MISCELLANEOUS TOPICS IN VISUAL PERCEPTION

AUTHOR

Thomas Salmon: Northeastern State University, USA

PEER REVIEWER

Scott Steinman: Southern California College of Optometry, USA

PAST POINTING

In some cases in which a person acquires an extraocular muscle (EOM) paresis, if he/she views an object in the field of action of the paretic muscle with his/her paretic eye and tries to quickly point at the object, he/she will tend to point beyond its actual position. This is known as **past pointing**, and is probably due to the greater than normal proprioception from that muscle, which affects the egocentric sense of visual direction. Past pointing is also sometimes seen when an amblyopic eye with eccentric fixation is forced to fixate.

GESTALT THEORY OF VISUAL PERCEPTION

We previous learned how the visual system seems to work as a Fourier analyzer, breaking up an image into its spatial frequency components for later synthesis by the brain. But it also appears that the visual system decides what the image is before using all the data, and fits the data into the preconceived image. This brings up the topic of bottom-up and top-down processing.

Bottom-up processing: This approach says that the visual system receives basic information about the components of an image and simply assembles the pieces into an image of the whole object. The sensors (the eyes) receive the basic information, which is then analyzed (broken down) and relayed to the brain along different parallel pathways. It is then reassembled in the brain.

Top-down processing: says that the visual system does not just passively assemble sensory components, but is actively creating the image. That is, it selectively organizes sensory data to fit into a reasonable unit or form. This is referred to as the **Gestalt theory**, from the German word gestalt, which means form. The brain tries to interpret incoming data into a form that makes the most sense based on previous experience and from the basic way the visual system works. In this way, what we see is based not only on the retinal image, but also on how the visual system interprets the retinal image.

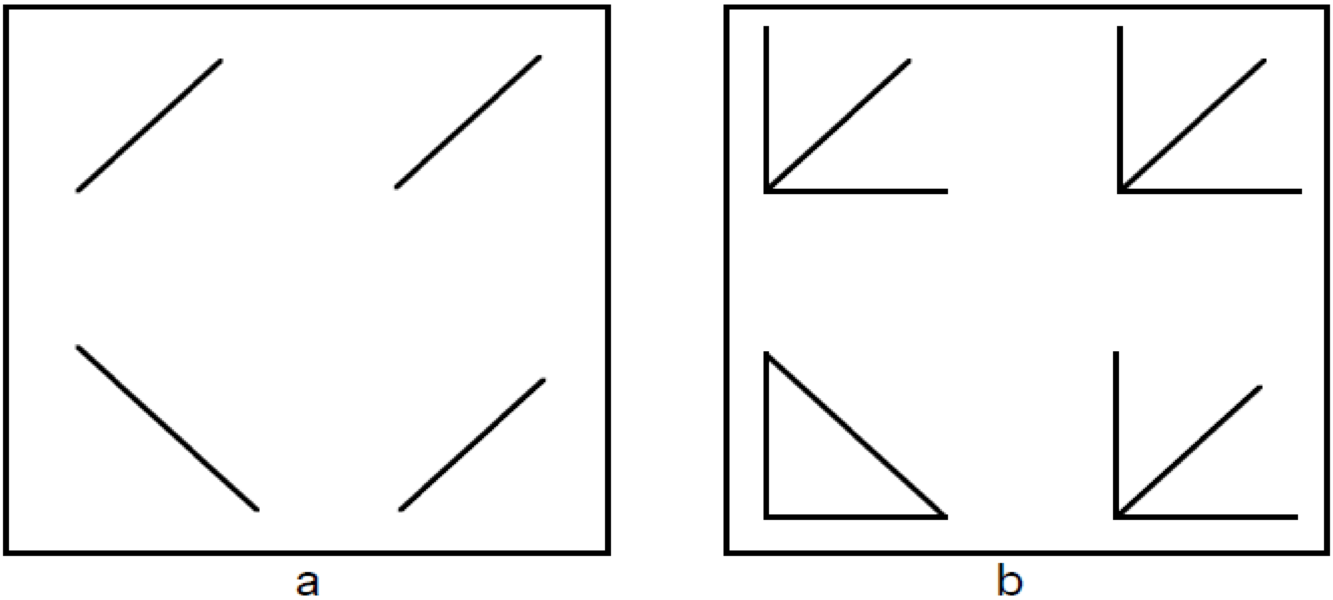

Figure 37.1 *Find the different object in frame a. Try again in frame b. In which frame can you more quickly and easily identify the different object? Redrawn from Matlin, Sensation and Perception, p.130 (1997).*

Figure 37.1 demonstrates a simple experiment to show the importance of Gestalt processing. It shows that what we perceive is more than just the sum of smaller parts. A subject is tested to see how long it takes him/her to locate, among the four objects in each frame, the one that is different. In both frames, the different object is a 135-degree diagonal line. The difference is more easily detected when the line is part of a more complex object (the triangle).

