

# **True Colors**

## *Color-blindness and Seeing*

By Jessica Fujimori

"Whoa--what happened here?" The photo professor squinted at the image on the projector screen, a picture of a glassblower that looked like it was taken through an orange lens, the color very distorted.

"What's wrong with it?" asked the student who had taken the photo, looking dismayed but unsurprised, his chin in his hand.

"It's orange," the professor replied. "What does it look like to you?"

"It looks...completely normal," the student answered.

The photograph did look normal--to the student, an MIT graduate student in science writing who had been color-blind his whole life. To the rest of the class, the photograph was far from the reality that our professor wanted us to capture with our cameras. Whose reality is real?

The reality of the majority tends to win out, which isn't really fair since the number of color-blind people is non-negligible; approximately 8% of Caucasian men and less than 4% of women are color-blind. Those numbers include a spectrum of conditions, from people who can see no color at all (monochromats) to people who simply see a more muted form of certain colors.

### **Color-blindness and Dalton's eyes**

One of the first attempts to study color-blindness is a slightly gruesome story involving the eyes of John Dalton, a color-blind chemist who was important in the development of modern atomic theory. Dalton thought he was color-blind because he had a blue tint in his eye that absorbed red and green light, preventing him from seeing it.

"A macabre twist in this tale," writes Martin Tovée, a researcher in the Psychology Department of Newcastle University, is that Dalton was so convinced he was right, he gave instructions that, on his death, his eyes should be removed and dissected to confirm his hypothesis." When his physician did not find such a blue tint upon dissection, he assumed Dalton's color blindness was a brain defect.

Modern molecular genetics have illuminated the truth: color blindness is genetic (Dalton's brother was also color-blind) and is caused by "mistakes" in the genes for the pigments in the back of our eye that are sensitive to different wavelengths of light. Mistakes in the coding instructions that the body uses to create the pigments mean the wrong pigments are produced, so the eye is sensitive to different wavelengths of light,

and the viewer sees the colors of the world differently.

### What we see

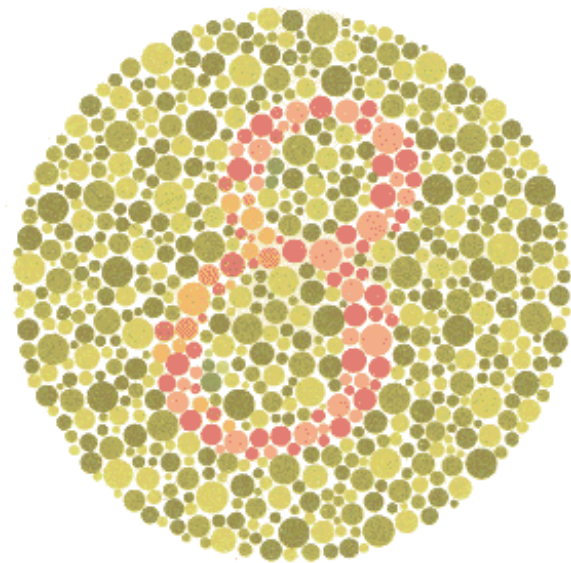
My curiosity about color-blindness was piqued because my boyfriend, Paul, falls has a form of color-blindness; he does not see the color red as vibrantly as most people. This fact led to a barrage of questions from me about what this looked like to him, what that looked like...questions that did not really have an answer. He sees what he sees and I see what I see. The best he could do was to describe what he imagined the relative difference between what we saw was, based on what he knew about his color deficient vision. Since Paul has trouble seeing red, he has trouble distinguishing between blue and purple. Purple is just blue mixed with red, so to him it often appears blue. And I knew he saw the world differently, but I couldn't wrap my head around it, so I kept asking.

"What color is my shirt, the long-sleeved button-up in the closet?" I probed.

"This?" Paul groaned in mock frustration at the challenge and pulled the shirt into the light, where it is easier for him to distinguish colors. He fingered the fabric carefully and held it close to his face, as if examining the quality of the light-colored material. "Purple?" he guessed correctly. "Light colors are harder," he explained to me, moving across the room to pick up a dark purple bag of mine. "Like this one--Yeah, that's purple," he said sheepishly, suddenly self-conscious as he noticed the laughter I was holding back.

