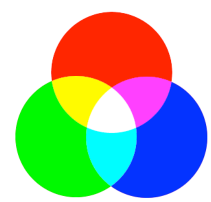
When I was a child I used to pester my mother with such profound questions she could never answer. These questions often dealt with the philosophical and the metaphysical. "What do humans evolve into?" "What happens when you go into a black hole?" "Is my blue the same as your blue?" Being a graphic designer who routinely dealt with color swatches, that last one was probably her favorite. So I set out on this project to answer this question for the both of us. Is color relative to an individual? Or is it shared between everyone?

To answer this question, one must understand what exactly color is. Color is made of light. Without light there is no color. Sir Isaac Newton first discovered that white light contains all seven basic colors of the rainbow. The consensus at the time was that white light was a pure gift from god. Newton, armed with a couple prisms, disproved this and at the same time, discovered how rainbows are formed, why the sky is blue etc. Naturally, a few poets were less than happy with Newton. Apparently all the magic of nature was stolen from them. Newton also discovered that day how colors interact with each other. The additive model, often used in theatre and stage lighting is based on mixing the light, while the subtractive model is based on mixing the pigments. The subtractive model is often used in combining inks and dyes for printing.

Notice something interesting: the mixing of the additive red, blue, and green (RGB) creates the cyan, magenta, and yellow (CMY) colors, while the mixing of CMY creates RGB colors. And again, the mixing of all additive colors together creates white, and mixing the same way for subtractive colors create black.



Also essential to answering the question is a basic understanding of the eye and how it sees color. The retina is situated at the back of the eye. It is packed with hundreds of millions of tiny organs called rods and cones. The rods take up the majority of the retina. They do not perceive color but do perceive light. The cones are the organs in charge of color reception.

Research indicates that there are three different cones for humans. Red, green, and blue. This makes us trichromats. That means we are able to see in three colors. But by combining these three colors we can see roughly one million shades and hues. Other organisms like dogs are dichromats. Only possessing blue and green cones. Most color-blind people also lack red cones. Some other organisms, like the mantis shrimp, possess an astonishing 12 different varieties of color cones. Research also indicates that the ratio of red vs. blue vs. green cones is also unique to an individual.

Some people see even more. The painter Claude Monet had his lens on his eye removed surgically and for the rest of his life could see the ultra violet light invisible to those of us with intact eyes. Our eyes are capable of seeing in ultra violet but our lenses reflect the light before it reaches our retinas. Also living among us are people with a mysterious fourth cone. These individuals are almost exclusively women who might experience a range of colors invisible to the rest. It’s possible these so-called tetrachromats see a hundred million colors, with each familiar hue fracturing into a hundred more subtle shades for which there are no names, no paint swatches. And because perceiving color is a personal experience, they would have no way of knowing they see far beyond what we consider the limits of human vision.

The first hint that tetrachromats might exist came in a 1948 paper on color blindness. Dutch scientist H.L. de Vries was studying the eyes of color-blind men. He tested their vision by having them perform a basic matching task. Twisting the dials on a lab instrument back and forth, the men had to mix red and green light so that the result, to their eyes, matched a standard shade of yellow. To compensate for their difficulty in discerning hues, color-blind men need to add more green or red than normal trichromats to make a match (Greenwood).

Out of curiosity, De Vries tested the daughters of one subject and observed that even though they were not color-blind and seemed to distinguish red and green as well as anyone, they needed more red in their test light than normal people to make the match precise. If the women weren't color-blind, what were they?

A few years ago scientists at Newcastle found one. A doctor living in northern England, referred to only as cDa29 in the published scientific papers, is the first tetrachromat known to science. There's no way she's the last.

What would it be like to see through cDa29's eyes? Unfortunately, she cannot describe how her color vision compares with ours, any more than we can describe to a dichromatic person what red looks like. Scientist Jay Neitz also hypothesized that tetrachromats might not experience any new colors at all. They are trapped in a world suited for humans with three color cones. Every paint, every dye, every ink is created with the basic three-color model. He also suspects that "the natural world may not have enough variation in color for the brain to learn to use a fourth cone. Tetrachromats might never need to draw on their full capacity. They may be trapped in a world tailored to creatures with lesser powers. Perhaps if these women regularly visited a lab where they had to learn—really learn—to tell extremely subtle shades apart, they would awaken in themselves the latent abilities of their fourth cone. Then they could begin to see things they had never tried to see before, a kaleidoscope of colors beyond our imagining" (Greenwood).

