BY MIKE WOOD

Chimerical colors

AS I'M SURE YOU KNOW BY NOW if you've read any of my columns, color fascinates me. Just about everything else in our world is understandable and measurable by some kind of physical model or device, but color is 100% perceived and in our brain. There is no real-world quantity we can measure that exactly equates to what our eyes and brain perceive as color. It's not just the spectrum of light, it's way more than that. Color depends on surroundings and our state of mind; color is elusive. We have words in our languages to describe it, but we can never be sure that what we each see is the same.

We try and make color manageable by coming up with diagrams such as the familiar CIE 1931 color space shown in **Figure 1**.

We are taught that the horseshoe shaped space represents every color that the color sensors in our eyes and the brain can distinguish, and we use this, or something like it, as the basis of our color science. Without going any deeper we are immediately aware of the problem magenta line across the bottom of the curve. We know that going counterclockwise round the chart from red to blue takes us through all the wavelengths of light from long to short, so why does the brain join the shortest blue back to the longest red and create these imaginary magenta colors? Color mixing everywhere else along this line makes sense. If I have a red light mixed with a yellow light, then the eye/brain simply averages the two to come up with the color in the middle, amber. Similarly, everywhere else around the horseshoe. However, at some point, the brain decides to go the other way and instead of blue plus red averaging, as you might logically expect, to green it instead takes a shortcut straight back to red and invents some colors as it goes. None of these magenta line colors exists as a single wavelength, even though we see them that way. They can only exist as a mixture of two or more other colors. This is all old news you might say, and indeed it is, but are there other colors that we can see that don't actually exist?

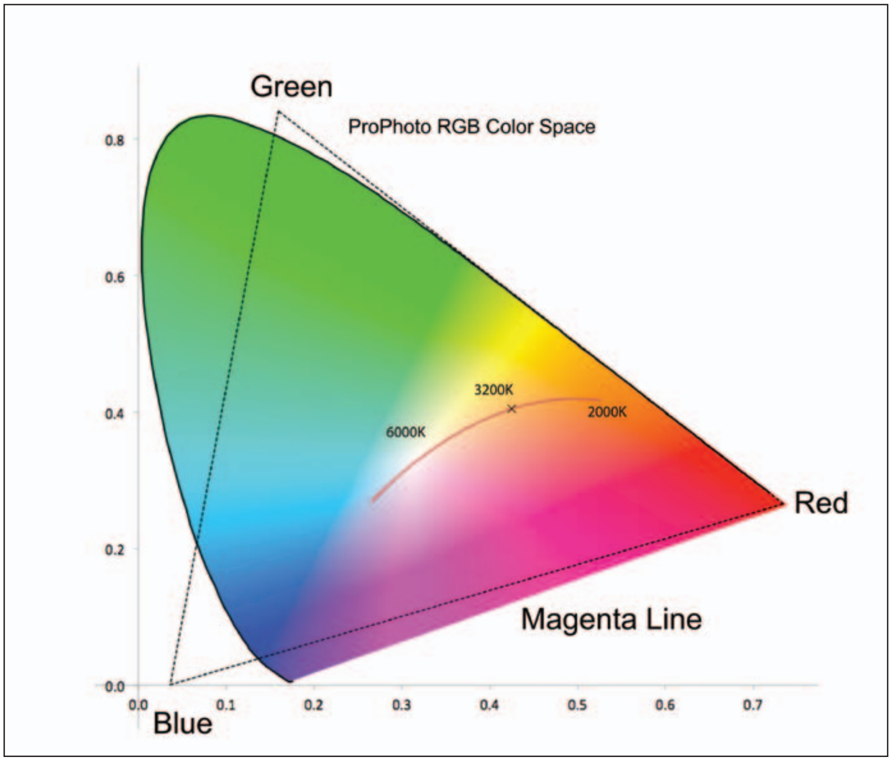

Figure 1 – CIE 1931 color space

> "Why does the brain join the shortest blue back to the longest red and create these imaginary magenta colors?"

I'm not talking about the red, green, and blue triangle I've shown in **Figure 1**. That's the ProPhoto color space. It uses imaginary blue and green color points that lie outside of the visible gamut in order to simplify RGB math and avoid negative numbers, but we can't see those colors. Now, what about colors outside that horseshoe that we can somehow see?

Imaginary colors

There are actually a few types of imaginary colors, but today I want to talk about just one, the class known as chimerical colors. These are all colors that we can perceive (I won't say "see" as they aren't really there) by exploiting our vision system. They are imaginary colors that can be seen temporarily by looking fixedly at a strong color for a while until some of the color sensitive cone cells in our eye become fatigued, temporarily changing their color sensitivities, and then switching our gaze to a markedly different color. For example, staring at a saturated primary-color field then looking at a white object results in an opposing shift in hue, causing an afterimage of the complementary colors. You've likely very familiar with this effect and may have seen some of these examples before but may not have realized that you are perceiving colors that can't exist. Chimerical colors themselves fall into three subcategories; hyperbolic, self-luminous, and Stygian. *The examples here are all drawn from a 2005 research paper by Paul Churchland entitled, "Chimerical Colors: Some phenomenological Predictions from Cognitive Neuroscience."*

Hyperbolic colors

Hyperbolic colors are colors that have saturations that fall outside the horseshoe and are therefore, impossibly highly saturated. They can't exist in nature nor, if you strictly adhere to simple vision theory, should we be able to see them, but . . ..

Figure 2 is a graphic which helps you see a hyperbolic orange.

