Perception Lab 3: Is Seeing Believing?

Vision is a magnificent, specialized sense that gives us the ability to observe movement, shape, perspective, and color in our environment. It has one of the most complicated and sophisticated neural systems of all the senses. Yet, more information is known about this system than any other vertebrate sensory system. Well-developed vision is based on using two eyes to process light information.

Each eye is connected to the brain by an optic nerve that contains numerous nerve fibers (figs. 1-3). Between the eye and brain at an area known as the optic chiasm, fibers from each optic nerve cross the midline of the brain. As a result, some fibers from each eye make connections with the opposite side of the brain. The fibers going to the left and right sides of the brain are now a combination of the fibers from the optic nerve for each eye, as shown in Figure 1. This new combination of fibers at the optic chiasm is known as the optic tract.

This arrangement allows visual messages from both eyes to reach each side of the brain. Because fibers cross over to the opposite side of the brain, the right hemisphere of your brain "sees" the left half of whatever you are looking at, while the left hemisphere "sees" the right half, as shown in Figure 2. This phenomenon of nerve signals crossing to register information .in the opposite side of the brain, and vice versa, occurs also with the sense of touch and the control of movement.

Light reflected from the objects in our visual field enters through the cornea and the lens of the eye. The cornea and lens help to focus a clear image of the visual world on the retina that is composed of three layers: ganglion cells, bipolar cells, and photoreceptors. See Figure 3. Before the light strikes the photoreceptors, it must go through the ganglion and bipolar cell layers.

The photoreceptors are composed of approximately 125 million rods and approximately 7 million cones (Pirenne, 1967) that convert light into electrical signals. Rods are more sensitive to light than cones and respond in dim light, but do not relay color information. Cones are specialized for bright light and supply the brain with information about fine detail and color,

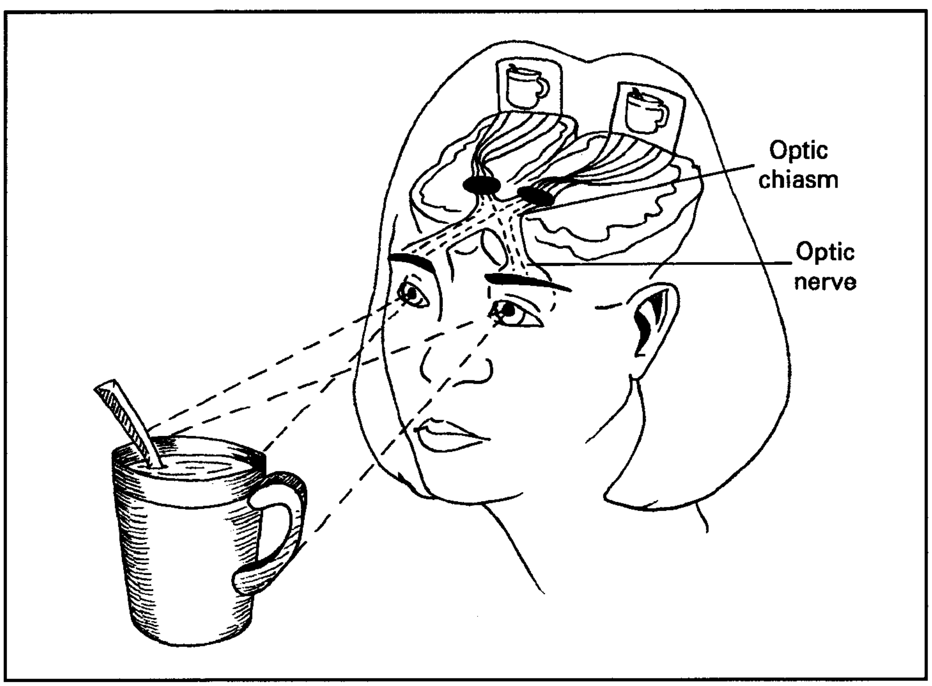

Figure 1. Note the visual pathway of the left and right eyes and the crossing of some fibers at the optic chiasm.

