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DEPTH PERCEPTION

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CONTEXT OF STEREOPSIS

Vision provides us with information about what things are, and where they are. The visual perception of what an object is largely depends on the retinal image and neural processing that supports monocular vision. Aspects of monocular vision that we have already studied included:

- Spatial vision (contrast sensitivity, visual acuity, etc.)
- Colour vision
- Visual adaptation
- Temporal vision

The perception of where things are may be referred to as space perception. Space perception may be broken down into the sense of direction and distance. Visual direction is a function of both monocular and binocular vision. Earlier, we studied:

- Oculocentric (monocular) and
- Egocentric (binocular) visual direction.

DEPTH PERCEPTION

Both monocular and binocular vision contributes to our perception of distance—that is, **depth perception**. Distance perception may be categorized into absolute and relative depth perception.

- Absolute depth perception (distance perception) is an estimate of the physical distance, in units such as meters, to an object. It is based primarily on monocular depth cues.
- Relative depth perception (depth perception) estimates the location of objects in relation to other objects, rather than in terms of physical distances. It is based on monocular and binocular depth cues.

Note that a person can still have depth perception even without stereopsis. In fact, when viewing distant objects (beyond about 6 meters), stereopsis contributes little to depth perception; monocular cues are usually more important. Stereopsis provides only relative depth information, while absolute estimates of distance require monocular cues. Both monocular cues and stereopsis work together to give absolute and relative depth information.

MONOCULAR DEPTH CUES

A review of monocular depth cues may be found in Schwartz Chapter 10. Monocular depth cues include **pictorial cues**, **motion parallax**, and the **kinetic depth effect**. When we think of monocular depth cues, we usually think of the pictorial cues, which are the geometric features or image effects contained in two-dimensional images that give the illusion of depth or distance. We see these everyday on computer monitors, televisions, and in photographs. Even though the images are flat, we perceive depth or distances. These illusions of depth do not require binocular vision. Some of the pictorial depth cues are:

Size
Retinal image size can be used to estimate the distance to an object. Image size is inversely proportional to the distance. It requires some knowledge about the object. The image of a person standing far away is small, but you already know approximately how tall he/she is. With that understanding you can estimate the true distance.

Two things could cause a decrease in retinal image size:

1) Object size remains constant but distance increases, or
2) Distance remains unchanged but the object shrinks.

Since you know that most objects don't shrink or grow, you brain usually interprets changes in retinal image size according to choice #1—that the distance, not the object size, is changing. This is closely related to the principle of **size constancy**. This is the principle that, in vision, the perceived size of an object remains relatively constant, even if it's retinal image size changes.

Shape constancy (form constancy) is similar to size constancy. The perceived shape of an object remains relatively constant even if the actual retinal image shape changes, as it happens due to changes in viewing angle. Size and shape constancy can be used to explain some interesting illusions, such as the **moon illusion** (Schwartz p. 243-244) or illusions such as those illustrated in **Schwartz Fig. 10-1** or **Steinman 7-1**. A similar illusion is described in **Emmert's law**, which states that:

A projected after-image or eidetic image is altered in size in proportion to the distance of the surface on which it is projected. An eidetic image is defined in the Dictionary of Visual Science as, "An extraordinarily experienced, mental picture based on the recall of a previous visual experience and characterized by its clearness, apparent realness, and accuracy of detail." (Dictionary of Visual Science, 1997)

Steinman Fig. 7-2 *illustrates Emmert's law. Can you explain this figure?*

Figure 25.1 *Is the man holding a little person in the palm of his hand?*

Size constancy creates this illusion. Can you explain how?

Q Can you explain the moon illusion (Fig 25.2)?

***Figure 25.2** The moon illusion.*

Linear Perspective
This is based upon the principle of size (above).
The distance between two parallel lines decreases with increasing distance.

Texture

- This is also related to the size principle.
- Angular size of repeating patterns decreases with distance.

***Figure 25.3 Size**, linear perspective and texture are demonstrated here.*

- Nearer objects block objects that are further away.

Clarity

- This is also known as aerial perspective.
- Farther objects appear to have lower contrast, or may appear slightly blurred.
- This is based on optical principles such as scatter or defocus.

Lighting and shadow also contribute strongly to our perception of three-dimensional depth and distance.