Another study might prove that color has an "auto-calibration" mechanism in the brain. Similar to the experiment in which people wore goggles that inverted their vision. After a few days the brain righted the vision. The findings, strongly suggest that our perception of color is controlled much more by our brains than by our eyes. "We were able to precisely image and count the color-receptive cones in a living human eye for the first time, and we were astonished at the results," says David Williams, Allyn Professor of Medical Optics and director of the Center for Visual Science. "We've shown that color perception goes far beyond the hardware of the eye, and that leads to a lot of interesting questions about how and why we perceive color" (Sherwood).

In the experiment, Williams and a postdoctoral fellow, Yasuki Yamauchi, working with the Medical College of Wisconsin, gave several people colored contacts to wear for four hours a day. While wearing the contacts, people tended to eventually feel as if they were not wearing the contacts, just as people who wear colored sunglasses tend to see colors "correctly" after a few minutes with the sunglasses. The volunteer's normal color vision, however, began to shift after several weeks of contact use. Even when not wearing the contacts, they all began to select a pure yellow that was a different wavelength than they had before wearing the contacts (Sherwood). "Over time, we were able to shift their natural perception of yellow in one direction, and then the other," says Williams. "This is direct evidence for an internal, automatic calibrator of color perception. These experiments show that color is defined by our experience in the world, and since we all share the same world, we arrive at the same definition of colors" (Sherwood).

When it comes to colors, the English language is delightfully inventive. Interior decorators, crayon crafters, paint manufacturers and textiles to mention a few, are constantly coming up with ever more imaginative color names. To linguists, however, all the sample chips in a paint store can be categorized by a mere eleven English words. While one decorator's "buttercup breeze" may be another's "desert bouquet," to a linguist they are both yellow. But even eleven is a lot compared to the Berinmo, a small tribe of hunter-gatherers that lives along the Sepik River in Papua New Guinea. The Berinmo language categorizes colors with just five words. This makes the tribe a good subject for studying a linguistic concept that first gained wide interest in the 1950s. Called the linguistic relativity hypothesis, if one people categorizes color differently from another, they should perceive it differently as well (Fountain).

In a recent British psychological study, the Berinmo were shown samples from a 160-color chart and asked to identify them by color. In addition to having fewer colors than English speakers, the categories are different. To English speakers, blue and green are separate colors. Berinmo have one word for both, but they draw a distinction within what English speakers consider yellow, with the word "nol" on one side and "wor" on the other (Fountain).

The critical part of the study came when the researchers asked the Berinmo to remember colors, by showing them a specific color, waiting a short time, and then asking them to match the first color from two similar alternatives. Sometimes the two choices came from same general color category, and sometimes not (Fountain).

The researchers found that the Berinmo were much better at matching colors across their "nol" and "wor" boundary than across English blue and green categories (after having been shown the blue-green distinction). And English speakers, given the same tests, performed well at blue-green matches and poor at matches across the Berinmo categories. A similar effect occurs with the color "indigo." Most English speakers seldom use the word "indigo" and thus a small percentage actually perceive it (Fountain).

Science seems to be at odds with itself on the topic of color perception. In most cases the side that believes color perception can be flexible and unique uses the eye as proof. And on the opposite side of the spectrum, those who support the belief that color is universal to all, call upon the brain as primary evidence, such as Dr. Williams and her experiments. However, there is some middle ground. The researchers of the Berinmo language phenomenon believe that experience and language above all others dictates what colors one perceives and experiences. But which side is right?

In my own humble opinion, I would have to agree with fragments of all the factions. First and foremost your experience, especially in developmental childhood years, dictates what colors you perceives. That cannot be changed. Not even with lenses or tinted glasses. The brain has oriented and calibrated itself based on one’s personal color experiences. This often prevents tetrachromats from utilizing their gift. However, science still understands all but a small percentage of the brain. There are still many mysteries to the body and how it works. And like a gorgeous sea of stars and nebulas on a vacant rural beach, un-filtered by lights or majestic double rainbows stretching all the way across the sky, that's what makes it beautiful. There's beauty in the unknown.

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