"This study suggests that we process figures more than simple isolated features. The triangle created in part b is a real figure, not just a diagonal line added to a right angle." (Matlin p. 129)

Gestalt theory says that we tend to group parts of a visual scene into objects based on several basic principles such as the **law of proximity** or the **law of similarity**. These are illustrated in Fig. 21-2 from Kandel p. 389 (Essentials of Neural Science and Behavior, 1995, Appleton & Lange).

- **Law of proximity:** We tend to group elements of an image into one object if they are close together.
- **Law of similarity:** We tend to group elements of an image into one object if they are similar.

Because the visual system works to some extent using a Gestalt approach (seeing objects as a whole), it not only assembles pieces, but sometimes mistakenly visualizes whole objects when they don't exist. An example is seen in Fig. 37.2, where you see a square, though none exists.

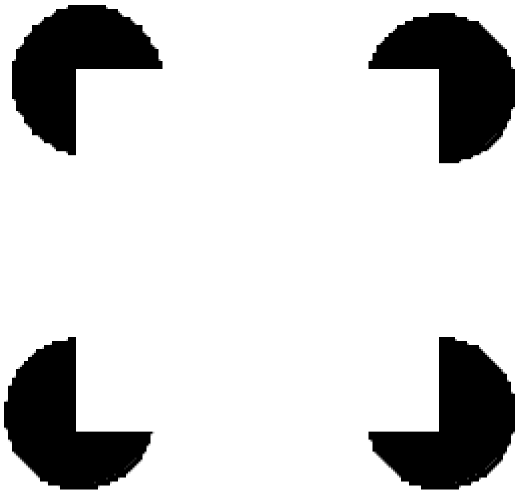

Figure 37.2 *The illusory square.*

In a top-down (Gestalt) approach to perception, the visual system quickly interprets an image based on some, but not necessarily all of the visual data. This is strongly influenced by our previous visual experience. The visual system may begin to recognize an image and then make a presumption about what it is. Even if some parts of the image contradict the presumption, the visual system may persist in believing the presumption. This is illustrated by a figure from **Matlin (Figs. 5.29)**.

FIGURE-GROUND

This brings up the concept of **figure-ground** visual processing. In any scene, one particular object, referred to as the **figure**, is the center of our attention. Everything else in the scene is just the background (the ground) for the object of our attention. Quoting from Kandel (p. 390):

Maurits Escher writes: "Our eyes are accustomed to fixing on specific objects. The moment this happens, everything around is reduced to background [...] The human eye and mind cannot be busy with two things at the same moment so there must be a quick and continual jumping from one side to the other. "

This is illustrated by Fig. 37.3 and the famous drawings shown in **Kandel's Figs. 21-3 and 21-4**. Can you see both the figure and ground at the same time? The visual system selects one object in a scene as the focus of attention, then all else becomes the background. This is referred to by Kandel as a **winner-take-all strategy**.

