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Disability Research Paper

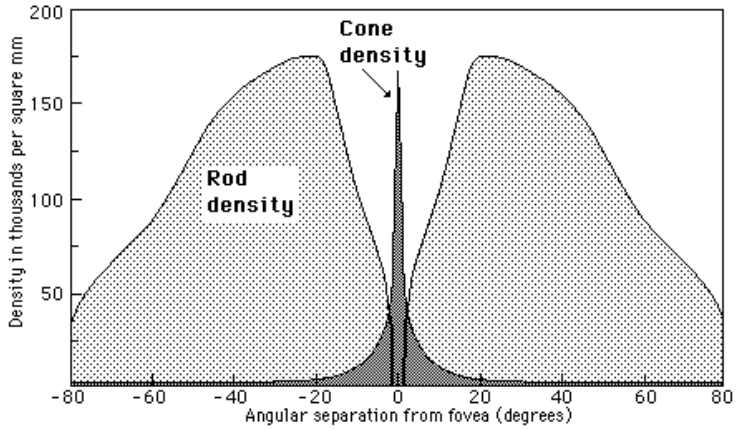
The ability to distinguish color is taken for granted by those with perfect vision. But for a large population, color-blindness ranges from a persistent annoyance to a significant disability. In many cases, those with lesser degrees of color-blindness may live without ever knowing they don't see the world in a full spectrum of color. A number of very simple visual tests have been developed to determine if someone is color-blind, though once diagnosed there is no surgical procedure, treatment, or cure. The products available to compensate for this disability are quite few while the implications and opportunities for designers to consider in everyday products are numerous. This document will discuss human optics, the variations of color-deficient vision, populations and situations affected, and products designed with this disability in mind.

The Human Eye

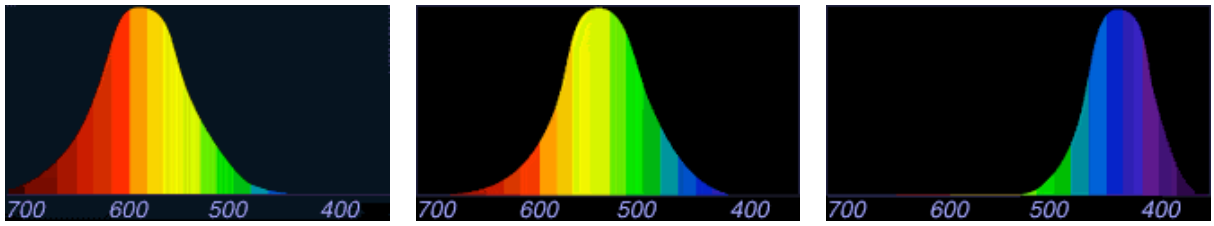
The human eye receives visual information from a 200 degree field of view. Light passing into the eye is focused on the retina which is comprised of two types of photoreceptor cells, rods and cones. These cells convert light energy to electrical energy then transmit that information to the brain. The brain combines and interprets the information as color, luminosity, and motion.

Rods are 20-times as numerous as cones and have 1000-times higher light sensitivity, but do not perceive color information. They are located around the center of the retina allowing the rods to pick up on image information in the periphery of the field of view and be more attuned to motion detection. Rods high sensitivity to light make them responsible for human night-vision, but their slow adjustment rate can take up to 30 minutes to reach the optimal dark adaptation. While color is handled by cones, rods pick up more light intensity information from shorter wavelengths of light, meaning red colors are more difficult to see at night than blues and greens.

Cones are concentrated in the center 15 degrees of the eye's field of vision. Visual acuity, resolution and color are associated with cones, but this center field of view contains no rods and therefore creates a blind-spot for night-vision and sensitive motion detection. The graph below shows the density of rods ver-



sus cones across the field of vision from the fovea, or center of the retina. Different types of cones are responsive to three segments of light wavelength between 400nm for violet and 700nm for red. These types are referred to as red-cones (Long-wavelength), green-cones (Medium-wavelength), and blue-cones (Short-wavelength). Red-cones are the most numerous, accounting for 60% of the 7 million cones in each eye. Green-cones make up 30% and blue-cones are only 10%. The three images below graph the range of visible light spectrum accommodated by each set of cones.



Red-sensitive or, L-cones *Green-sensitive or, M-cones* *Blue-sensitive or, S-cones*

Afflicted

The term color-blind is somewhat misleading in its association with those it affects. Only 0.0025% of the population actually see in black and white. The rest of those with color-blindness are unable to see parts of the visible spectrum due to deficiencies in certain cones. The deficiency is inherited on the X chromosome making women primarily carriers and men more commonly afflicted. A very small percentage is caused by some eye diseases. Overall, 7-8% of males have some form of color-blindness while only 0.4% of females are affected. A further breakdown of percentages and the ophthalmological terms referencing their conditions follows:

Trichromat: Full ability to see using all three colors, red, green, and blue.