With the page of this journal well-lit (or your monitor reasonably bright), stare with a fixed gaze at the black dot in the center of the cyan circle for at least 10 seconds, then quickly shift your gaze to the black dot in the center of the orange square. You will see a ghostly circle of hyperbolic orange. An orange that has more than 100% saturation and is much more "orange" than the square surrounding it. This orange falls outside the CIE 1931 gamut shown in **Figure 1** and is not possible to produce with lighting or pigments. It exists, albeit fleetingly, only in your brain. You can do this with any color and perceive super reds, or extra blues, it just happens to work well with orange and the limitations of both printing and RGB monitors.

Self-Luminous colors

Self-luminous colors are colors that appear to glow even when viewed on a medium such as paper, which can only reflect and not emit its own light. These colors are off the CIE chart, not in terms of gamut, but in terms of luminosity. **Figure 3** shows an example, use the same viewing technique as you did for **Figure 2**.

After fixating on the green circle and then switching to the white square you will see a pinkish circle that glows. It may appear to be brighter than the white square it's against, which is brighter than is possible.

Stygian colors

Finally Stygian colors. These are colors with the opposite perception than the self-luminous, they appear darker than they can possibly be, darker than black. They are simultaneously dark and very highly saturated which is a combination that can't actually occur. The name Stygian comes from the river Styx, which Plato described as being "all of a dark blue color, like lapis lazuli, yet as black as ink."

> **"They can't exist in nature nor, if you strictly adhere to simple vision theory, should we be able to see them, but . . ."**

You know what to do. Stare at the dot in the yellow circle for a good time, then switch to the black square. You will likely see a circle which is clearly a deep blue, but extremely dark, darker than it has any right to be. A color you might love to

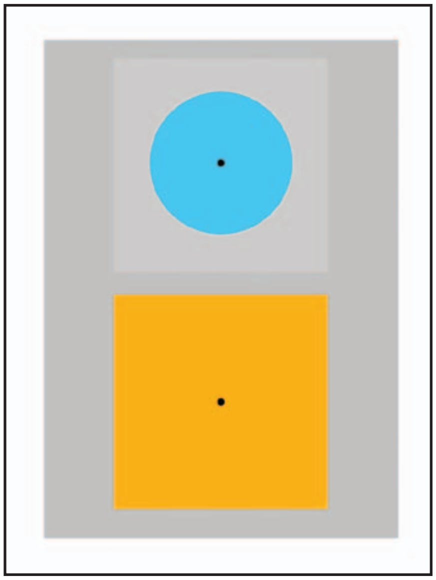

Figure 2 – Hyperbolic orange

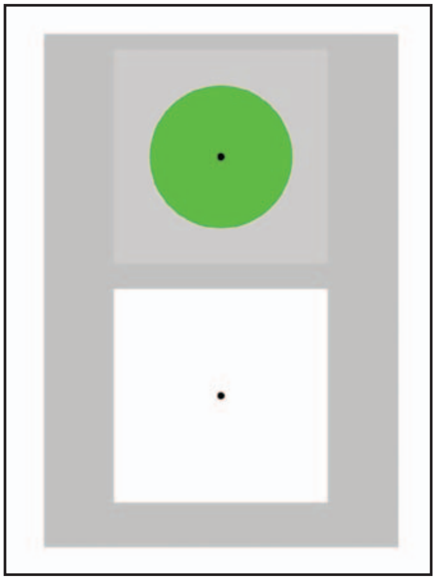

Figure 3 – Luminous red

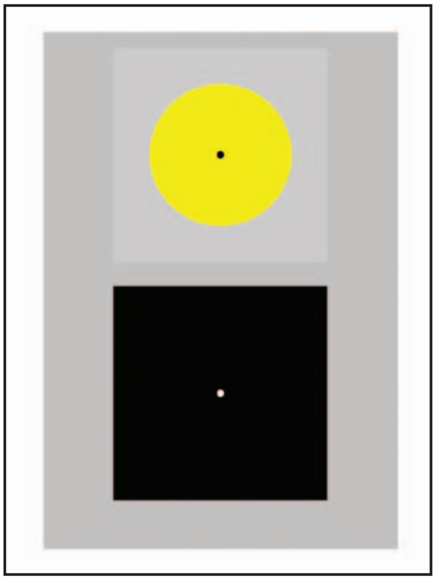

Figure 4 – Stygian blue

have on your cyc in a night scene but that, unfortunately, like the other examples, is a figment of your imagination. No gel or esoteric LED can exist that looks this color. As with the other examples, you can do this with colors other than blue, but, to me at least, blue is the most satisfying.

> **"They are simultaneously dark and very highly saturated which is a combination that can't actually occur."**

Interestingly, although I say you can't reproduce these colors on stage, perhaps you can, at least for a moment. If a scene is lit with, say, an aqua blue such as that used in **Figure 2**, then switches rapidly to a dark stage with an amber cyc then, for a brief moment, the audience will see that amber cyc as a hyper amber. The speed of switching of LEDs would make this effect much stronger than the languid color change of incandescent lights. It's quite likely that lighting designers are doing this kind of thing anyway, without realizing they are creating impossible colors. ■

Mike Wood runs Mike Wood Consulting LLC, which provides consulting support to companies within the entertainment industry on product design, technology strategy, R&D, standards, and Intellectual Property. A 40-year veteran of the entertainment technology industry, Mike is a past President of ESTA and Co-Chair of the Technical Standards Council. Mike can be reached at mike@mikewoodconsulting.com.

Reference:

"Chimerical Colors: Some phenomenological Predictions from Cognitive Neuroscience," in *Philosophical Psychology* vol. 18 no. 5 (October 2005)