A boy experiences defective color vision by using special glasses.

Exploring What the Eye Cannot See

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At Spain's Science Museum of Granada, visitors can explore the limits of human vision—and how optics can overcome them.

The human visual system is a masterpiece of optical engineering. It allows us to navigate the world through depth perception, peripheral vision and accommodation to different focus distances.

Perhaps just as interesting as what the eye can do, however, is what it can't—including visualizing microscopic objects or seeing infrared light. Fortunately, for nearly every visual constraint we have, an optical technology has been developed to help compensate for it. Thus, probing the limits of human vision presents an excellent opportunity to educate people about optics and the critical enabling role it plays in our lives.

So, when the Science Museum of Granada asked us, as members of the optics department at the University of Granada, to organize an exhibit that would engage public interest in science, we created an interactive exploration of "what the eye cannot see." Since our department specializes in vision and color vision, we felt well equipped to bring this exhibit to life.

Each of the following sections describe a limitation to the human visual system and some of the demonstrations we devised to illustrate it and highlight relevant optical technologies. For each limitation, a scientist-trainer gave an introductory explanation and then showed a demonstration in small groups. Individuals were also invited to actively participate in some of the experiments. Many of these ideas and experiments could be easily replicated in a classroom setting.

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Spectral limits

The exhibit introduced visitors to the light that lies beyond the spectral range that our visual system can perceive—in other words, ultraviolet and infrared radiation. A scientist explained how fluorescent and phosphorescent objects absorb light and then re-emit it under less-energetic wavelengths and thus glow under exposure to ultraviolet light. Visitors were given the opportunity to see in the infrared range by using a thermographic camera that displays images on a large screen.

Intensity of radiation

The human visual system is also limited with respect to the intensity of radiation it can handle. Human vision is very restricted in dim light, and, alternatively, if the eye receives radiation above a certain limit, it will be blinded and the retina may be irreparably damaged. The iris is the first protective barrier for high-intensity radiation, but its effectiveness is restricted because the minimum diameter is only about 2 mm. Often people need to use sunglasses as an auxiliary means of protection.

The exhibit included several experiments related to this topic. For example, people could see an image intensifier (night binoculars) in operation; they could perform the "giant iris experiment," in which they look at their own pupil enlarged and observe its response to light variations; and they could observe and handle various modes of protection against extreme radiation intensities (e.g., welding glasses and high-optical-density filters for looking at the sun).

Object size and distance

The visitors peered through a microscope and telescope. They learned how the development of these instruments has influenced microbiology and astronomy. In one experiment, visitors could not only see the tiny blood vessels in their own retinas but also the blood cells within those vessels.

Defective color vision

Not everyone perceives color in the same way. To experience this, the visitors looked through special glasses that simulated anomalous color vision. They could also take a color-anomaly screening test. These were among the visitors' favorite experiments; they were eager to experience how color-blind people perceive the world.

Color constancy

What happens if we use a digital photographic camera to capture images of surrounding scenes? Does it behave in a manner that is similar to the human visual system? Illumination may be a fundamental factor that determines how we perceive objects. For instance, meat or fish may look appetizing or not depending on the lighting in the room. To demonstrate this, we showed the visitors pictures of the same objects taken under different lighting conditions. We also asked visitors to observe objects under various colors of illumination. We discussed the differences and explained why white balancing is necessary for digital cameras.

Polarization

Humans are not able to determine the state of polarization of light entering their eyes. But we can see which areas of a transparent rigid object are under stress if we use a polariscope. This device is based on the photoelasticity phenomenon.

Speed

The exhibit explored how fast our visual system can react to temporal changes through an experiment with a stroboscope, in which visitors can "freeze" a rotating wheel. It also explained the phenomenon of visual persistence—which refers to the amount of time that the retina retains information it has been stimulated with; visual persistence limits how fast our visual system can react to changes.

3D Vision

Why do we have two eyes? In this portion of the exhibit, visitors explored depth perception and 3D vision. They used stereoscopes to view anaglyphs and holograms of images shot in Granada more than 120 years ago.

In addition, the exhibit included a comparison between the human visual system and that of other animals. Different animals have varying spectral ranges, intensity thresholds and visual acuities that are tailored to their unique environments. Cats and other nocturnal vertebrates, for example, have a layer of tissue near the retina that reflects more visible light into the retina, allowing them to hunt their prey at night.

The exhibit was initially planned to last three months, but it was recently extended for three additional months due to the enthusiastic reception among visitors. It is slated to end in September 2009. We are very satisfied with the exhibit and glad that it has been a useful tool for bringing people closer to optics. ▲

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