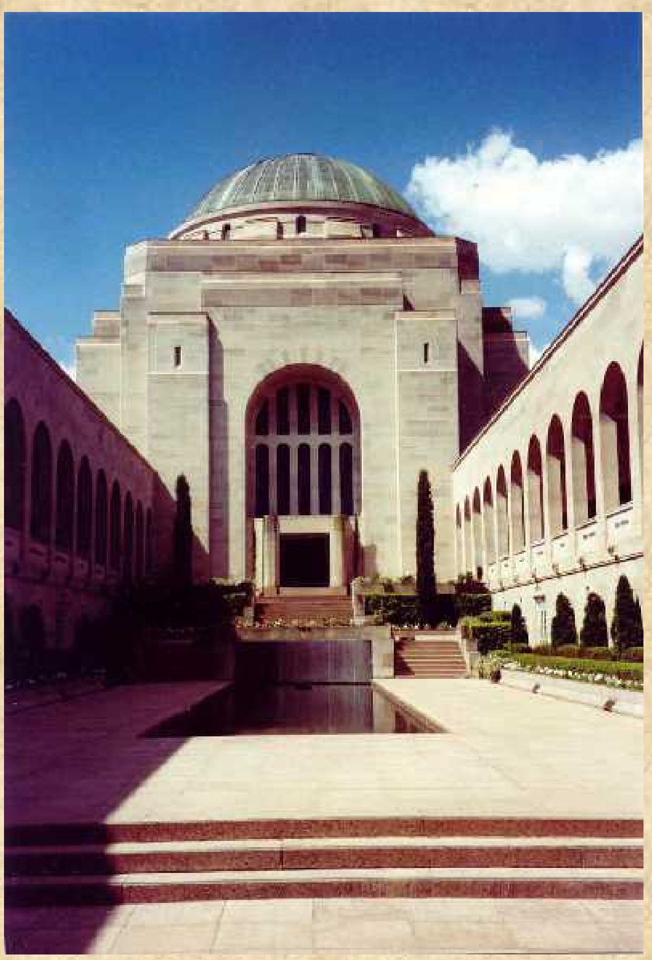
Pictorial Depth Cues

Interposition or Occlusion
Shading and **Shadows**

attached shadow

Pictorial Depth Cues

Interposition or Occlusion
Shading and **Shadows**

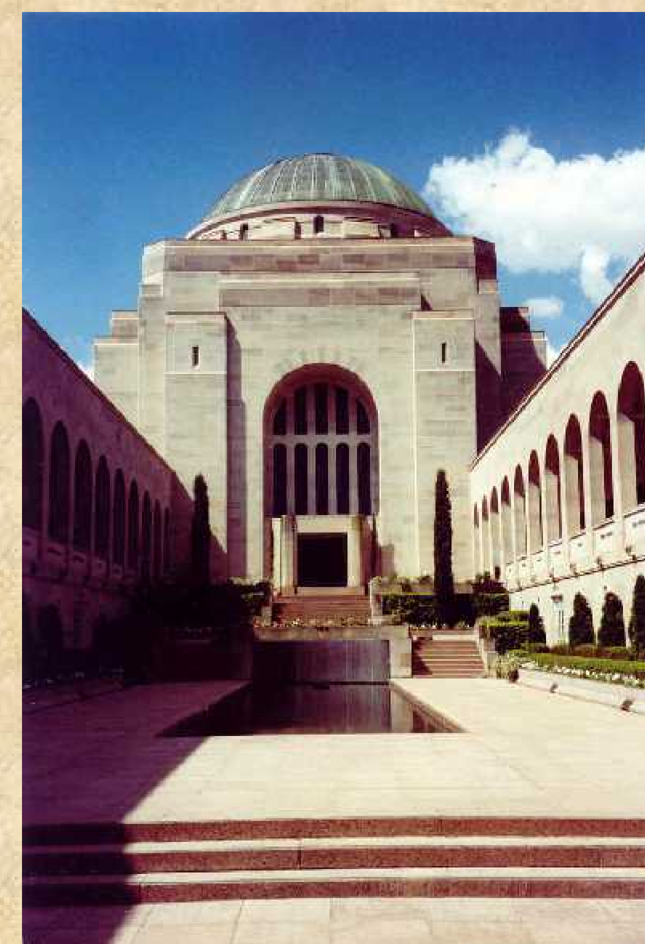


shadow:
cast and attached

Pictorial Depth Cues

Interposition or Occlusion
Shading and **Shadows**

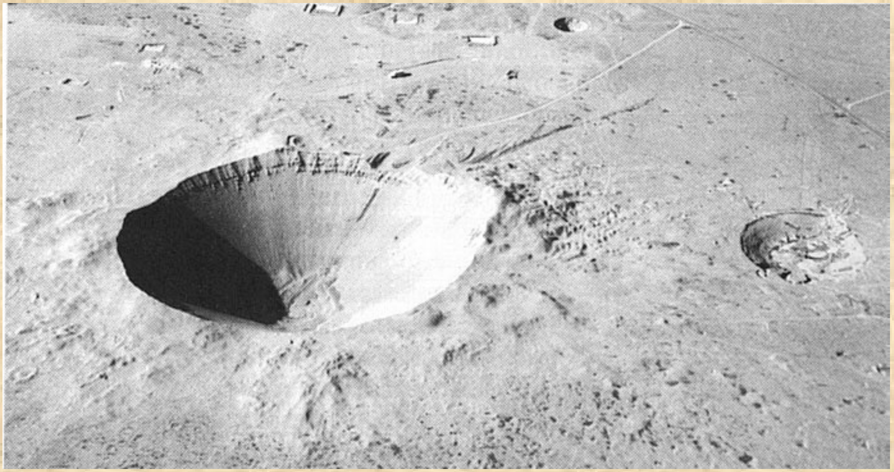
Any shadows in this picture?



shadow:
cast and attached

Pictorial Depth Cues

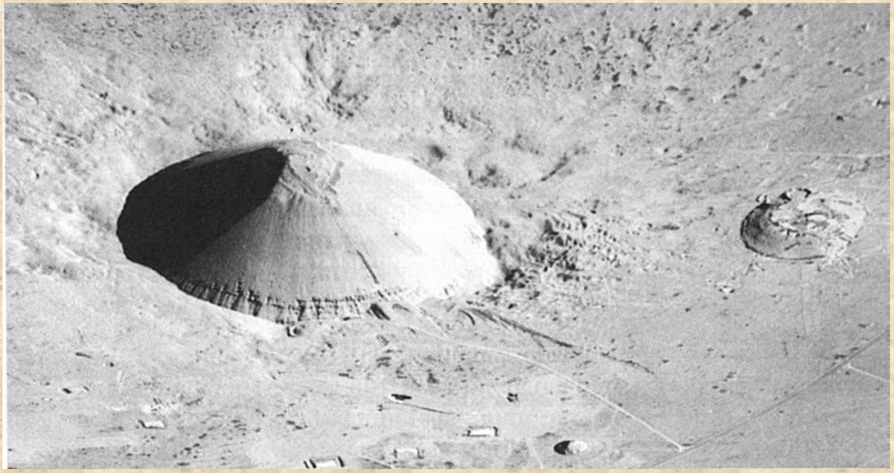
Interposition or Occlusion
Shading and Shadows



a shaded crater

Pictorial Depth Cues

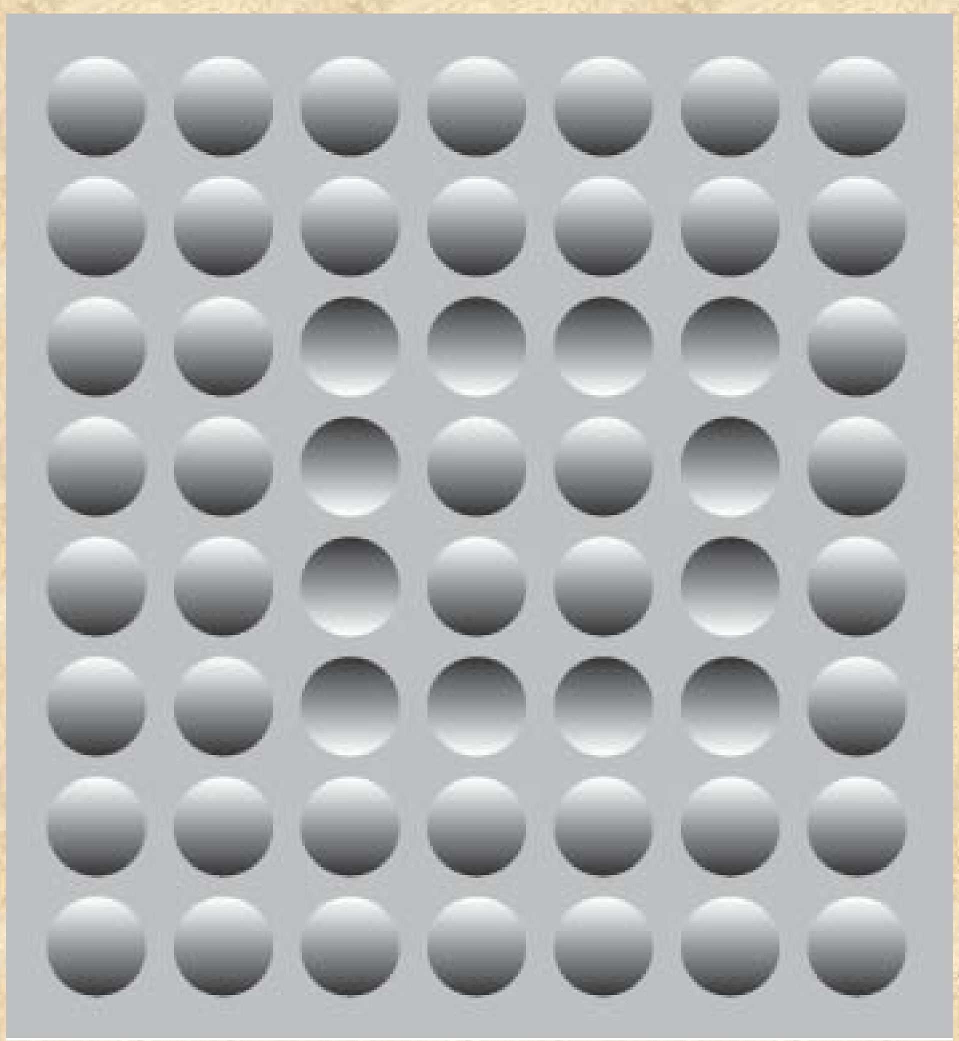
Interposition or Occlusion
Shading and Shadows



