Color Me Human

BY VINCENT P. MALLETTE

Human beings are visually driven animals. We squeeze everything possible out of light, so it's not surprising that we should put different "information handles" on different wavelength ensembles by encoding them with subjectively recognizable labels. These labels are *colors.*

Calvin of comic-strip fame asked his dad why old photos were in black and white; Dad said the world changed in the 1930s and took on color; when Calvin then asked why paintings have been in color for hundreds of years, Dad informed him that many great artists were insane, and imagined color before it existed. But, in fact, there's nothing insane about color.

All primates seem to have substantial color vision. The higher apes have a three-channel color sense like us; more primitive monkeys have two channels. The big news, discovered in the 1980s, is that dogs can see some color, blue in particular. Researchers now believe that most mammals will turn out to have modest color sensitivity, a few percent of what humans have.

Millions of schoolkids, including me, were taught that animals saw only in black and white, yet it was known as long ago as 1910 that even fish can see color. (Ironically, within certain bands, some fish can make finer color distinctions than humans—it's important for their mating.) Certain insects can see "colors" (identify wavelengths) in what is to us ultraviolet—they use it to spot flowers with tasty nectar.

There is now good information on how human beings, at least, see color. Six million color receptor cone cells line the back of each of your eyes. Each cone contains only one pigment, and there are three families of pigments. They are conventionally called "red," "green," and "blue," but in fact their absorbances peak at about 570, 530, and 440 nm. There is heavy overlap among all three channels. That, in fact, is how the trick is done: it's the overlap. When a mess of wavelengths comes in, the brain looks at the *ratios* of the excitations. This is a powerful stratagem, and it imbues us with tremendous color discrimination.

Human beings can distinguish at least 10,000,000 shades of color. The great authority on color, Edwin Land, said that even the best spectrophotometers could only do 20–40% as well. This wealth of colors is bought at a certain cost, however: ambiguity about wavelength composition.

The same "brain" color, for example an orange, can be excited by different combinations of spectral components. A set of monochromatic lasers, blended, will produce a specific color; a completely different set of lasers can produce that same color. These look-alike, but differently constituted, colors are called metamers. They're sort of like Hollandaise sauces that are made by different chefs with different ingredients, but that are indistinguishable in taste. We're lucky, really, that the eye has this "shortcoming," because otherwise the matching of colors would be difficult, and color printing, color photography, and color reproduction would be next to impossible.

Metameric pairs

Metamers as an idea were recognized by Newton, but they were not explained on a scientific level until the work of Hermann Grassmann (1809-1877). Grassmann was an unsung schoolteacher whose understanding and formulation of color theory was 50 years ahead of his time. Grassmann created the modern three-dimensional representation of color in terms of hue, brightness, and saturation. He recognized that these are the only aspects of color that the human eye—and brain—can operate on. A corollary of Grassmann's scheme is that even nonspectral colors like purple can be created by mixing proper proportions of spectral colors, *because the spectral colors include every wavelength visible to the human eye.* In other words, there is no way that nonspectral colors can be made except by excitation of the eye by spectral colors.

It wouldn't be fair to end this article without some attention to the 8% of our readers (almost all of them men) who have anomalous, or impaired, color vision. Each pigment in the cones has its own gene. If the gene is missing or defective, which most commonly happens to red or green, that color is not seen, or is seen in a deficient way. The bottom line is that color-handicapped people have millions more metamers than the rest of us, so they see many colors—which appear as different colors to us—at the same.

In the future, what colors are seen may change. Already people are being born who have extra copies of the green gene, with response shifted 20 nm to the red. In time (millions of years), these folks could have four-channel color vision!