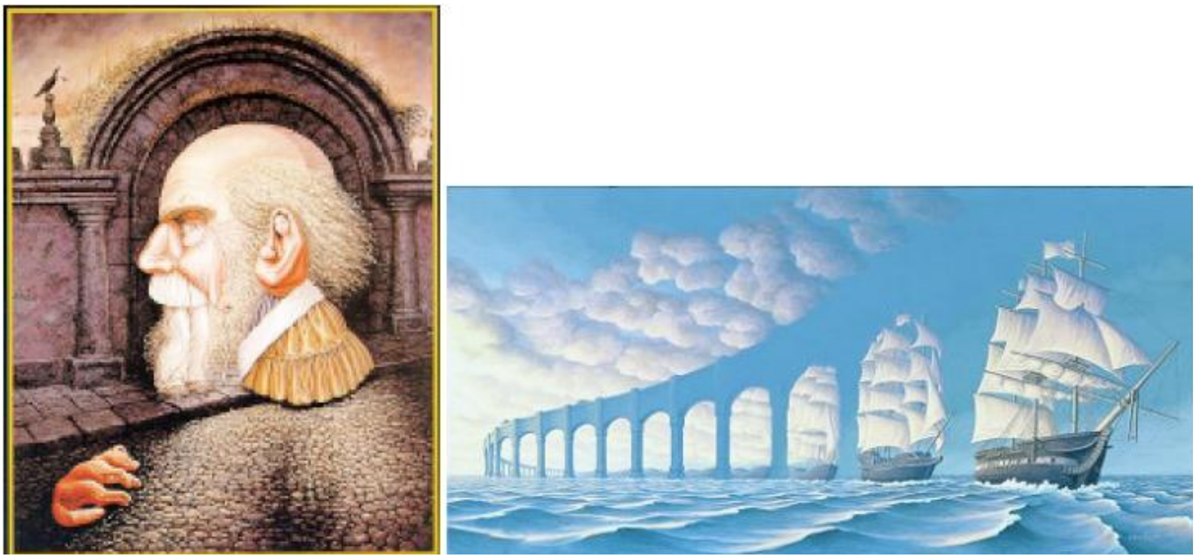

Figure 37.3 *Two figure-ground examples.*

AGNOSIAS

Even though the sensory organ provides the brain with all the information contained in an image, if the brain cannot anticipate or assemble the data correctly the person may not be able to make sense of all the visual data. This is apparent in cases of visual **agnosias**, when a person may not be able to perceive an important aspect of an image, in spite of being able to see all the parts. This may be due to damage in the part of the brain responsible for processing a particular kind of visual information. Examples are listed below:

- **Object agnosia:** inability to understand the purpose of or recognize certain objects.
- **Prosopagnosia:** inability to see faces as a whole, while seeing all the parts.
- **Movement agnosia:** inability to see movement (motion blindness).

Blind sight: In some cases, a blind person may still see realistic vivid visual scenes. Even though the eyes aren't providing the brain with visual input, the brain may still be processing stored visual information, or the visual centers may be receiving stimulation from other brain regions. If the visual centers are stimulated, the patient may experience visual perception identical to that originating from the eyes. This is similar to the case of an amputee who feels an itch on his/her phantom limb.

MOTION PERCEPTION

When objects in our field of view move (assuming our eyes are stationary), the image of that object will sweep across the retina. So you might assume that this is the basic data that allows us to perceive motion - movement of the retinal image.

Stroboscopic movement creates the illusion of objects in motion by showing, in rapid succession, images in adjacent retinal locations and is the basis for **apparent motion** in videos and computer monitors. But there are some instances in which the retinal image remains in basically the same location, yet we can perceive motion. This occurs during a smooth pursuit eye movement when we fixate a moving object.

For example, if you follow a bird flying across the sky, you keep its image on your fovea, yet you can see that it's moving. As we saw with visual direction, the visual system takes into account the movement of the eyes, as well as the changing position of the image on the retina, when perceiving motion.

COROLLARY DISCHARGE THEORY	One theory of motion perception hypothesizes that whenever the brain initiates a head or eye movement, a corollary innervation is sent to a "comparison structure", which compares retinal image movement with eye/head movement data. For example, if your right eye turns left, (the fixation point moves left), you will expect the retinal image of stationary objects to move across the nasal retina. This information would be sent to the comparison structure. When your eyes execute the movement and the image moves across the nasal retina, this is consistent with the signal previously sent to the comparison structure. When the signal from the head/eye movement matches the retinal image movement, the two signals cancel and you will perceive no motion. See **Matlin Fig. 8.8a**. If, on the other hand, your eyes follow a woman who is walking from right to left, her retinal image remains in the same place (no retinal movement). The retinal image for the woman does not move (contrary to the head/eye movement data); this is a disagreement between the retinal-image data and the eye/head movement data, therefore the visual system will perceive that the woman is moving (**Matlin Fig. 8.8b**.) This is just one theory of motion perception.
SELF-MOTION	As you drive down a road, the surrounding images sweep past your retinas. This pattern of moving retinal images is called the **optic flow field**. Sometimes the optic flow pattern on your retina can fool you into thinking that you are moving when you really are not. This can occur, for example, when you are stopped in traffic, looking straight ahead, then all the cars around you begin to move. You may have a strong perception that you are moving backwards and may even instinctively hit the brakes. This phenomenon is called **self-motion**. Self-motion is usually caused by optic flow in your peripheral retina.
AUTOKINESIS	In this visual phenomenon, a small stationary object appears to move, when viewed against a background that has no contours. For example, if you watch a small illuminated ball in a dark room, the ball will appear to move around. This may be due to eye movements, which will cause the image of the stationary light to move to different retinal locations. Since you are unaware of involuntary eye movements, your visual system does not take these into account. It interprets the changes in retinal image location as movement of the object.
INDUCED MOVEMENT	When a stationary object is contained in a frame and the frame begins to move, the object appears to move in the opposite direction of the frame. This is known **as induced movement**, and many different theories have been proposed to explain it. Another example of induced movement is the apparent movement of the moon when seen through a layer of moving clouds.