a shaded crater,
photo upside-down

Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows

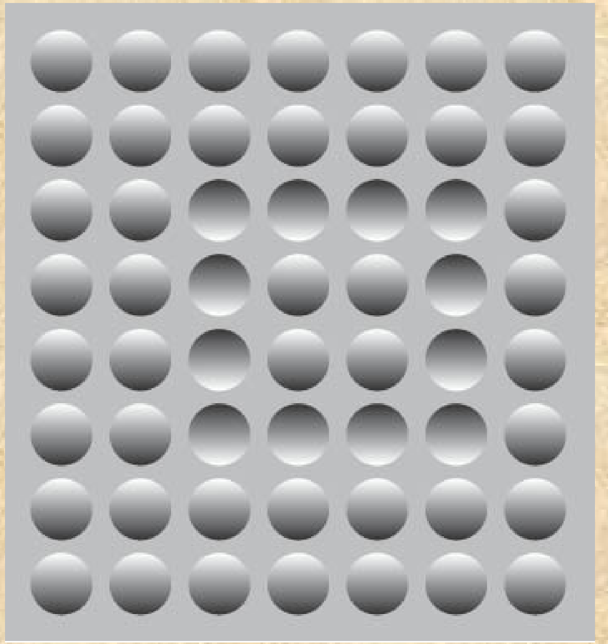


visual system assumes
light from above (in a
retinal coordinate system—
view with your head upside-down!)

Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows

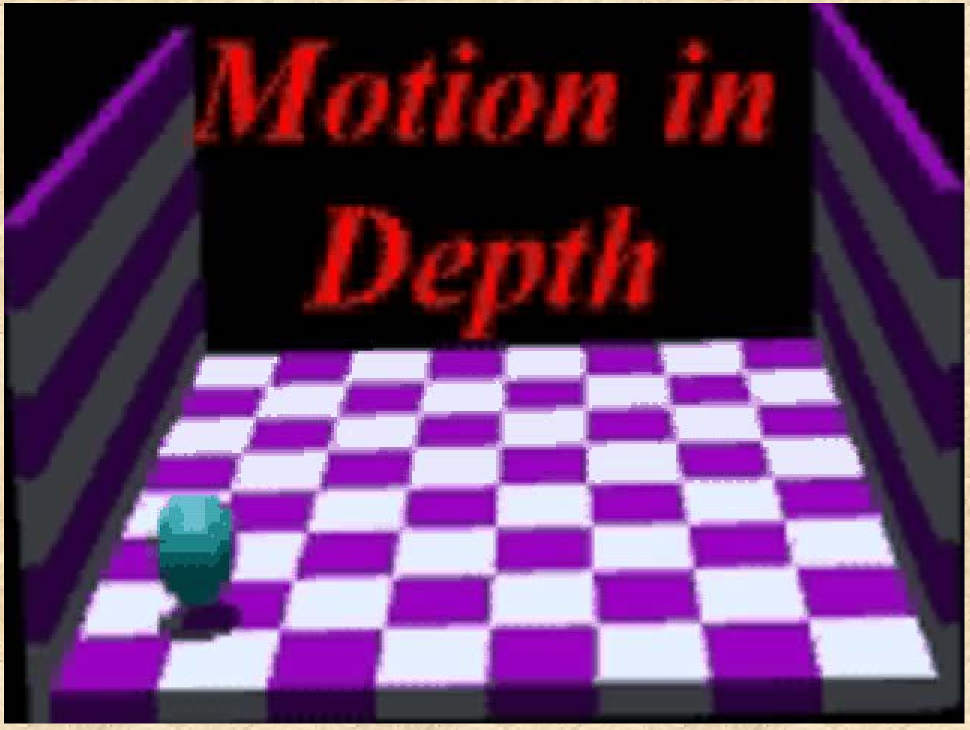
Any shading in this picture?



visual system assumes
light from above (in a
retinal coordinate system—
view with your head upside-down!)

Pictorial Depth Cues

Interposition or Occlusion
Shading and **Shadows**



from http://gandalf.psych.umn.edu/~kersten/kersten-lab/demos/shadows.html

by Kersten, Mamassian and Knill

Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows
Aerial Perspective
(aka atmospheric perspective)

scattering of light by molecules and particles along the path from a distant surface to the eye causes a spatial blurring and loss of contrast

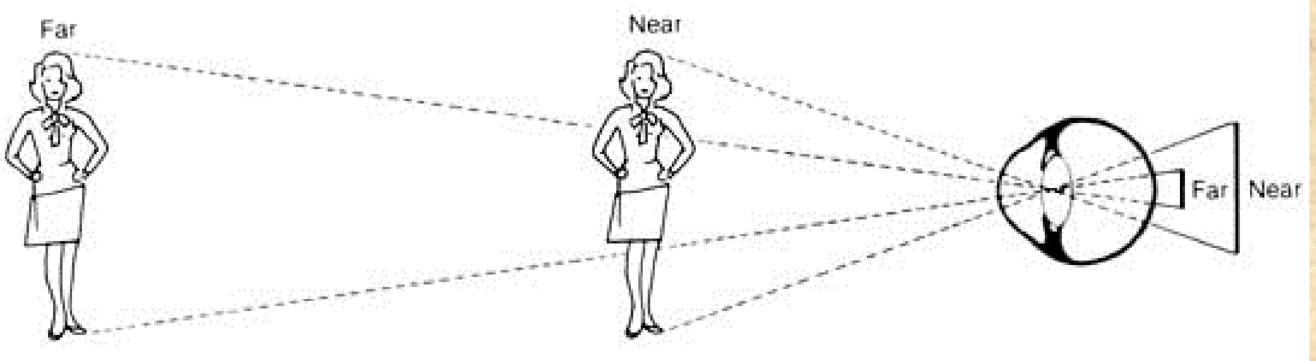
Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows
Aerial Perspective

short-wavelength light is scattered more than light at longer wavelengths;
things off in the distance look more blue

Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows
Aerial Perspective
Retinal and Familiar Size (Relative Size)



If we know the rough size of an object (say, a person), then we can infer from its retinal image size how far away it is.

Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows
Aerial Perspective
Retinal and Familiar Size
Linear Perspective

from J.J. Gibson (1957)

lines parallel in 3D space
converge at a vanishing point

Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows
Aerial Perspective
Retinal and Familiar Size
Linear Perspective

things close to the vanishing point: distant
things far from the vanishing point: near

lines parallel in 3D space
converge at a vanishing point

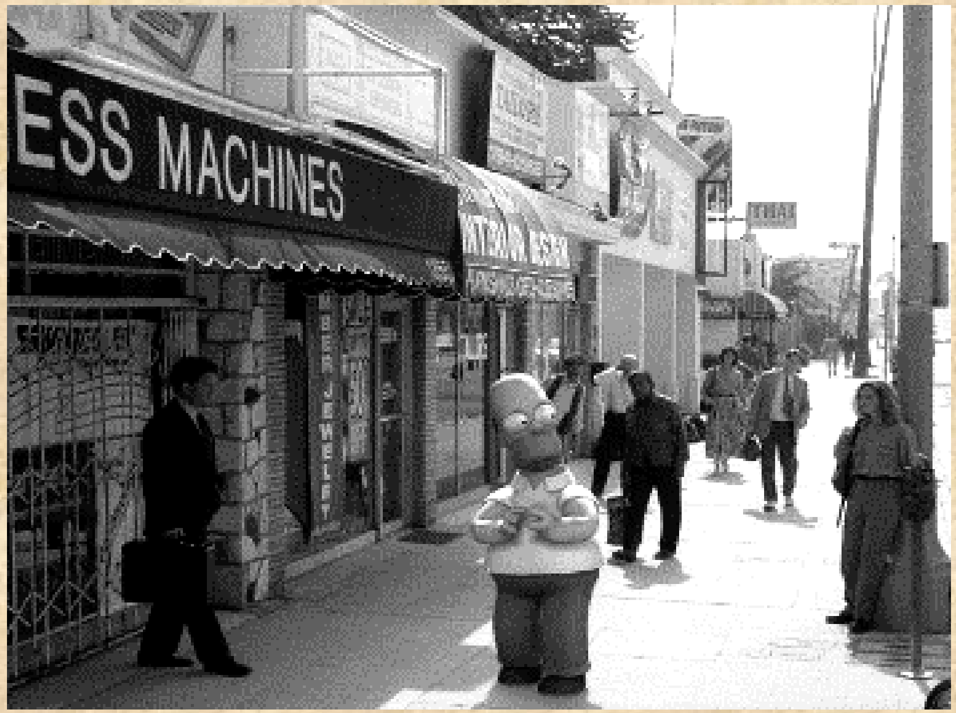
Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows
Aerial Perspective
Retinal and Familiar Size
Linear Perspective

Perugino's *Christ Delivering Keys to St. Peter*, 1485

Pictorial Depth Cues

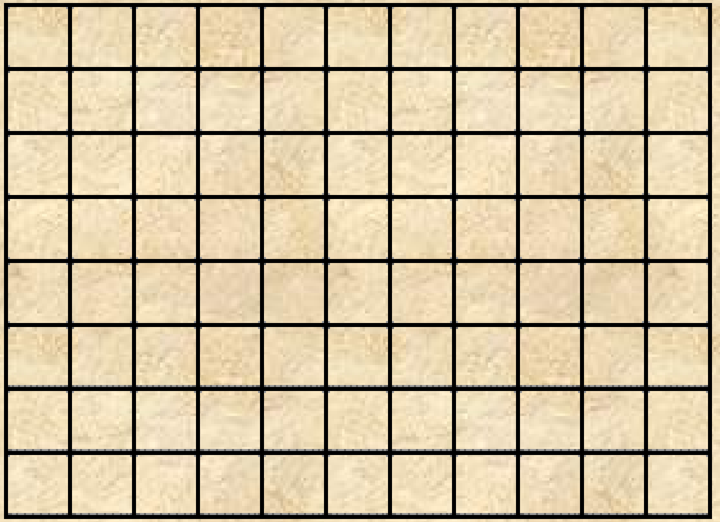
Interposition or Occlusion
Shading and Shadows
Aerial Perspective
Retinal and Familiar Size
Linear Perspective



Any perspective cues in this picture?