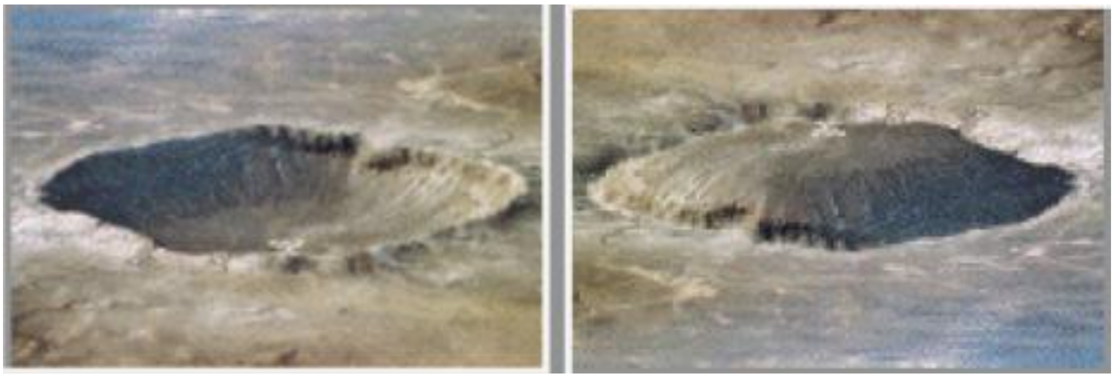

Figure 25.4 *Two identical pictures, except the right one was flipped upside down.*
This reverses the position of the light/dark contours and creates a completely different perception of depth.

Figure 25.5 *How many of the monocular depth cues can you identify in this painting by Dru Blair, the famous aviation artist? Also note the strong illusion of motion*. (http://www.drublair.com)

Motion Parallax

Motion parallax can also provide vivid monocular depth information, because if you view a scene while moving, the relative position of objects will change, depending on their locations relative to your fixation point (**Steinman Fig. 7-9**). That is why, when you drive along a road in the evening, watching the trees go by, the moon appears to be moving in the same direction you are driving. On the other hand, if you fixate on the trees, nearer objects will appear to be moving in the opposite direction.

- Objects nearer than fixation - against movement
- Objects beyond fixation - with movement

Motion parallax can also be used to determine whether an ocular opacity, seen during direct ophthalmoscopy, is located in front of or behind the pupil.

Kinetic Depth Effect and Biological Motion

Another monocular depth cue is the **kinetic depth effect**. The flat image of a rotating object, such as a computer animation, or the shadow of a turning wire, projected on a screen, acquires a strong perception of three-dimensional depth because of the motion in the image (**Steinman Fig. 7-10**). The kinetic depth effect and **biological motion** can elicit a strong sense of three-dimensional depth perception even though they are not binocular phenomena.

"A variety of cues, including binocular disparity, interposition, shading, and texture, are used by the visual system to infer structure and depth. However, a very compelling perception of structure and depth can be elicited on the basis of motion alone. [...] Transformations in the visual field resulting from the movement of objects, as well as movements of the body, head, and eyes, can be sufficient to produce a perception of depth. The perception of depth resulting from the systematic transformation of retinal images is called the kinetic depth effect. [...] Our ability to infer structure and depth is so powerful that motion alone, without form, can be a sufficient stimulus. [...]One particular kind of motion, biological motion, is produced by the complex patterns of movement produced by humans and animals. [...] Johansson attached lights to the shoulders, elbows, wrists, hips, knees, and ankles of actors and them made motion pictures of them moving about in a dark room. All that was visible on the film was the pattern of movements made by the lights. To their great surprise, Johansson and colleagues discovered that as soon as the actors began moving, naive observers could immediately perceive that the lights were attached to otherwise invisible human beings."

This technique is being used increasingly in movies to create very realistic animated figures. Using a technique called motion capture; film producers record the biological motion of real people, and then apply it to computer-generated figures.

*"*A technique called motion capture allows actual movement to be recorded and applied to digital characters. An actor wears reflective markers at key body joints, and surrounding cameras record the motion of reflected infrared light in the computer. Later, this motion data is transferred to the digital character."

The following web site, (http://www.pbs.org/wgbh/nova/specialfx2/) describes how special effects, including motion capture, were used to create virtual people for the movie Titanic, and it has other interesting demonstrations, such as a virtual Marilyn Monroe (http://www.pbs.org/wgbh/nova/specialfx2/marilyn.html). This technique was also used to create the character Gollum, in the Lord of the Rings trilogy. To see an interesting video of how they created Gollum, go to the following web site, and select the "Bringing Gollum to Life" video. (http://www.lordoftherings.net/index_flat_editorials_golluminterview.html).

Figure 25.6 *Gollum, played by actor Andy Serkis.*

These monocular depth cues provide a very useful sense of depth and in many instances monocular depth dues are superior to binocular cues such as stereopsis. Sometimes monocular depth cues can conflict with each other and lead to various interesting visual illusions. Some common illusions are described in Schwartz Ch. 10. Some of the best demonstrations of visual illusions may be found at the Illusion Works web site: http://psylux.psych.tudresden.de/i1/kaw/diverses%20Material/www.illusionworks.com/html/jump_page.html

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