including black and white. The visible spectrum of light contains the following wavelengths: red, orange, yellow, green, blue, indigo, and violet. There are three different kinds of cones that respond to the wavelengths of light. One cone is sensitive to the longer wavelengths and detects reds more readily, while another is sensitive to

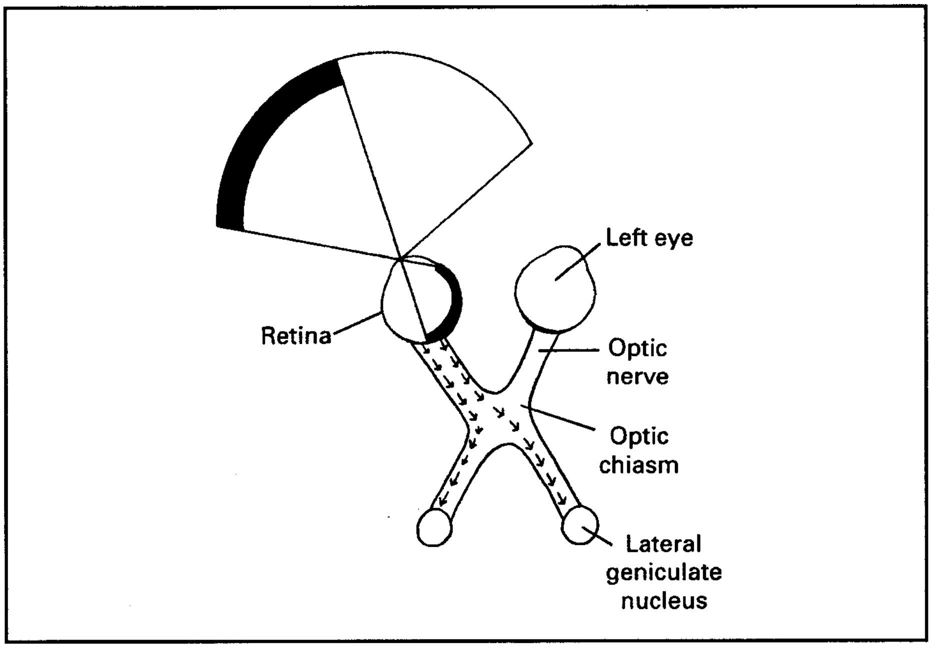

Figure 2. View of the visual pathway from below. The images received by the lateral half of the retina reach ganglion cells whose fibers do not cross at the optic chiasm. Those detected by the medial half of each retina reach ganglion cells whose fibers do cross at the optic chiasm.