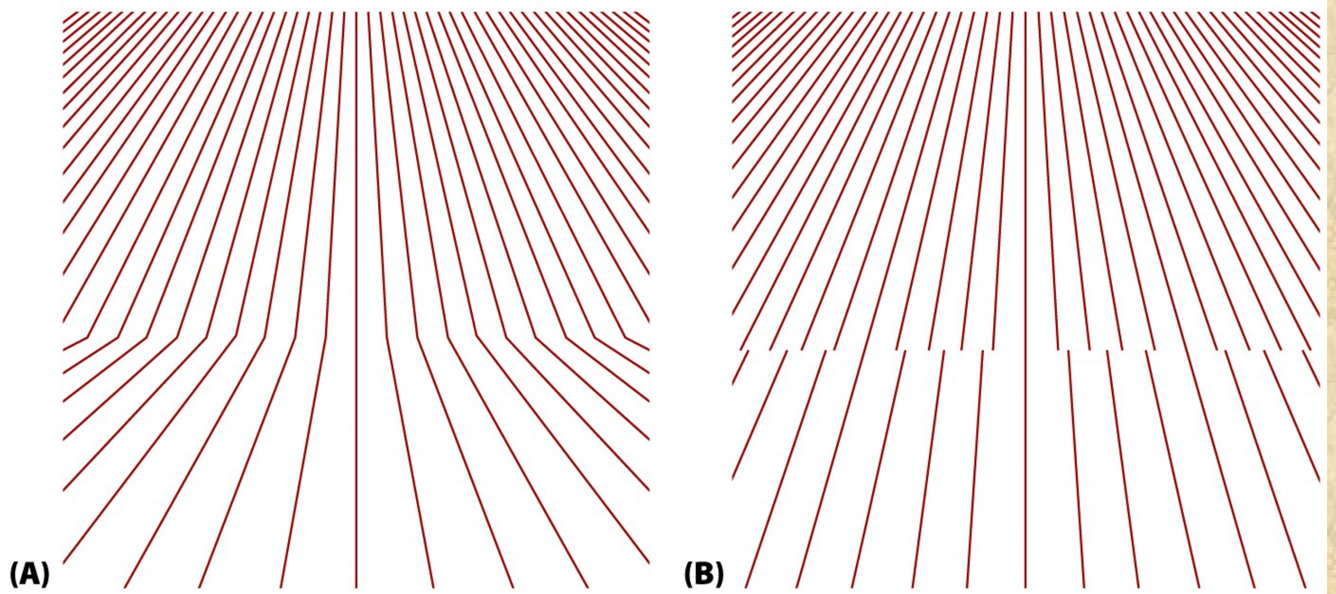
Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows
Aerial Perspective
Retinal and Familiar Size
Linear Perspective
Texture Gradients



Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows
Aerial Perspective
Retinal and Familiar Size
Linear Perspective
Texture Gradients



Psychology, 8/e Figure 5.31

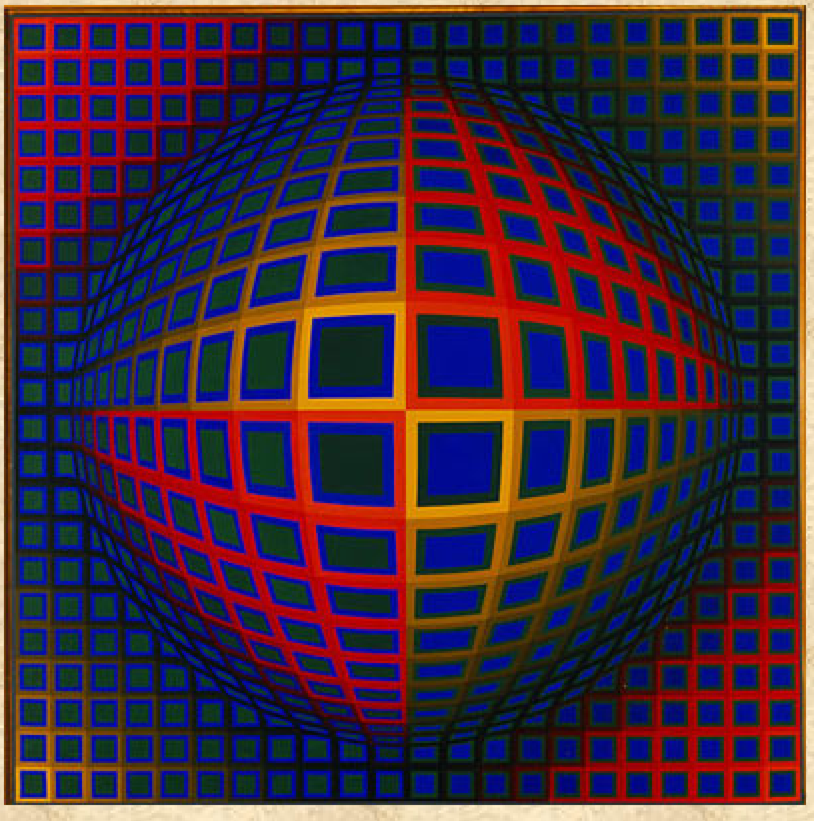
Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows
Aerial Perspective
Retinal and Familiar Size
Linear Perspective
Texture Gradients

Caillebotte, 1877

Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows
Aerial Perspective
Retinal and Familiar Size
Linear Perspective
Texture Gradients



Victor Vasarely, *Vega-Nor*, 1969

Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows
Aerial Perspective
Retinal and Familiar Size
Linear Perspective
Texture Gradients

Psychology, 8/e Figure 5.30

Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows
Aerial Perspective
Retinal and Familiar Size (Relative Size)
Linear Perspective
Texture Gradients

Height in the Plane (Relative Height)

things toward the bottom of an image tend to be nearer than things toward the top

Pictorial Depth Cues

Interposition or Occlusion
Shading and Shadows
Aerial Perspective
Retinal and Familiar Size (Relative Size)
Linear Perspective
Texture Gradients

Height in the Plane (Relative Height)

Physiological Cues

Accommodation

The crystalline lens of the eye changes shape to help keep objects in focus

near accommodation – lens more curved
far accommodation – lens more flat

likely a weak cue to depth

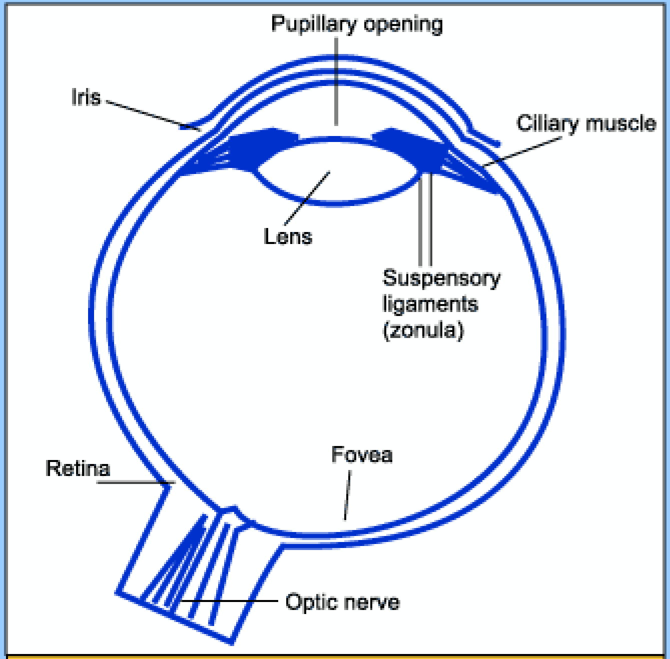
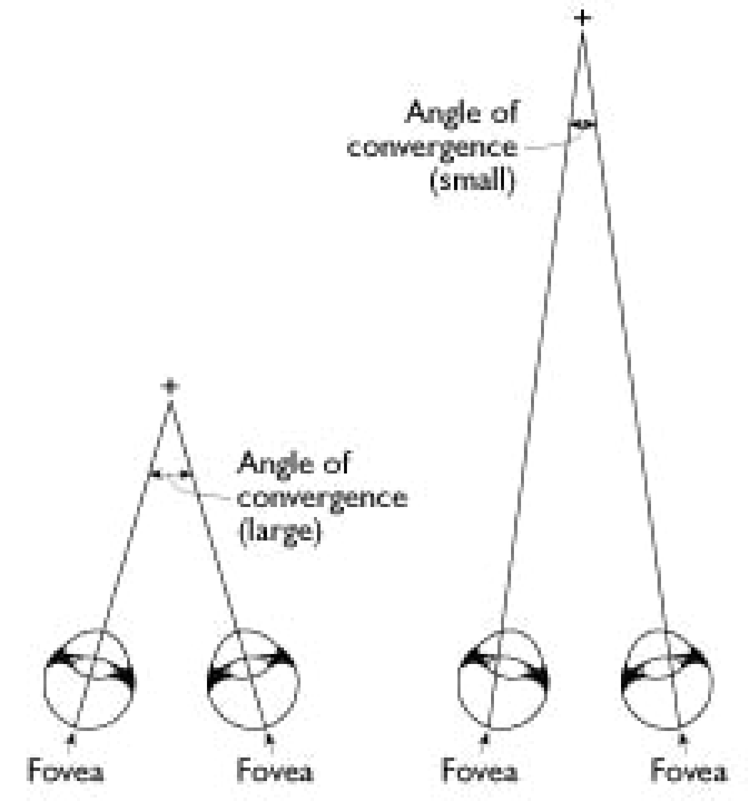


