How We Perceive Color

Color perception is the result of the physical properties of light, the specialized photoreceptor cone cells in our eyes that detect light, and our brains that use surroundings and context to interpret the signals received from the eye. In this station we will examine each of these processes.

Materials

1. Color vision poster with diagram of the retina.
2. Color blindness poster with Rodney Schreiner's photographs illustrating three forms of color blindness.
3. Light box and power cord.
4. Didymium lens and glass filters (3).
5. Hidden image 6 x 6 test cards placed on a white foam board. A2, A3, A4, A6, A8, A15
6. Laminated black and white shape cards, for matching to test cards.
7. Goggles with green or blue filter to view test cards. Goggles with pink filters for colorblind people.
8. Ethanol wipes for goggles.
9. Scribble cards to view with goggles and filters.
10. Color illusion boards (2) and stop sign illusion.
11. Bookmarks to give out.

Procedures

(1) **Look at the picture of the electromagnetic spectrum.** Electromagnetic radiation is energy that travels in waves. These waves vary from very short, very high energy waves (gamma rays) to long waves such as radio waves that are as much as a quadrillion times longer. Electromagnetic radiation is all around us (can feel heat of infrared, sunburned by uv, etc.) but the only part we can see is the tiny band of visible wavelengths ranging from purple to red. Each color of light that we see corresponds to a defined wavelength. Our eyes have photoreceptors that can detect three colors – red, green, and blue (**see poster**).

(2) We can use filters to see that colors correspond to different wavelengths of light. The LED lights in this box emit defined wavelengths of light that we see as red, yellow, green, and blue. **Hold the filters over the LEDs and see which lights appear dimmer.** The didymium filter blocks yellow light only (589 nm). The 580 nm filter blocks blue light but has no effect on yellow and red (every wavelength to the right of green/yellow on the spectrum). The green light looks yellow because it's a mix of yellow and blue and all the blue wavelengths are blocked. The 550 filter lets red, yellow, and some blue light through, so that green still looks green but is dimmer.

(3) We can use the green goggles or the blue filter to simulate color blindness. **Hold them over the LEDs and see which colors disappear.** The green goggles block red light (and some yellow light).

(4) **Look at the cards without the green goggles and with the green goggles.** People with normal vision should be able to see all the shapes. If a person is colorblind, they can only see A15. (For very young children, there are shapes for matching. Put on the green goggles and see what happens when a person is unable to detect red light. A15 is visible with or without goggles. This simulates protanopia, when the red cones are completely defective. **Look at the cards with the blue filter** – is it easier to see some of the shapes? This simulates deuteranopia, partial deficiency of the red cones. Partial deficiency of red or green cones are the most common forms of inherited color blindness. Let them try the pink goggles, which block green light and thus enhance the

contrast between red and green. If a person with normal vision wants to try the pink goggles, that's ok – they will see changes in color and contrast.

(5) **Look at the poster that shows three types of color blindness. Note the red and pink tulips.** Protanopia and deuteranopia involve defects in cones that detect red or green light. Tritanopia is rare and is due to defects in blue-detecting cones. Red-green color blindness affects ~8% of males. Inability to detect any color is extremely rare. Although these types of color blindness are inherited, color blindness can be acquired, as a result of disease (glaucoma, macular degeneration), trauma, or toxins or metabolic or vascular diseases that damage the retina or optic nerve.

(6) **The picture cards also show examples of what a colorblind person would see.** This is important to keep in mind when preparing documents, especially graphics. Microsoft Word has a "Check Accessibility" function that will point out bad color combinations. In Photoshop, VIEW/Proof Setup will visualize protanopia and deuteranopia.

(7) **Red-green color blindness is due to defects in either green or red cone photoreceptors, leading to an inability to see either green or red light.** When light hits an object, some wavelengths are absorbed and others are reflected. The color of the object is determined by the wavelengths of light that are reflected from that object. To people with normal vision, an object appears red because red cones detect red light reflected from the object. An object appears green because green cones detect green light reflected from an object and an object appears blue because blue cones detect blue light reflected from the object. A person with defective red cones is unable to detect red light and a red object appears dark. A brown object appears greenish because brown is a mix of red and green. *Most color blindness is partial - a person can perceive a difference between red and green, just not the same way as people with normal vision. In fact, colorblind people are often better at detecting camouflaged objects.*

(8) **Optional:** The scribble cards and filters can be combined to see how blocking certain colors makes the pattern pop out.

(9) We have looked at how wavelengths of light "create" color and how our eyes detect these wavelengths of light. However, our brains are also really important in perceiving color. **Look at the boards.** Are the colors the same? Lift up the boards and see if you are correct. These boards show that our brain looks at the surroundings in deciding what the color is. What color is the stop sign? Lift up the flap. Our brain assumes the stop sign is red because stop signs are always red and because the bluish background makes us think the sign is red. However, the sign is purple.

Bookmark shows a diagram of eye and photoreceptors and the color spectrum in color blindness. There's a game on the back that gives an example of how eyes and brain work together, or, maybe, not together.

References:

Frey Scientific/Roylco Teacher's Guide to the Color Vision Perception Kit

Vischeck Color Vision Simulator examples of colorblindness: https://www.evl.uic.edu/barnes/HCI441/Lectures/Lecture9/Examples/Accessibility/VischeckExamples.htm