AGE RELATED CHANGES IN VISION

VISUAL ACUITY IN INFANTS	How well do infants see? Researchers using various techniques such as forced choice preferential looking, optokinetic nystagmus or VERs estimate that the visual acuity of new-born infants is about 20/1200 (0.5 c/d), and it improves to adult levels by about age 3-5. As a general rule of thumb, Dr. Davida Teller, pioneer in infant vision research, says that **an infant's grating visual acuity in cycles/degree should be about equal to his or her age in months**. Recall that you can convert between Snellen acuity and spatial frequency in c/d using a conversion factor of 600. For example, a 30-month infant should have acuity of 30 c/d, which corresponds with a Snellen denominator of 600/30 or 20. That is, 20/20. A six-month-old baby should have acuity of 6 c/d, which corresponds with a Snellen denominator of 600/6 or 100; that is, 20/100.
OTHER VISUAL FUNCTIONS	**See Fig. 17-13 in Schwartz** to see when other visual functions develop to the adult level.
VISION CHANGES IN ELDERLY PATIENTS	Vision scientist Movshon has said, with regard to changes in vision with age, "Things start out badly, then they get better; then, after a long time, they get worse again." Even in the absence of any ocular disease, we expect to see the following changes in vision for elderly patients: decline in contrast sensitivity and senile miosis. **Schwartz Fig. 17-14** shows that we expect to see a gradual decline in the contrast sensitivity function (CSF) at mid to high spatial frequencies. This may be due to smaller pupils, which reduces retinal illumination and due to early nuclear sclerosis, which reduces contrast in the retinal image. In addition, there may be age related changes in the neural elements. With age the pupil gets smaller, and this is referred to as **senile miosis**. While the typical 20-year old patient may have 6-mm diameter pupils, the average 60-year-old patient would have a pupil diameter of about 3 mm. This would reduce light by 75%. With this in mind, if you prescribe sunglasses for your elderly patients, you may need to order a lighter tint. A possible benefit of smaller pupils would be a greater depth of focus, so even with a small uncorrected refractive error the patient might see better than you expect. Changes in the crystalline lens probably account for a gradual change from with-the-rule to against-the-rule astigmatism with age. Recall that we previously discussed why patients with cataract might develop anomalous colour perception due to reduced short-wavelength light on the retinas. Therefore, after cataract surgery, things may look bluer than usual. **Schwartz Fig. 17-15** shows a gradual reduction in visual acuity as a function of age. Increment sensitivity also declines with age and must be taken into account when measuring threshold visual fields. Temporal resolution and motion perception also appear to decline with age.

BIBLIOGRAPHY

Steinman et al. **Foundations of Binocular Vision**. McGraw-Hill, New York, 2000. Chapter 2, p. 19-20

Schwartz S. **Visual Perception - 2nd Edition**. Appleton & Lange, Stamford, CT, 1999. Chapters 9 and 17

Matlin MW and Foley HJ. **Sensation and Perception**. Allyn and Bacon, New York. 1997. p.130.

Howard IP and Rogers BJ. **Binocular Vision and Stereopsis**, Oxford University Press, New York. 1995.

Von Noorden GK. **Binocular Vision and Ocular Motility - 5th Edition**. Mosby, St. Louis. 1996.

Benjamin, W. **Borish's Clinical Refraction**. WB Saunders, Philadelphia. 2006.

Ciuffreda KJ and Tannen B. **Eye Movement Basics for the Clinician**. Mosby, St. Louis, 1995.

Kaufmann PL, Alm A and Francis HA. **Adler's Physiology of the Eye, 10th Ed**. Mosby, St. Louis, 2003.

Hart W. **Adler's Physiology of the Eye, 9th Ed**. Mosby Yearbook, St. Louis. 1992.

Moses, RA. **Adler's Physiology of the Eye, 8th Ed**. Mosby Yearbook, St. Louis. 1987.

Griffin JF. **Binocular Anomalies - Diagnosis and Vision Therapy, 3rd Edition**, Butterworth-Heineman, 1995.

Kandel. **Essentials of Neural Science and Behavior**, Appleton & Lange, 1995.

Regan D. **Binocular Vision** (**Vol 9 in Vision and Visual Dysfunction, 1991**).

Reading RW. **Binocular Vision**. Butterworth Publishers, Woburn, MA, 1983.