Figure 12

Physiological Cues

Accommodation

Convergence & Divergence

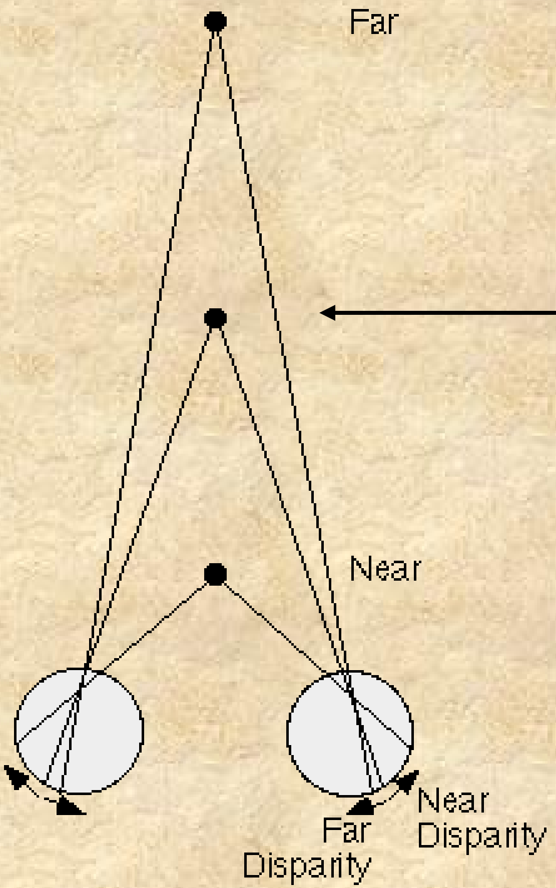


vergence movements of the two eyes, in opposite directions, to fixate

-likely a weak cue to depth

Binocular Depth Perception: Stereopsis

Disparity – the difference between the retinal images of the left and right eyes



Suppose that your eyes are converged on a point of intermediate distance.

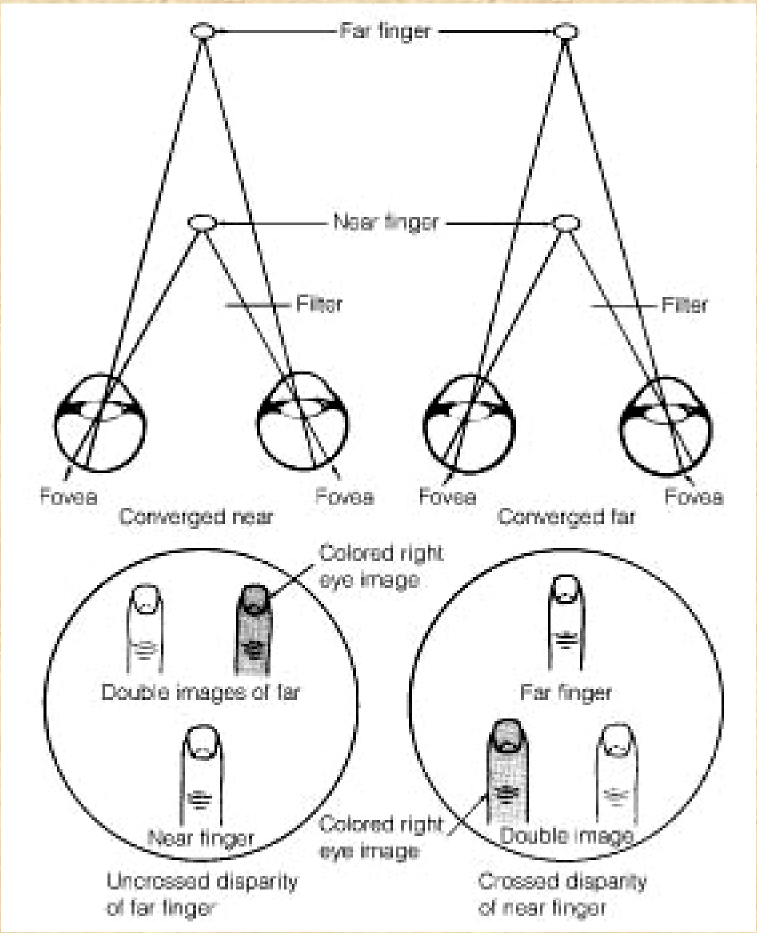
A point lying closer ("Near") will give rise to retinal images displaced towards the ears (temporally) – *crossed disparity* or *near disparity*

A point lying farther ("Far") will give rise to retinal images displaced towards the nose (nasally) – *uncrossed disparity* or *far disparity*

Binocular Depth Perception: Stereopsis

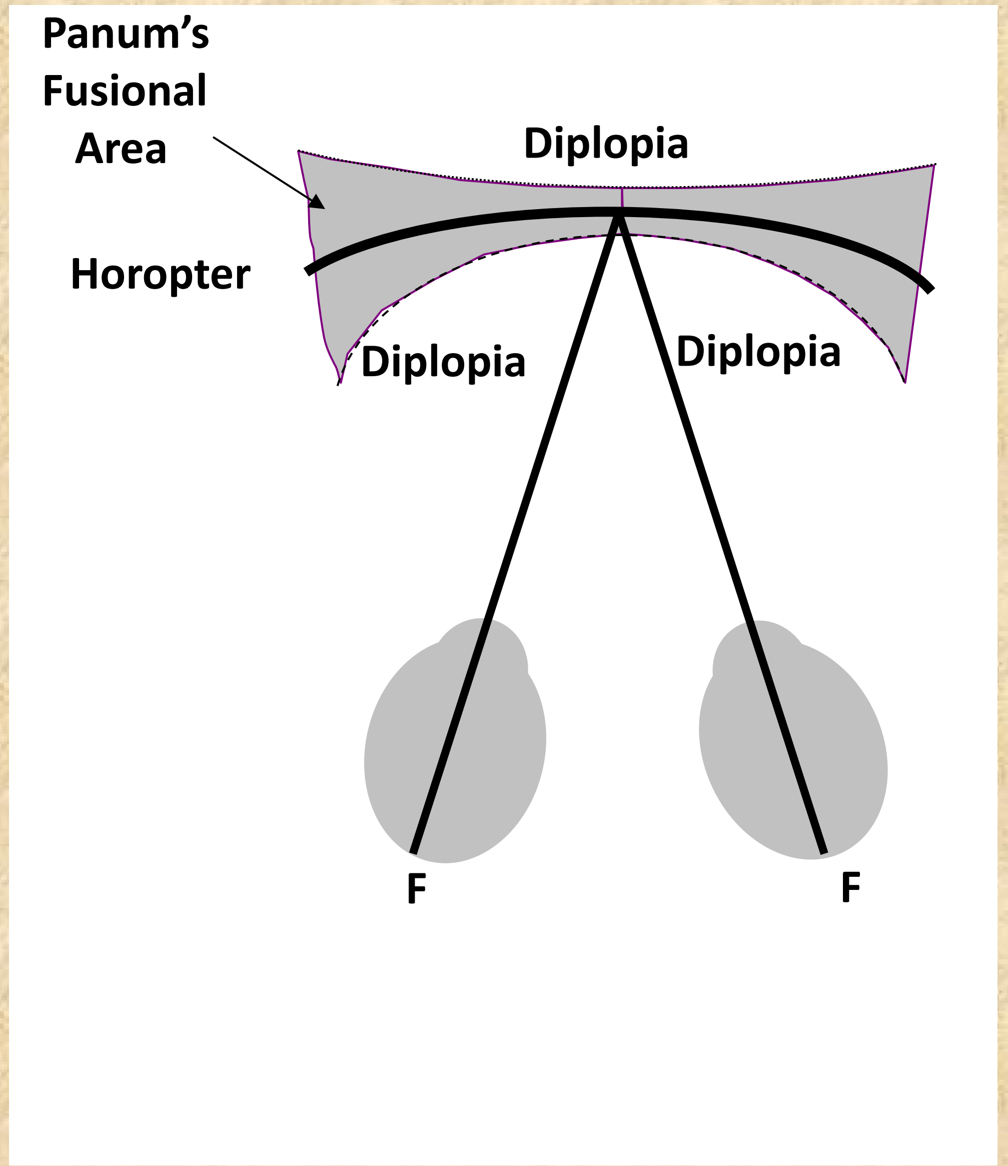
Fusion – the merging of disparate retinal images into a single, unified percept

Diplopia – double vision arising from failure of fusion



Fusion is possible within Panum’s area.

Points which lie outside this area appear *diplopic* (double image).