Still unsatisfied with the clash of our realities, I turned to online color-blindness tests. The Ishihara Color Blindness Test depicts numbers as a series of dots on a circular background of differently colored dots. On the first test

plate, Paul saw a 3 where I clearly saw an 8 made up of red dots on a background of green dots. There were different shades of red and green, but the number 8 was still clear to me. Paul and I, both indignantly certain that we were correct, went through individual dots to figure out where our realities parted way. On the left side of my 8, I pointed out the dots that I saw as part of the red group of dots. To Paul, apparently, those dots looked different than the dots on the right side of my 8 that formed his 3.



When I thought about it a little more, I realized that he was right; the shading of the dots on the left side looked more light orange than pink or red, and actually fairly close to the color of the light-green dots in the background. I just hadn't thought about it enough to notice the subtle difference, since the 8 stood out so clearly to me. So in a way, he saw more accurately than I did.

I went through test after test with him, and each time we saw something different I was just as surprised. How could two people who share such similar worldviews in a metaphorical sense view the world so differently?

As a concluding remark to a series of questions and tests that may have wounded his pride slightly, Paul turned to me and said, "Well, we can see in the dark better." A moment later he admitted he was pretty sure that was a myth to make color-blind people feel better, but I wasn't so sure. After all, 8% is not that small of a fraction of a human male population. Could there have been an evolutionary advantage of some sort that ensured the inheritance of color-blind genetics?

### **To see color or not to see color?**

Trichromacy, what we call normal color vision, depends on three different light-absorbing pigments in the eye's retina. That's why TV screens only need to use red, green and blue pixels to create what looks to us like the real world in all its colorful glory. Many primates have trichromatic vision, but most other organisms do not. Most other mammals are dichromate, meaning they have two pigments. That's one type of color-blindness among humans; the lack of a third pigment means they cannot distinguish between red and green at all. And some birds, fish and reptiles have us beat at four pigments, which enable them to see ultraviolet light that we humans cannot.

So clearly, different types of color vision have held their own in natural selection, probably because they have different types of advantages. As for color-blindness, it may have its own.

The trichromatic vision of many primates and humans could have been useful, for example, in identifying ripe red fruit in green foliage, while dichromats might have been at a disadvantage. But maybe the disadvantage was actually a trade-off; one study "showed that human dichromats were better able to detect texture camouflaged by color than color-

normal trichromats." Another study found that scotopic vision, or the ability to see in dimmer light, is indeed better in color-blind people than color-normal people, just as Paul had suggested. Maybe color-blind and color-normal people even worked together using their respective advantages to perform better as a whole group. "Viewed in this way," the authors of that study wrote, "color blindness is not necessarily a vision deficiency, but rather a different evolutionary solution to the trade-off between photopic and scotopic vision."

In other words, maybe each of us, color-blind and color-normal, see what we see not because it is reality, but because it is what best enabled our ancestors to survive and pass their visual genetics on to us.

### **Lighting and color**

To see color, we need light, and as light changes, so does color. The color appearance of an object is mostly defined by the way light reflects off its surface in certain wavelengths. Color constancy means "colour appearances do not fundamentally change under...shifting illumination conditions," according to a 2011 article in *Optics & Laser Technology*. But, as the article points out, "it is obvious that human colour constancy is not perfect; in fact it is precisely the imperfection of colour constancy that makes colour vision the deliciously subtle experience it often is."

It's true; the lighting of what we see shapes both how we see it and how we perceive it. My photo professor often urges us to "go back when the light's better," in the evenings or early morning. A brightly lit scene speaks differently to us than a dim candlelit scene, even if all the same objects are present in the exact same orientation. That's true of all color-

normal people. And given that color-blind people can see better in dimmer light, they have better color constancy than color-normal people. So how can we color-normal people say that what we are seeing is what's really there, or at least, what's more really there than what color-blind people see?



