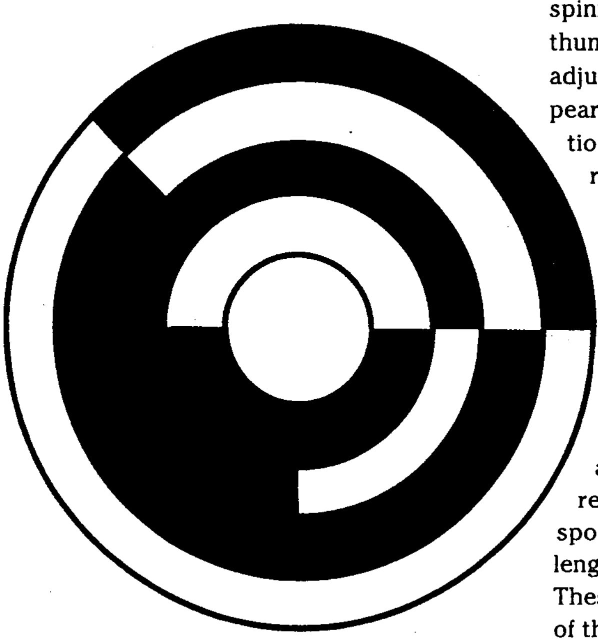
# Colors from the black and white

Believe only half of what you see, the adage says. This age-old wisdom is a warning that our sense of sight is easily deceived. Optical illusions can result from geometrical tricks that play havoc with the preconceived notions of our perception—like Escher's prints. They can also result from the very physiology of the eye itself.



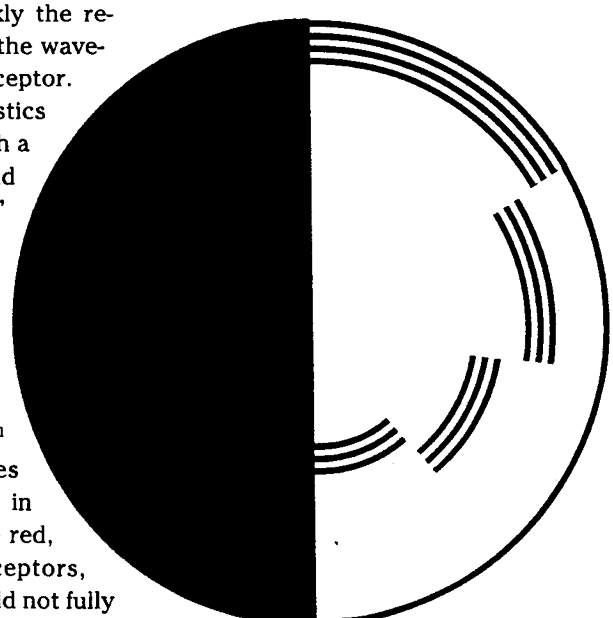
**Spinning these patterns creates the illusion of color.**

One interesting and perhaps one of the most difficult to explain illusions related to the eye's physiology is the perception of color from spinning disks imprinted with patterns of only black and white. These so-called subjective colors,[1] known as Fechner colors after the scientist who reported them in 1838, appear as a series of colored rings on a flickering grey background. Several examples of disk patterns, also called Benham's Tops, are shown in the figures. To see the effect, carefully copy these patterns using a compass and ruler (or better yet computer graphics) and rotate them so that the circular arcs seem to fuse into complete—and colorful—circles. A convenient way of spinning a disk is to mount it on the thumbwheel of a sewing machine and adjust the speed until the colors appear. Reversing the direction of rotation (or equivalently, using the mirror image of the disk pattern) will reverse the series of colors seen.

From the beginning, this illusory perception of color was believed to be due to the variation of the retinal response time with wavelength. Photoreceptor response to light stimulation is not instantaneous, but grows and decays in a non-uniform way. The profile of response and how quickly the response peaks depends on the wavelength sensitivity of the receptor. These temporal characteristics of the retina, combined with a stimulating disk pattern and an appropriate "flicker rate" of rotation, act to create imbalances in the color-sensitive mechanisms in the visual system, producing the perception of color from a black and white pattern.

Although early schemes[1] dealt with the differences amounting to milliseconds in peak response times of the red, green, and blue photoreceptors, these differences alone could not fully explain the effect. Even now, according to Joel Pokorny at the University of Chicago, no truly unassailable model for the phenomenon of subjective colors currently exists. However, more complex visual processes have been taken into account as theories are refined.

Of the 100 million photosensitive elements (rods and cones) in the retina, about 6 or 7 million are the color receptors known as cones that come in three distinct types, each being sensitive to only a portion of the visible spectrum: the short, middle, or long wavelengths. However, only about one million neural fibers are present to bring the modulated flow of signals from the rods and cones to the brain. So although in a small area of the central retina receptors are individually connected to nerve cells, most receptors are located in groups that share the same cell. These groups integrate receptors with different wavelength sensitivities. Such mixtures of receptors are called color-opponent cells and respond differently to light than singly connected receptors. They may act, in fact, like neural networks where individual receptors either stimulate or inhibit the total nerve cell response. Under normal (*i.e.*, static) conditions, color-opponent cells help the eye detect very subtle color differences. However, the flickering conditions caused by flashing lights or (in our case) rotating disks are thought to disturb the static operation of the visual network.



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