Stereopsis

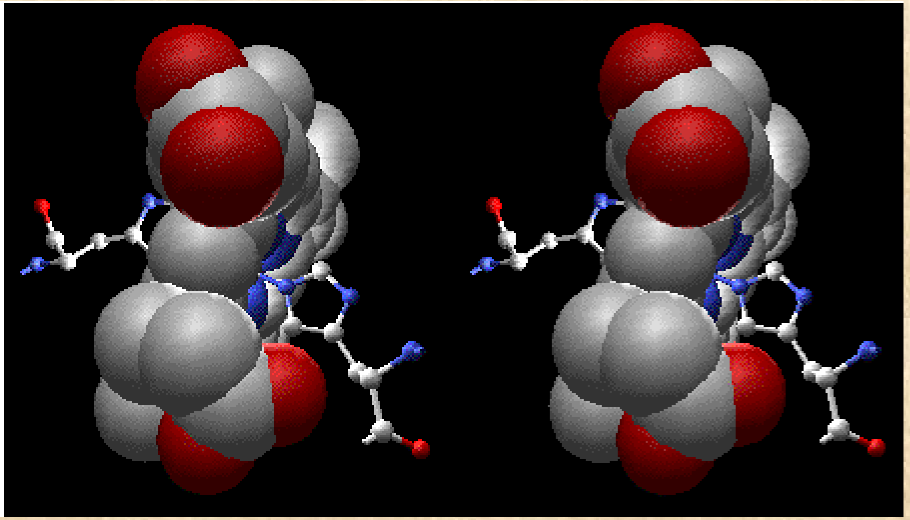
ability to recover depth information from binocular disparity

people possess this ability to greater or lesser degrees;
perhaps as many as 10% do not have usable stereopsis

- such people are *stereoblind*

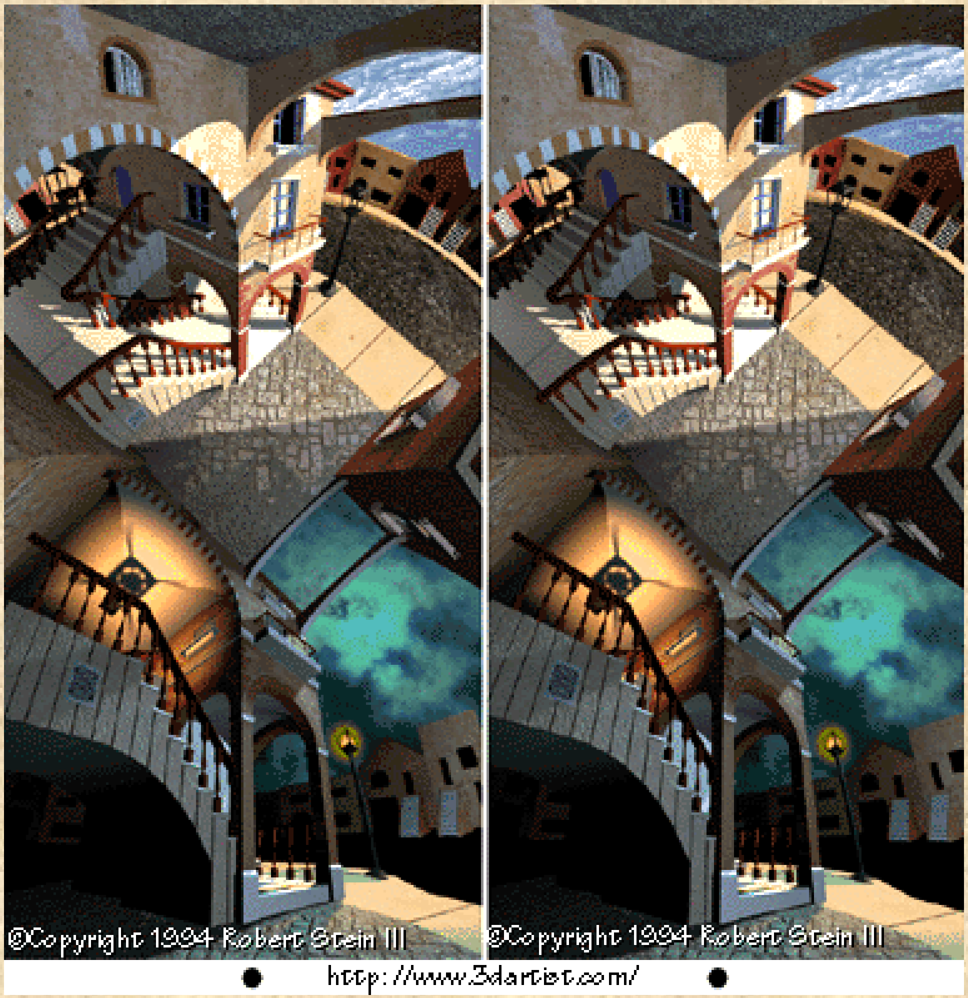
Among the easiest stereo displays to view are *stereo pairs*, for which one tries to *cross* one's eyes so that the image at left and the image at right come to lie atop one another in the center.

Here's another...

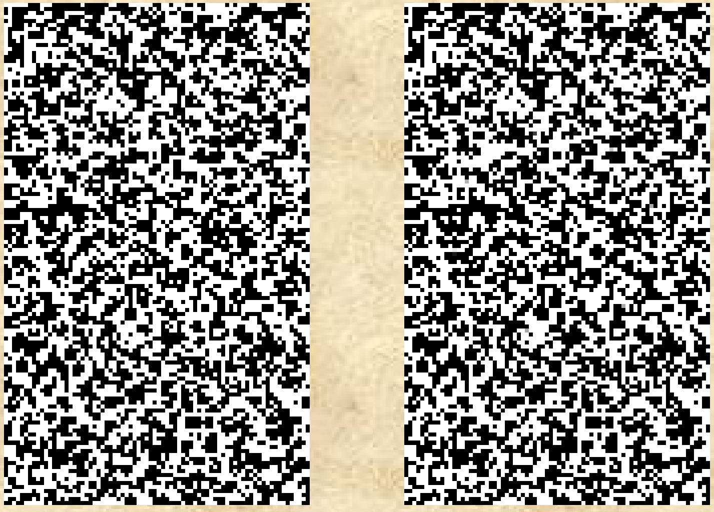


Yet another...

Here is an Escheresque stereo pair...



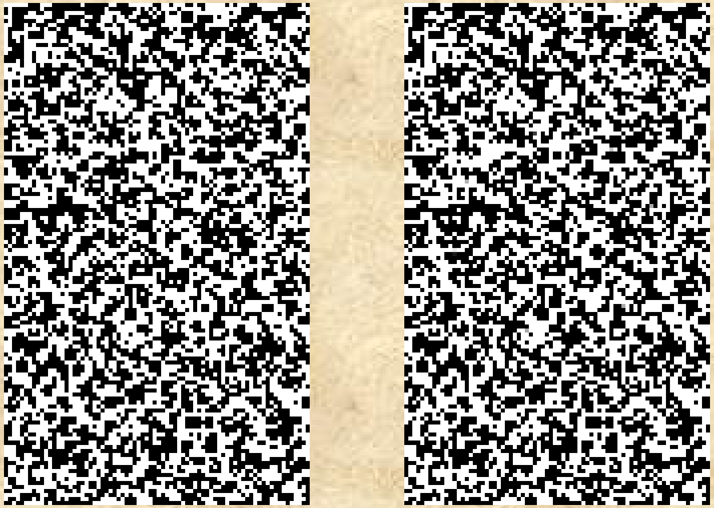
Vision scientists have, since the work of Bela Julesz, used *random dot stereograms* in experiments on stereopsis. These provide little cue to 3D content other than disparity. The stereo pair below works in the same way as the previous stereo pairs but might take a little more effort.



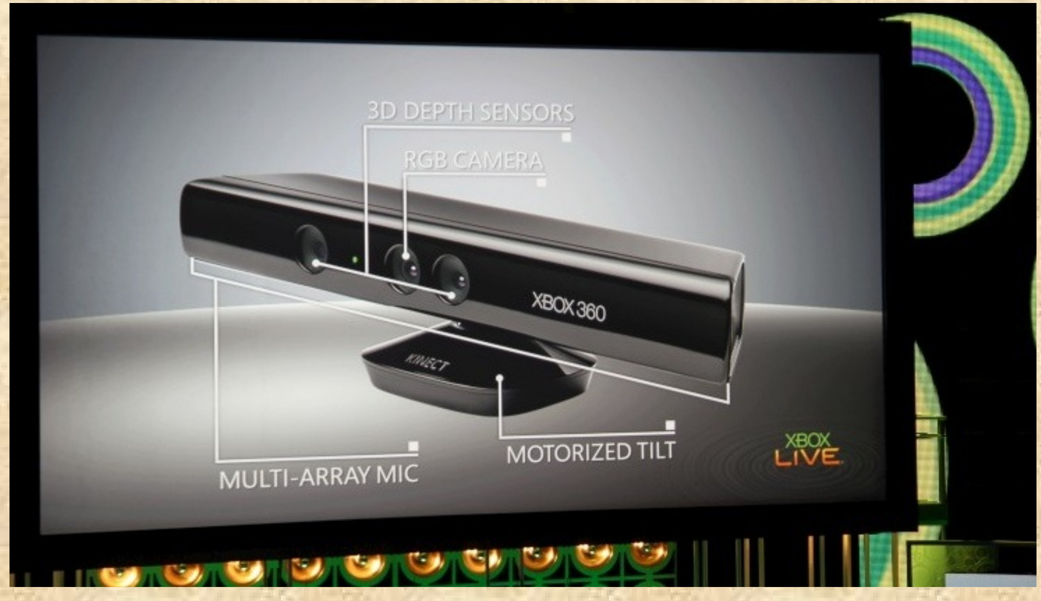
fine book: Bela Julesz (1971) Foundations of Cyclopean Perception. (Chicago: Univ. Chicago Press).

Such displays demonstrate the notion of *global stereopsis*, the perception of depth in the absence of monocular shape or form.