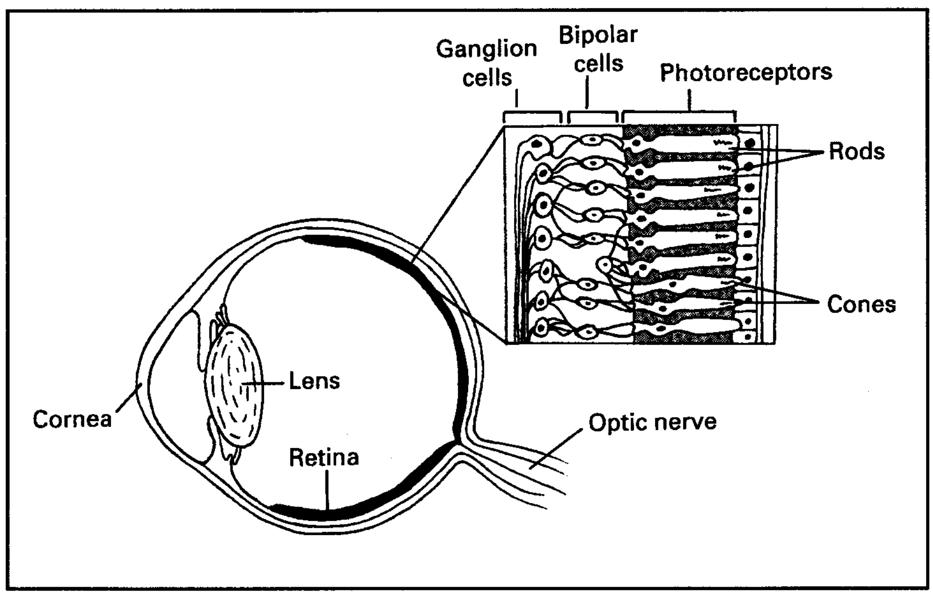

Figure 3. Diagram of the eye showing the cornea, lens, and retina. The enlarged area shows a section of the retina containing the rods, cones, ganglion cells, and bipolar cells.

shorter wavelengths and detects blue more strongly. The third type of cone detects wavelengths in the middle range of the visible spectrum and detects green more efficiently. The response of the cones is over a wide range of the visible spectrum with overlap between their sensitivity ranges, especially red and green. See Figure 4. The brain analyzes information from all three types of cones. Working together, these three types of cones detect all the thousands of colors humans can see.

Images appearing on the television screen consist of small dots of red, green, and blue that combine to display any color. In the same way, the receptors for red, green, and blue in the eye can detect any color. Contrast effects influence our perception of color. The perceived brightness of an object depends not only on the intensity of the light from that object at the moment the eye is looking at it, but also on the intensity of the light the eye has received and the intensity of the light around the object (Gregory, 1990).

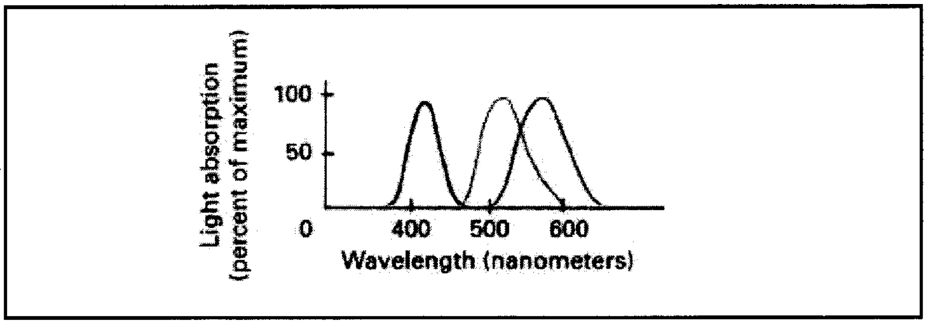

Figure 4. Absorption spectra for the three types of cones.

Color blindness is a visual disorder that occurs when the cones that detect color are not working properly or are completely absent. Although color blindness may be acquired through retinal diseases, the most common cause is genetic, due to a recessive mutation on the X chromosome. Since the defect is on the X chromosome, approximately 8% of the males and only 0.5% of the females in the population experience this disorder (Velle, 1987). Work done by Jeremy Nathans on the arrangement of the red and green pigment genes on the X chromosome offers an explanation for red-green color blindness. He found that color-blind males either do not have the gene for green pigment or possess a hybrid gene composed of parts of the red and green pigment genes. The lack of the gene or the hybridization of the red and green pigment genes contributes to the red-green color-blind condition.

The phenomenon of seeing an afterimage of an object is experienced. It is the result of the human vision's reliance on contrast effects. Light from the sun appears golden or white, but it actually is composed of all wavelengths of the visible spectrum. As light strikes a red object, we see it as red because the red wavelength of the white light is reflected back, while the other wavelengths in the white light are absorbed. When the red wavelength of light is reflected from the object, it passes through the cornea and lens of the eye, striking the cones. The red-sensitive cones convert the light into an electrical signal that travels through the bipolar cells to the ganglion cell layer. Here, the axons of the ganglion cells form the optic nerve that leads to the brain where the color red is perceived in the visual cortex. The process of staring for 30 seconds at a bright red spot overstimulates and fatigues the red-sensing cones. When the white only side of the paper is viewed immediately after staring at the red dot, white light composed of all the visible wavelengths of light is reflected back to the eye. Although the white light contains the red wavelength of light received by the eye, the red- sensing cones have been overstimulated (Hurvich, 1981) and do not respond to the red wavelength. On the other hand, the cones that sense green have not been overstimulated and absorb the green wavelengths in the white light. The electrical signals from the cones detecting green reach the visual cortex and a green spot is perceived, even though no spot of any color is present on that side of the paper. This spot is called an afterimage.

