Simple tricks of vision

(Editor's note: Take time out from technical papers and Society news for "The light touch," a fresh Optics & Photonics News column meant to be shared with students and children of all ages.)

We take the human eye for granted, but it is a remarkably powerful and sophisticated optical system. The array of optical sensors that form the retina are connected to a pattern recognition system far more powerful than the fastest supercomputer—the vision center of the human brain. The eye and the brain together give us an extremely detailed picture of the world, compensating smoothly for some of their own limitations. However, a few simple experiments can reveal some of the eye's limits.

Specialized nerve cells in the retina respond to light and transmit signals to the brain. There are two similar types: cones and rods. The roughly seven million cones respond to bright light and sense color. The 125 million rods respond to dim light, but do not sense color. The rods are so sensitive to light that they are essentially bleached out in sunlight and do not respond at all. However, they recover their sensitivity after you turn off the lights.

It takes a minute or two for your eyes to start to "dark adapt" as the rods turn on, to sense light much too faint for the cones. If you go outside on a dark night, you will see faint stars gradually come into view as your eyes dark adapt. It takes about half an hour for your eyes to become fully dark adapted, but the change is most obvious in the first few minutes outside. If you live in a brightly lit urban area, scattered light from street lamps, car headlights, houses, and signs makes the sky so bright that your eyes never fully dark adapt. You will never see colors at night, because the rods lack color receptors.

The differences between rods and cones, and the different patterns they make on the retina, have some interesting consequences that we don't often notice. The cones respond to all the colors in the visible spectrum, from 400 to 700 nanometers. However, the cones are not sensitive to wavelengths longer than 600 nm, so red objects seem darker at night than in bright light.

Many cones are packed tightly together near the center of the retina, a point called the "fovea," where the lens of the eye focuses light from objects straight ahead. Because they are tightly packed, the cones near the fovea have the highest resolution in the

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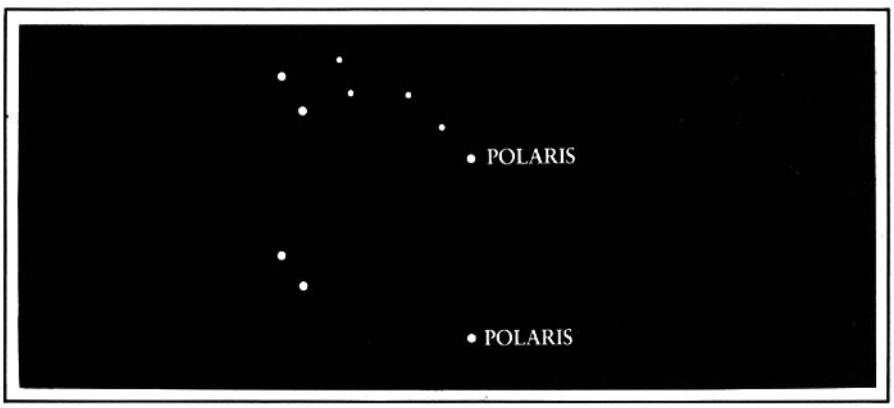


FIGURE 1. The faint stars in the middle of the Little Dipper are easier to see (above) if you look directly at Polaris instead. Try to look directly at the stars in the Little Dipper and they may disappear (below) because your eyes are focusing their light on the less-sensitive cones at the center of the eye.

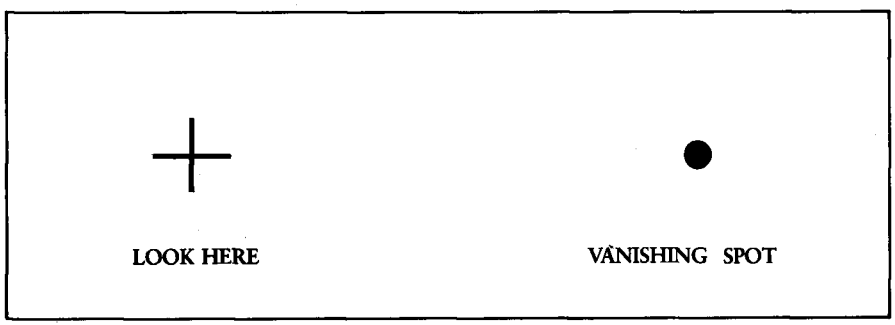


FIGURE 2. Close your left eye and focus your right eye on the cross. Move the page back and forth and the circle will vanish when it falls on your blind spot. (From Jeff Hecht, Optics: Light for a New Age, Charles Scribner's Sons, New York, 1988.)

JEFF HECHT is a contributing editor to *Optics & Photonics News* and *Lasers & Optronics*. He is the author of *Optics—Light for a New Age.*

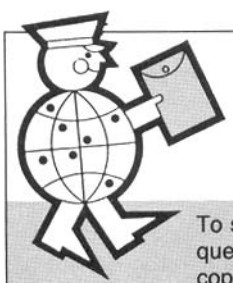
LIGHT TOUCH, *from page 55*

eye, giving us our detail vision. When we read, our eyes focus light onto the fovea and the surrounding area—the "macula"—so we can see the detail needed to make sense of the words. Some elderly people suffer a condition called "senile macular degeneration," which impairs their detail vision, leaving them unable to read books set in normal size type.

The tight concentration of cones near the fovea leaves no room for rods, so there are none near the center of vision. Most of the 125 million rods are on the sides of the retina. This means that at night you see poorly in the area where you direct your eyes, the same area where you can see best during the day. This makes seeing in the dark difficult, because we are so used to being in the light that we automatically turn our eyes toward what we want to see.

Amateur astronomers are well aware of this effect, and use a technique called "averted vision" to better view faint objects in the dark night sky. If they want to see a dim star, they focus their eyes on a nearby bright star. The dim star then appears off to the side. If their eyes wander toward the dim star, it may seem to vanish—because its light is focused onto the fovea, where there are no cones to respond to it. The best way to see averted vision work is by looking directly at a fairly bright star. You will see other, fainter, stars nearby, but those fainter stars will disappear if you try to focus on them. This works well with Polaris and the fainter stars of the Little Dipper, if your sky is not too bright, as shown in Fig. 1.

Rods and cones are not distributed symmetrically around the eye. They are absent altogether from one small area near the back of the eye, where the optic nerve connects with the retina. Normally, our brain conceals this blind spot by using information from our other eye. However, you can demonstrate its existence by closing your left eye and focusing your right eye on the cross in Fig. 2. Move the page back and forth, and at some point the circle will fall on your blind spot and vanish.



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