The task for the visual system is to find dots in one eye's image that correspond to dots in the other eye's image: the *correspondence problem*



Kinect



Structured Illumination

- rapidly shine infrared laser (left) in a large number of known directions
- use an infrared-sensitive camera (right) to measure where in the image the infrared spots fall
- infer the depth at the position of the infrared spot by comparing
    - the known direction
    - the known camera image position

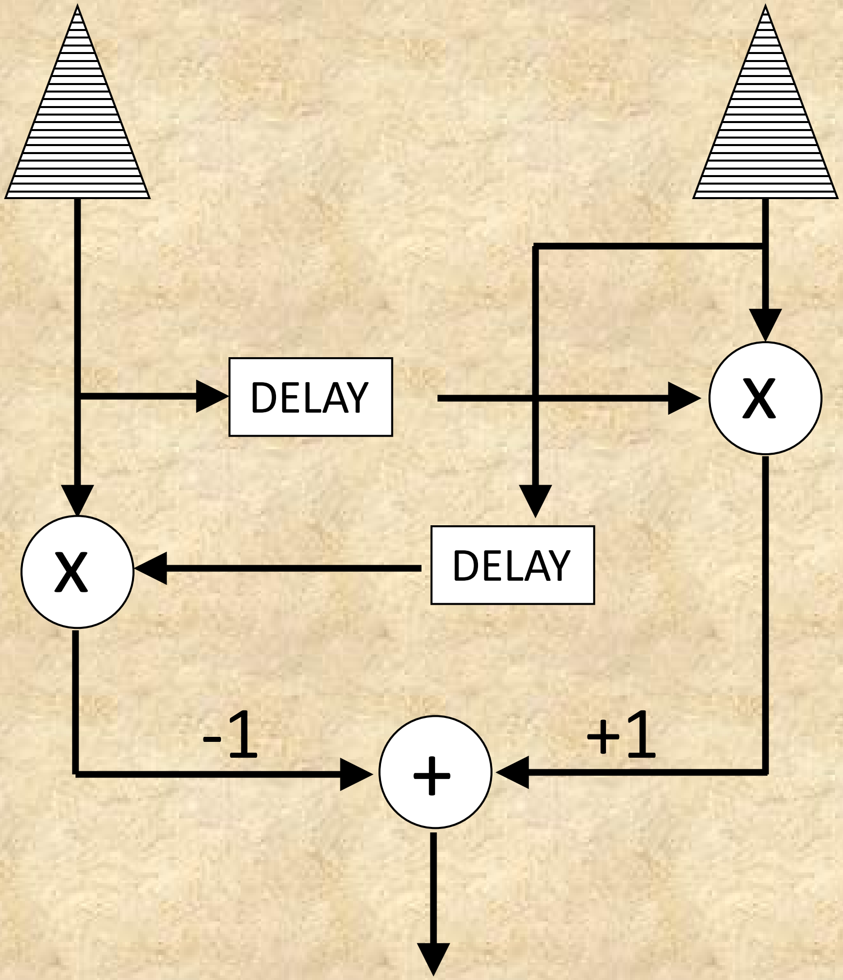
Result: Depth map across the visual image received by a second camera (standard RGB color camera, center)

Motion Cues to Depth

- Optic Flow (caused by motion of the viewer)
- Independent Object Motion

How do we perceive motion in the first place??

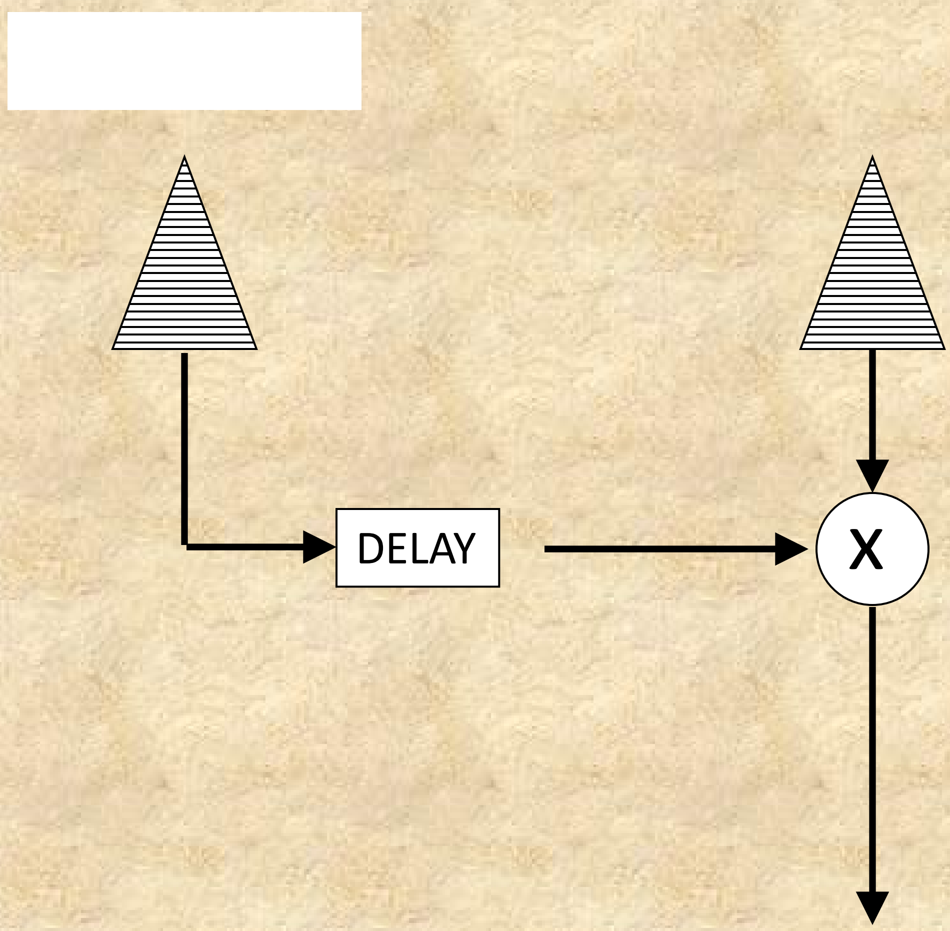
Motion Detectors (Werner Reichardt)



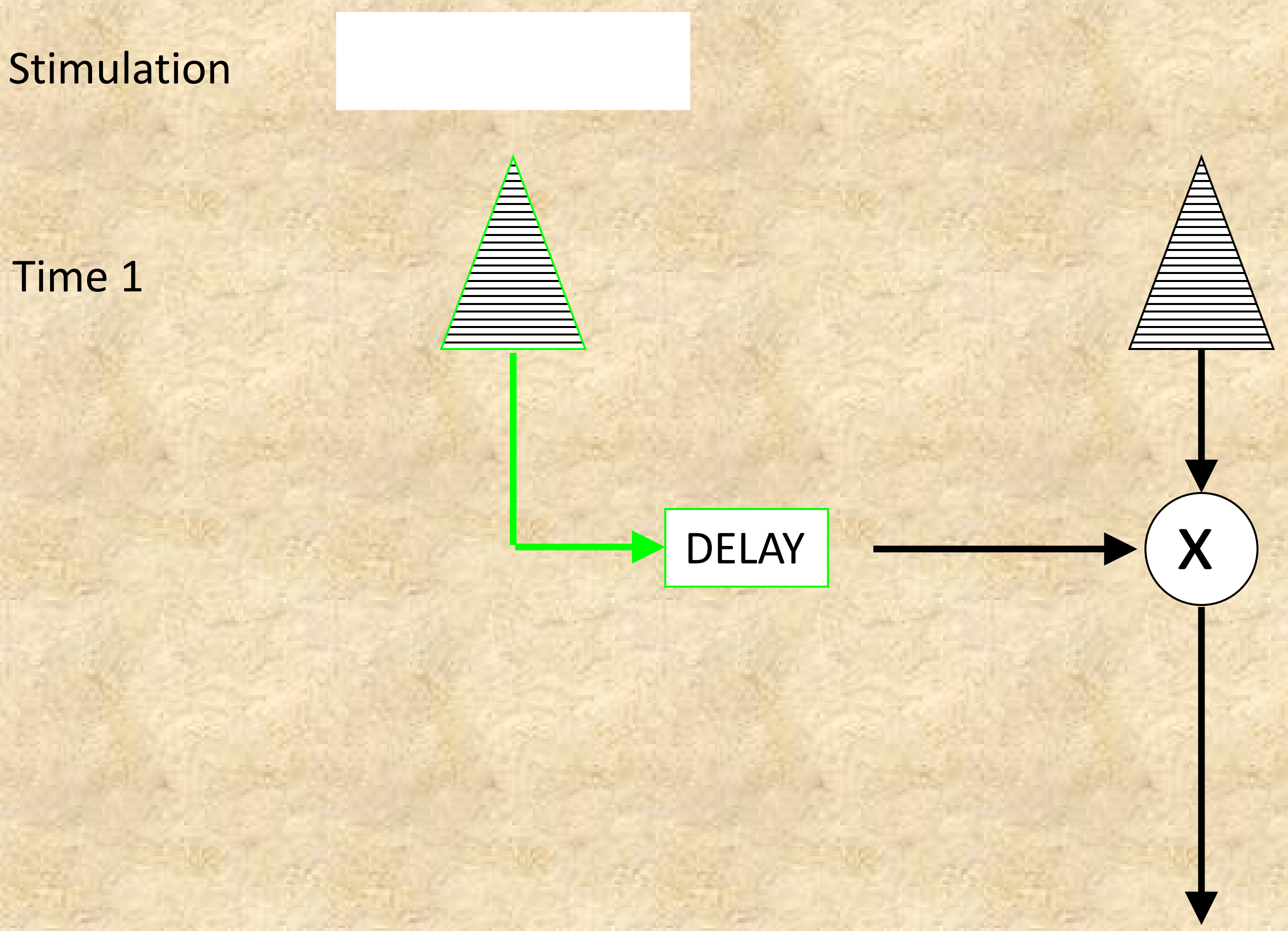
yikes!