Monochromacy: Complete inability to distinguish colors. 1 in 30,000 people have monochromacy, seeing the world in only black, white and various grays.
Anomalous: Reception of one color is misaligned. i.e.- The color receptor of the green cones is shifted toward the red end of the spectrum or the red cones are shifted toward the green end.
Protanomaly: Reduced red sensitivity affecting 1 in 100 males.
Deuteranomaly: Reduced green sensitivity affecting 5 in 100 males.
Dichromacy: Only 2 of the 3 colors are received. Red, green or blue is missing. Dichromacy is further divided into Protanopia, Deuteranopia, and Trianopia.
Protanopia: Unable to receive first color, red. When red cones are not present, overall light reception is reduced because of the large percentage of red cones. Images with large amounts of red will seem much darker than normal. Protanopia affects 1 in 100 males.
Deuteranopia: Unable to receive second color, green. Affects 1 in 100 males and of all varieties of color-blindness, deuteranopia is the most common color disability affecting women at 0.4% of the population.
Tritanopia: Unable to receive the third color, blue. Usually the result of an eye disease and very uncommon, affecting only 1 in 15,000 to 1 in 50,000 people.

Being color-blind

There are many situations when living without the ability to see color is severely hampering. Colors are used extensively while driving in brake lights, and the red, yellow, and green of traffic signals. LED indicators in many of today's electronics convey their message by changing from green or yellow to red or amber. Those in the food industry are susceptible to undercooked steaks, bad lettuce, and unripe or overripe tomatoes. Some of these situations are daily nuisances but people have found odd ways to take advantage of their disabilities. During World War II, color-blind men were sent on special missions because their decreased ability to see green led to an increased ability to see through or detect camouflage. Scenarios like this are rare, so designers need to pay special attention to their use of color in products they create.

Color in products

A product called ColorMax by Color Vision Technologies, Inc. in Tustin, California was cleared by FDA in November of 1999. ColorMax is a tinting process, similar to anti-glare and shading, applied to a lens to aid those with red-green color deficiencies. They do not benefit anyone with blue-yellow deficiencies nor total color blindness. They also do not allow the user to perceive colors in the same manner as people with proper color vision but they add darkness and brightness differences to colors that would be otherwise difficult to differentiate. ColorMax is available in 10 different shades, depending on the user's level of color blindness and can be coated onto prescription eyeglasses or added to clip-ons and various sunglasses. More

recently, the company has developed a soft contact-lens that will duplicate the functionality and benefits of the coated eye-wear lens.

Also helping people with color-blindness, New Pigment is a picture viewing computer application tailored for those with difficulties distinguishing colors. The program preferences allow adjusting color balance, brightness, and saturation in order to display images with higher color accuracy. While colors are not converted to a full equivalent of what a non-disabled viewer would see, the application adjusts unique tones to differentiate from one another.



To help determine the color of physical objects, Ann Morris sells a variety of digital color identifiers. These handheld devices can be placed on the surface of an object and the measured color is then read aloud. Advanced versions are able to interpret colors in both common color terms like “bright mustard” or “coffee brown” and use color models like HSL (Hue, Saturation, Luminosity) and RGB (Red, Green, Blue) for more detailed color identification. Surfaces with multi-colored patterns are measured and announced one by one in measured sequence. This advanced color reading is not inexpensive, with models ranging from $140 up to $825.

A product that most people see everyday is the exit signs made by Gilbert Industries. They use a lower 630nm wavelength spectrum of red that is more visible to those with red-green color-blindness. To those with full color vision, the sign looks slightly orange but only when compared to a standard red sign. To further this readability, Gilbert also makes a green text on black background Exit sign. While it greatly increases visibility to color-deficient people it does break away from the standard red colored signs. Both varieties of Exit sign are available in an extra bright version that helps to increase visibility for all people.





Gilbert has moved forward in increasing the visibility of their signs to a much wider range of people, but some areas could still be helped with a greater understanding color perception. In dark conditions, the rods are more adept at seeing than cones. By moving the sign color completely to the blue/violet short-wavelength spectrum that rods are more attuned to, people will be better able to find their way in dark corridors and emergencies. This same lighting principle is used on blue lighted airport runways. The opposite should be used in vehicle dashboards, where a red-color at night will not jostle the sensitively dark-tuned rods out of focus while diving.

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