A question that may arise is whether other colors besides red can cause an afterimage. The answer is yes. Afterimages will occur with the following pairs: red/green, yellow/blue, and black/white colors. Red paper will give an afterimage of green, green gives red, yellow gives blue, blue gives yellow, white gives black, and black gives white. Colors that appear to be of two colors such as red-yellow will give a green-blue afterimage (Hurvich, 1981).

In the first part of laboratory, contrast effects will be examined using shades of black and white. The same shade of gray will appear darker when surrounded by a white background and lighter when surrounded by a black background (Hurvich, 1981). The retina and the visual area of the cerebral cortex, working together, adjust the perceived brightness of two adjacent objects. The process of distinguishing between shades of gray begins in the retina where the ganglion cells respond most effectively to contrast in their visual receptive fields. Thus, the greater the contrast between shades of gray, the more stimulated these cells become. This produces a visual perception whereby a gray color appears darker against a white background than it does against a black background. The closer the background color is to the gray color being tested, the less the cells are stimulated. As a result, less contrast is perceived. How the retina and the brain do this has been the subject of much research, but is not yet fully understood.

Before beginning the actual lab experiments, Nancy will set up a prism and pass light through the prism to show how white light is separated into the colors of the visible spectrum. (See Figure 5). As a group, we will talk a bit about what happens when light passes through the prism.

Laboratory Activity I

1. Find the pile of magazines and observe a colored picture from a magazine. State the colors you see.
2. Then clip a piece of one of the colors they observed in the picture and observe it under the microscope. How does what you see under the microscope compare with what you saw when you looked at the same portion of the picture in its entirety.
3. Write in your notebook your ideas about perception of color photographs from a magazine photo when viewed with your naked eye and with the microscope.

Laboratory Activity II

1. Place a bright red adhesive dot ~2 cm in diameter in the center of a 10 x 18 cm white, unlined index card.
2. Hold the card so that the red dot is visible, and then to move the card toward their eyes until it is about 20 cm away and fills most of their visual field. You should hold the card very still and stare at the red dot for approximately 1 minute.
3. After 1 minute, flip the card over and look at the side without the dot and write down what you see.
4. Share your results with the other students at your lab bench and discuss the following:

   - What did you see when you flipped the card over?
   - Why did this occur?
   - What structures of the eye were involved?
   - How does the nervous system perceive a colored object that is not really there?
   - What color did you see? Can you explain why?
   - Did anyone see a different color?
   - If the shade of red were changed on the index card, would the dot you saw on the other side of the card be a different shade of the color you perceived when the card was flipped?

Laboratory Activity III: In this activity, you will place the same shade of gray paper behind the two holes of the black-white template (Figure 6). Three different shades of gray paper are found in the gray-scale template. Works in pairs.

1. Using a pair of scissors, cut out the holes of the black-white template.

2. Cut the six rectangles from the gray-scale template with scissors.

3. Lightly mark each piece of gray paper in one corner with a number for identification: light gray with a "1", medium gray with a "2", and dark gray with a "3".

4. Designate one member of the team to serve as the experimenter/data recorder and one as the subject. Team members should take turns in each role. The subject should turn his/her back to the table while the experimenter sets up trial number 1.

5. The experimenter should select two shades of gray paper and place one color behind each hole of the black-white template, so that a shade of gray paper shows through each of the two holes. The gray paper should show only through the holes and not extend beyond the edges of the black-white template. Several combinations of grays should be tried. For example, place gray shade 1 under the black, and gray shade 2 under the white. Also be certain to include three trials where each shade of gray is placed under BOTH holes.