Stimulation

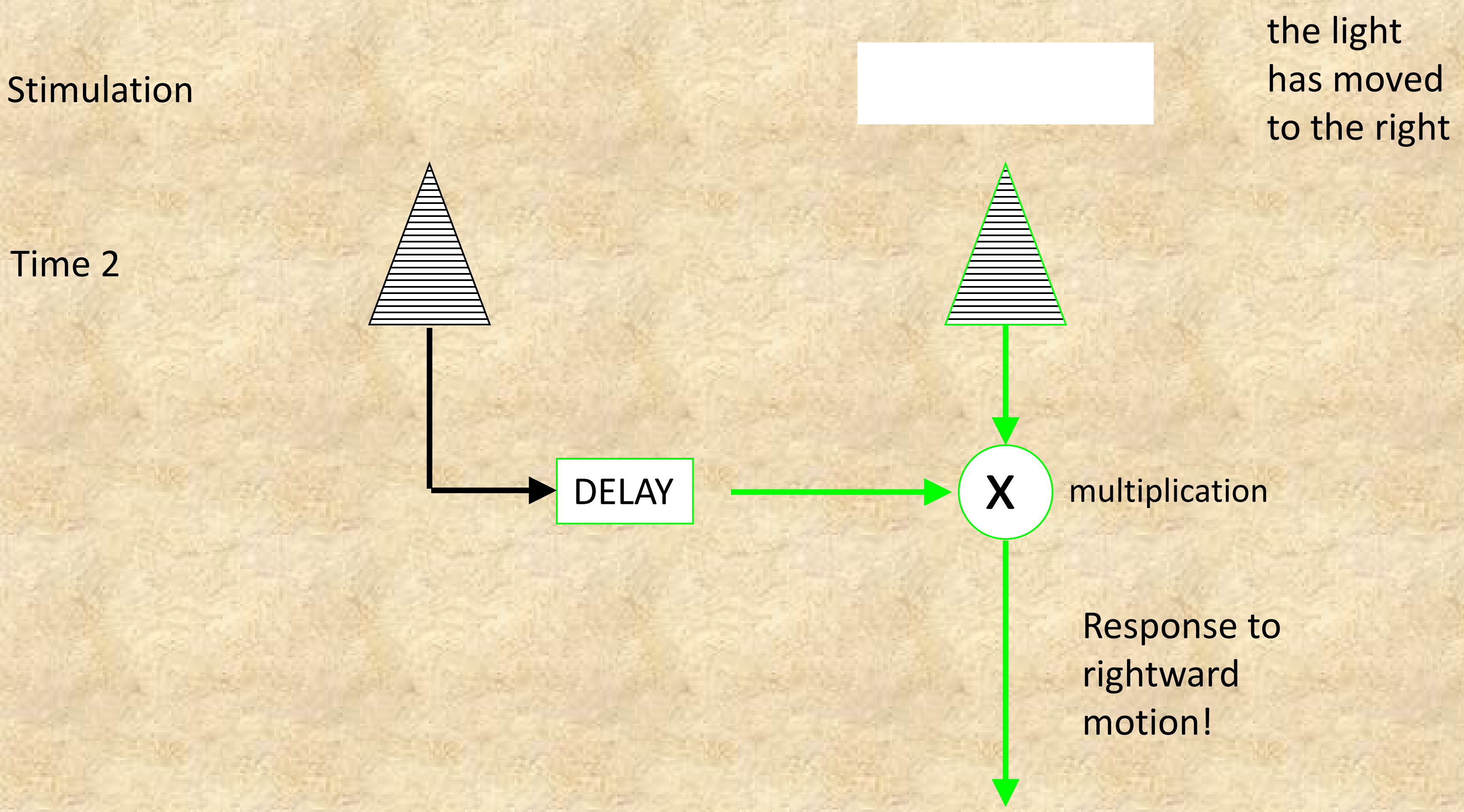
Time 1



Let’s try to detect a light moving to the left...



Positive response by the left receptor to the light, held in the delay mechanism for one time unit...

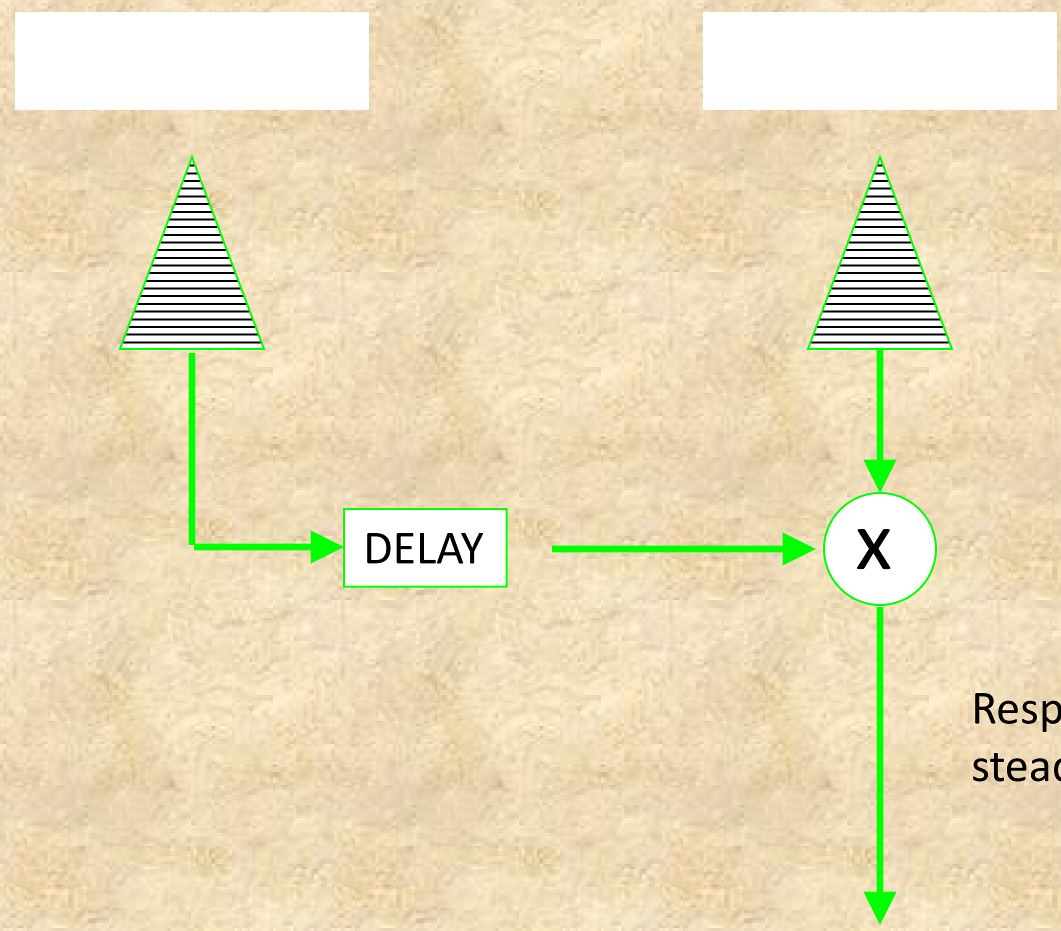


Positive response by the right receptor to the light, multiplied by the delayed positive response by the left receptor

A problem...

Stimulation

Shine a light steadily on both receptors

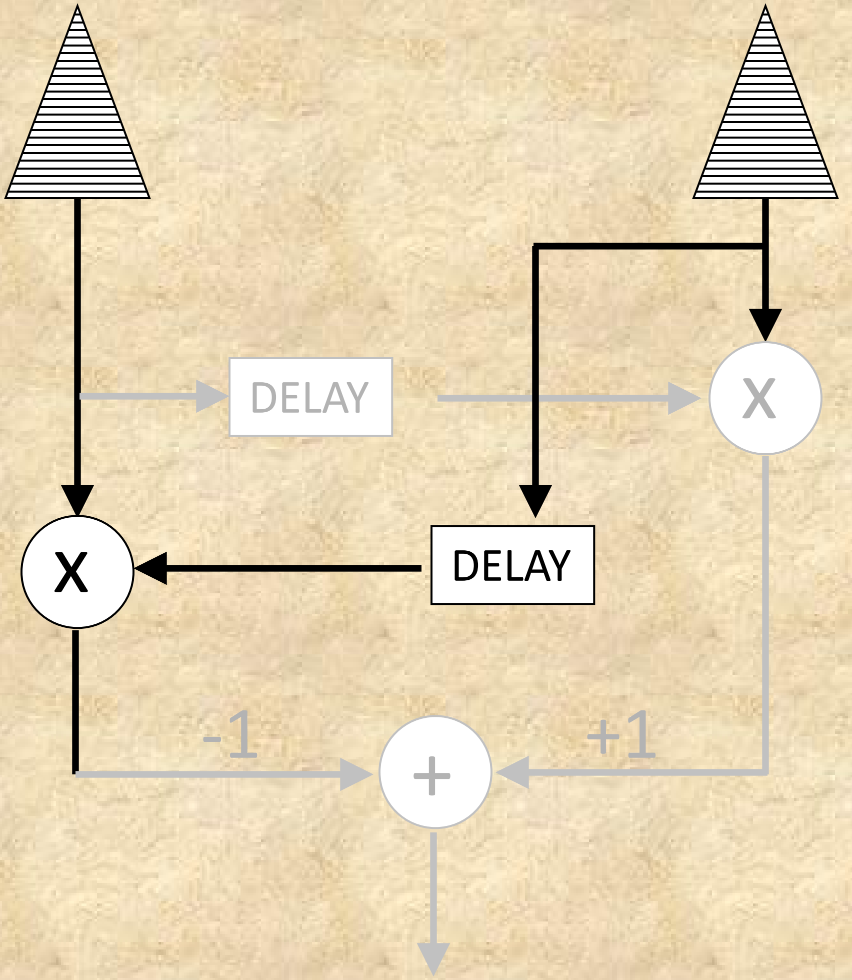


Responds to steady light (oops!)

We need a way to eliminate the response of such a system to a steady light covering both receptors.