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**A valley's appearance changes bathed in different light at various times of day.**

### The reality of the color-normal

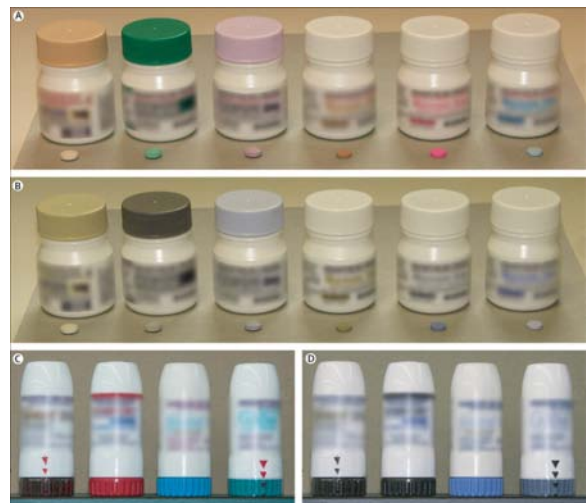
It may be wrong to call color-blindness a color deficiency, but the fact that color-blind people are a minority means that they must live in a world defined by the color-normal.

When we are in kindergarten, we learn the colors of the rainbow with a name acronym: ROY G BIV. "I never understood ROY G BIV," Paul told me. "Because to me it was red, orange, yellow, green, blue, blue, blue." It was only later

he figured out there was supposed to be a difference between the last three.

When we are learning to drive, the ability to distinguish between red and green is indispensable: "Studies have shown that colour-blind subjects take longer to recognize signal colours than subjects with normal vision and make twice as many errors in doing so," warned Morley Whillans, the author of a 1983 article about color-blind drivers' perception of traffic signals. In response to a questionnaire that Whillans developed, one color-blind man wrote, "I drive on the assumption that when I don't see the green (which to me looks white) it must be red, which I cannot see." He corrects his perceptions based on what he knows to be true in a color-normal world.

When we need to take daily medications, we often need good color vision to distinguish color-coded tablets or containers. A study published in *The Lancet* found that around 2% of people with color-impaired vision "had confused their medication because they had mistaken the colour of the tablets."



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**(A) shows color-coded pills and containers as seen by color-normal people; (B) shows them as seen by a color-blind person. (C) shows asthma inhalers as seen by color-normal people, and (D) shows the same inhalers as seen by someone who cannot see red.**

Because most people in the world see color trichromatically, that's how society is run. And that's partly why we think of color-blindness as a defect, since the limitations of color-blind vision become more apparent with systems based on trichromacy. If everyone were dichromate, traffic lights and medications would be very differently color-coded, and color reality would be very differently defined.

### **Reality and color**

Color vision is based on the ability to distinguish different wavelengths of light, which we perceive as different colors. Since color-blind people have a harder time differentiating certain wavelengths, it might seem easy to say that they perceive the world less accurately than color-normal people. But I don't think it's that straightforward.

Our brains tell us that we see something, and we believe them. We also believe that what we see is reality. Color-normal people may see certain wavelengths more accurately than color-blind people, but the reality is that no one sees and senses all that is present. Paul cannot see the dots from red laser pointers; they are invisible to him. But think of the birds and fish that can see UV light that we cannot; in some ways, they are experiencing more real "color" vision than any human can. Our color vision is dictated and constrained by our biology, our evolutionary ancestry, and our more immediate familial ancestry. What if we could actually "see" the full spectrum of wavelengths present in the world? Would the input be an incredible new sensation, or overwhelming, as is the experience of a blind person gaining the power of sight for the first time? Annie Dillard describes the trauma and delight in her lyrical essay *Seeing*:

In general the newly sighted see the world as a dazzle of color-patches. They are pleased by the sensation of color, and learn quickly to name the colors, but the rest of seeing is tormentingly difficult...The mental effort involved in these reasonings proves overwhelming for many patients. It oppresses them to realize, if they ever do at all, the tremendous size of the world....

We are all blind to the tremendous spectrum of wavelengths perturbing the world around us, invisible. The color we experience is beautiful and delighting, but can no more be called reality than what is seen by people who we call "color-blind."

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