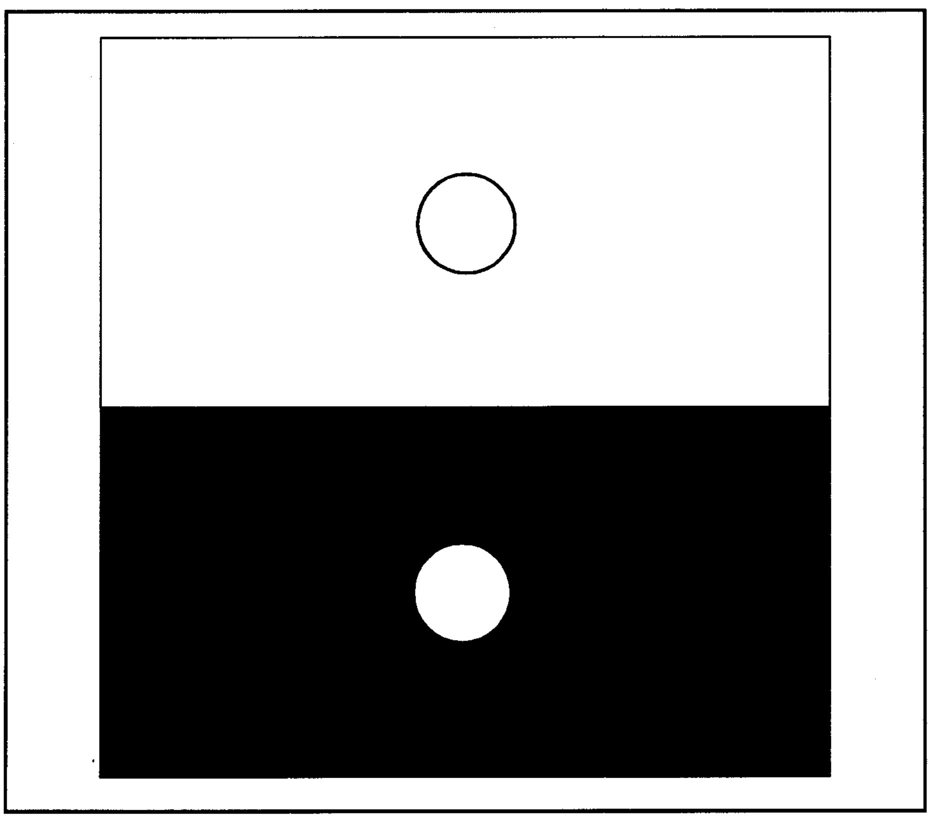

Figure 6. Black-white template.

6. During the trials, the subject should stand or sit at least one meter away when observing the gray papers through the template holes. For each trial, have the subject indicate which gray is darker, the one on the white side of the template or the one on the black side.

7. The data recorder should record the responses in a data chart. Place only the data with incorrect responses for trials into the computer spreadsheet.

8. Examine the class data and determine circumstances under which most of the students had errors.

Shade Under White	**# Correct**	**# Incorrect**	**Shade Under Black**	**# Correct**	**# Incorrect**
1			1		
2			2		
3			3		
1			1		
2			2		
3			3		
1			1		
2			2		
3			3		
2			2		
3			3		

With the data from these Laboratory Activities**,** work in groups to design and conduct experiments to learn more about visual and/or color perception. You should quantify (be able to use numbers) to describe your data where possible. Afterwards, each group should share its results with other members of the class.

Suggested questions students may wish to investigate include the following:

- Can other colors, such as green or blue, cause an afterimage?
- If the color observed is a mixture of two colors, how will this affect the afterimage?
- Does the color of the afterimage change with the shade of red?
- How is color perception affected by color blindness?
- Do animals see color? If so, how would one design an experiment to determine if they were able to perceive color?
- Is there a relationship between the time the dot is stared at and the intensity of the afterimage color?

And finally, there will be a series of optical illusions that we will ask you to examine both on paper and on the computer. Nancy will provide more details on the specific details of this activity on Monday.