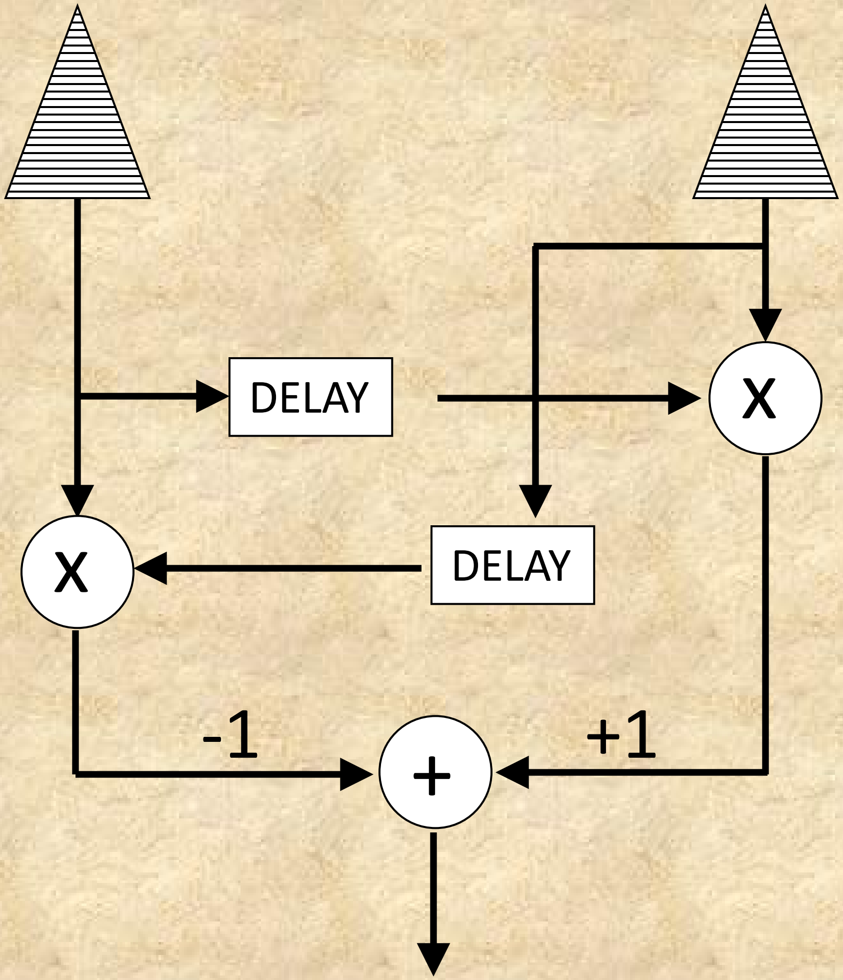
Solution, Part 1

Add a leftwards-motion detector

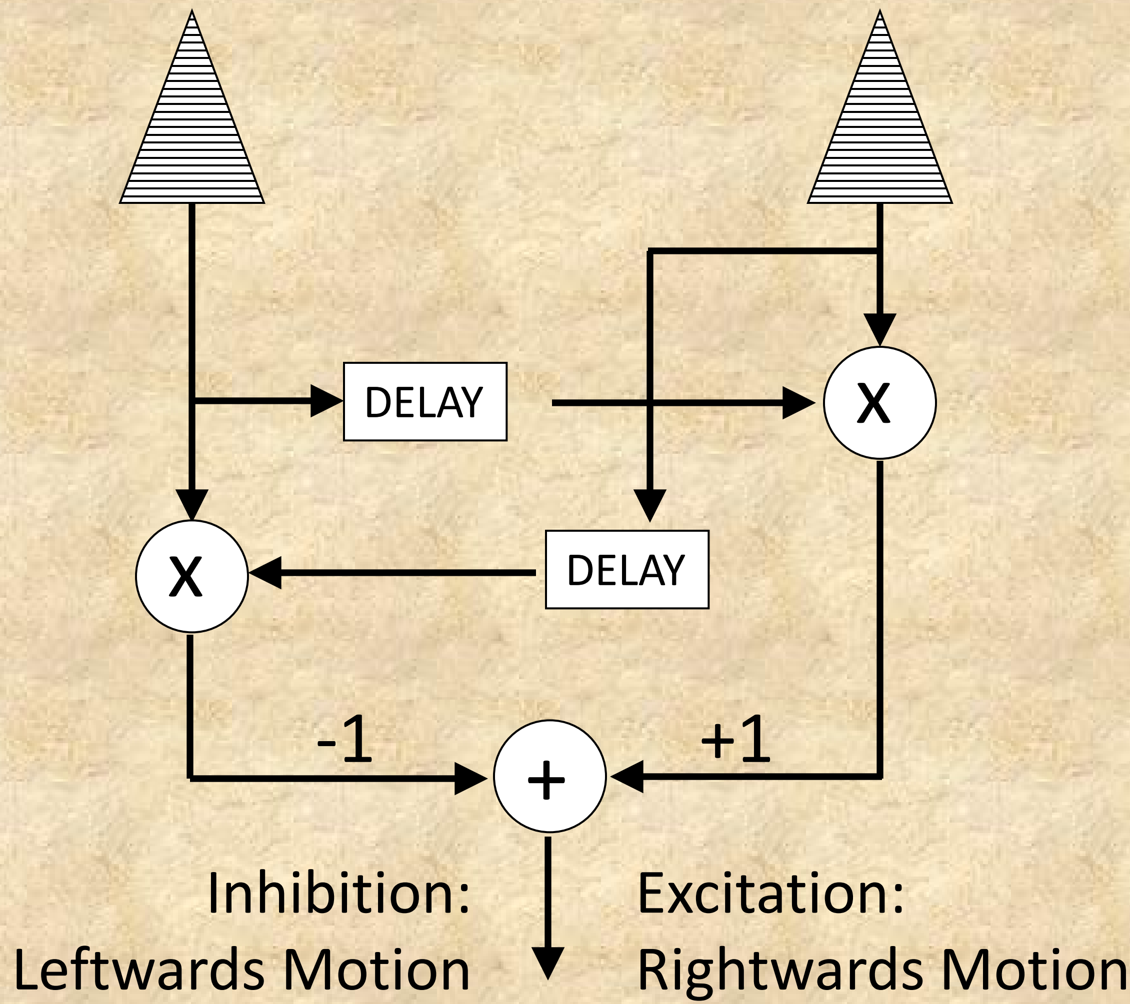


Solution, Part 2

Compare the responses of the leftwards- and rightwards-motion detectors



Reichardt Detectors: Motion Opponency



Reichardt Detectors: Motion Opponency

Leftward and rightward motions are compared by the same opponent neurons.

Upward and downward motions are compared by the same opponent neurons.

Causing such neurons to adapt to a motion stimulus can lead to interesting *motion aftereffects*.

http://www.michaelbach.de/ot/mot_adapt/index.html

Motion Cues to Depth: Structure From Motion

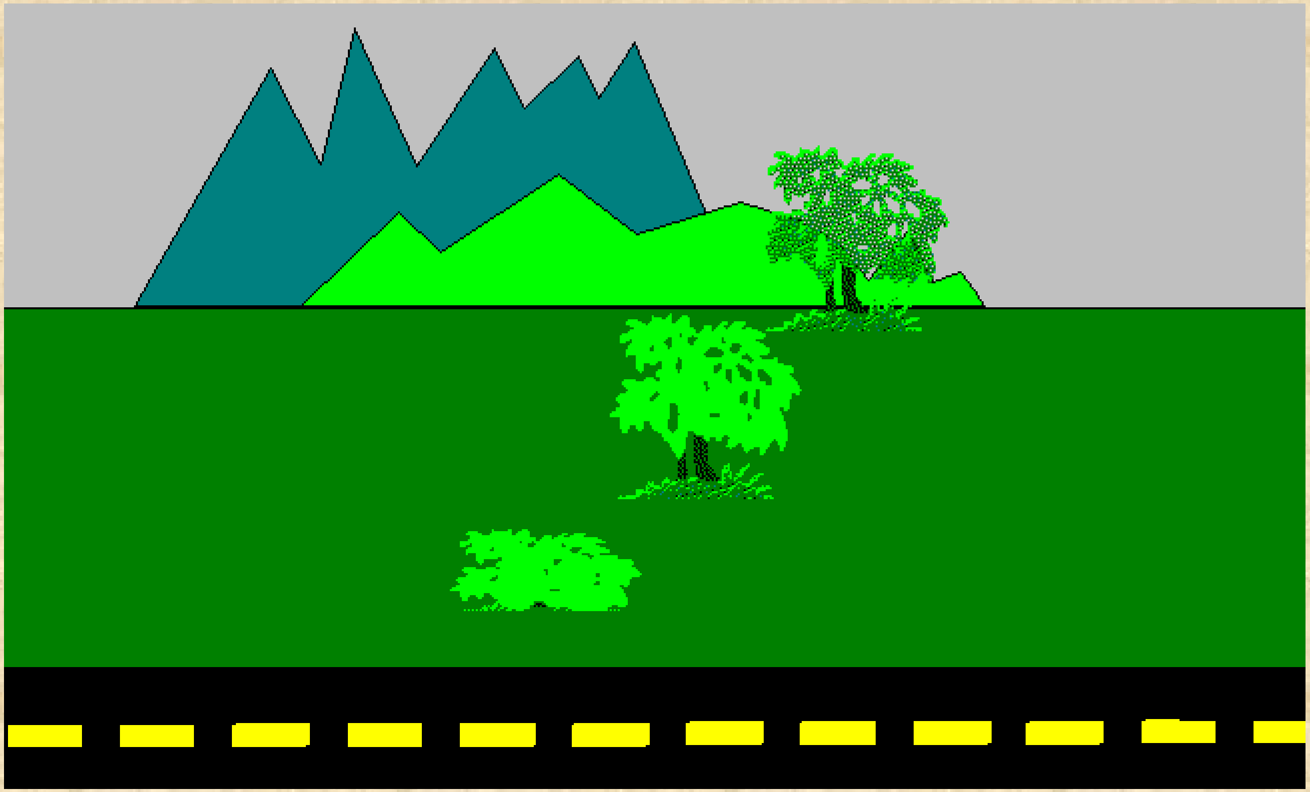
Independent Object Motion
provides dues as to
object shape and depth

Try http://www.michaelbach.de/ot/sze_Necker/index.html

Biological interpretation of apparent motion (Johansson)
http://www.michaelbach.de/ot/mot_biomot/index.html

try also
http://www.journalofvision.org/content/suppl/2011/01/13/2.5.2.DCSupplementaries/genderclass.swf
and
http://www.journalofvision.org/content/suppl/2011/01/13/3.4.1.DCSupplementaries/dog.swf

Motion Cues to Depth: Motion Parallax



as you move along, nearby objects move more rapidly through your visual field   distant objects move more slowly through your visual field