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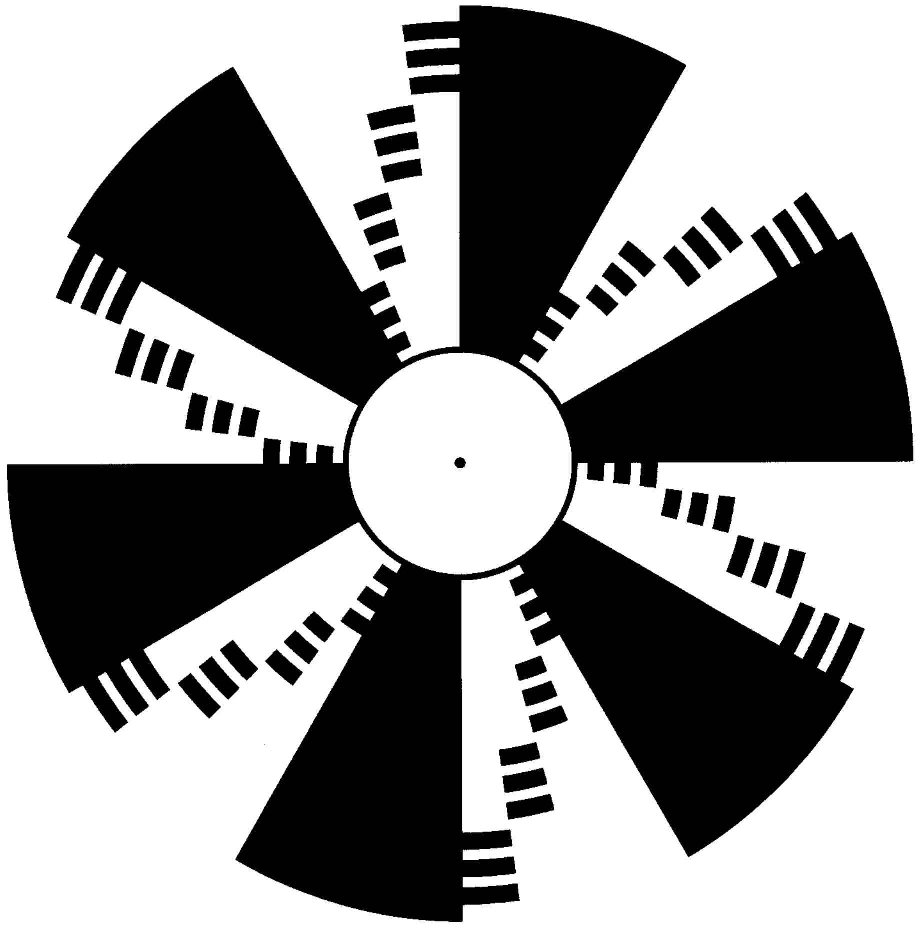

Experiments You Can Do

1. Can you see color from black and white? The surprising answer is yes. In 1826 Benedict Prévost, a French monk, observed colors—"a heavenly light" he called it—trailing from his fingers when he waved his brightly lit hands in a dark cloister. Since then the effect has been independently discovered by no fewer than 13 researchers, each one of whom said "Ah-ha, I'm famous" when he found it. What is this effect? Take the image in the upper right corner of this page,[1] blow it up with an enlarging photocopier, mount it on stiff cardboard, and rotate it. An old fashioned phonograph turntable is fine—try all the speeds—but they're so rare now you may have to use a variable speed electric drill. Attach the cardboard disk to a length of drill rod or a long bolt, and chuck that in the drill motor. You should see pale but definite colors trailing from the black arcs. What's happening? The accepted explanation today revolves (heh, heh) around unequal fatigue of the three color receptors. Any imbalance in the time response of our "white balance" will show up as a predominance of some color—and that's the color you'll see. A hundred years ago children's tops were sold that had Prévost patterns painted on them, and kids delighted in seeing the unexpected colors as the tops whirled.

2. Where is brown in the world of color? Brown is really a form of yellow (or yellowish-red) of low saturation and brightness. Like gray, it takes on its "psychological" value only by adjacency. Project a color slide that has a good patch of brown on a piece of poster board. Cut a little hole in the poster board and let the "brown" shine through and fall on a white card behind (all this in a dark room). You'll be surprised at the change. Try it with gray also while you've got the projector set up. (An overhead projector will also work. Make a brown slide with a brown marker or crayon on clear plastic; then proceed as above.)

3. Get one of those lanterns that has a red flasher on the back and, while looking straight ahead in a dark room, move it from the front of your visual field to the side. You'll see the red flashes gradually drained of color (because the color-sensitive cones are concentrated toward the center of the retina).

4. Take a shiny object like a silver pen and wiggle it rapidly between your fingers, so that the reflection of overhead lights is a blur. If the lights are fluorescent, you'll see alternating streaks of brownish-yellow and blue. This is not a psychophysical illusion (like the Prévost effect discussed above). Fluorescent phosphors driven by 60 hertz lines cycle continuously through these colors; the "white" that we see is a time average.

1. If you would like to receive an electronic copy of the image for the experiment, please contact Michael E. Knotts at 404/894-3422; 404/894-9958 (fax); or ph281mk@prism.gatech.edu.