THE SECOND C: Observer Metamerism

By Keith Hoover

"Do You See What I See?"

–Gilbert Noël Regney and Gloria Shayne

Having gone to the LOO (Light, Object, and Observer) three times [1], let's return once more and provide some visual evidence to tackle observer metamerism. Many courses on color teach that the Light and Object are variables and the Observer is a constant (LOO), at least as defined by the CIE in 1964. But real people are not mathematical models, and in this article, I will show real examples of how color perception varies across several individuals. But first, a little background.

THE D & H COLOR RULE

The D & H Color Rule is an example of a tool used to detect different types of metamerism. It incorporates two sliding rules—one varying from purplish gray to greenish gray and the other varying from orangish gray to blueish gray. Each rule is created using radically different colorants (thus making them color inconstant in different ways). A series of letters or numbers are placed at fixed intervals across the back of each rule identifying different shades along the gradient. The user moves each rule left or right until a visual match between the two rules is achieved in the front viewing window (see Figure 1). The corresponding number and letter on the back of the rule indicates the precise position of each user's "match."

Figure 1 *The D & H Color Rule. Look closely to see the wildly different reflectance curves representing the colorants used on the two sliders. The upper right images show one match as seen under two different light sources (or by two different observers). The bottom left image shows the settings from the back of the rule indicating the sliders' positions (M9) for a match.*

The D & H Color Rule was used to test the accuracy of light sources in different viewing cabinets. The user would first create a match under a specific light source in viewing cabinet A and then check the match under the same source in viewing cabinet B. If it didn't match under B, then the light source was different (illuminant metamerism).

It could also be used to detect observer metamerism. Various users would match the sliders and record the match settings. If the match settings differed between the users, then it meant that they did not see color the same way. One particular kind of mismatch indicated "red eye," a condition attributed to older observers with yellowed lenses.

The D & H Color Rule was a good tool for detecting the presence of metamerism, but it gave no indication of what a person was seeing across a variety of colors.

COLOR RENDITION EVALUATION

GTI makes an interesting device called the Simultaneous Color Viewer (SCV) [2] that allows a user to see the same color under various light sources at once (see Figure 2). By showing the same object simultaneously under multiple lights, it serves as a dramatic way to understand color rendition ("seeing is believing"). It is fair to say that people's color perception adapts to the lighting conditions surrounding them, so the SCV's stark contrast between color rendition in different light sources is exaggerated. Nevertheless, the SCV is a helpful tool to understand the critical importance of lighting.

But, what about the difference between the way that different people see colors under the same light?

THE GOLDEN EYE

In the January 2025 *AATCC Review*, I described LEDSimulator, a device that allows a colorist to match a physical color standard by adjusting wide gamut, tunable light sources that project color onto a white fabric. In that article, I discussed the CIE 10-degree Standard Observer color matching functions (CMFs) and how they likely differed from the general population. Nonetheless, the CIE 10-degree Standard Observer has proven successful as part of a of strictly-digital color management process. Mixing human color perception with a digital model requires another tack.

The concept of a "GoldenEye" correction matrix was discussed as a way of 1) capturing how individual colorists perceived a given set of colors and then 2) mapping the results back to the CIE 10-degree Standard Observer.

Figure 2 *The GTI Simultaneous Color Viewer shows the impact of different lights on the color rendition of a single sample.*

Methodology

A group of six colorists and advanced degree students with an interest in color used ColorWay software and the LEDSimulator device to create virtual matches to a set of 30 physical Coloro color standards. Each colorist imported master spectral data in ColorWay to generate virtual colors projected in LEDSimulator. Since conversion of spectral data into L*a*b* values involves the CIE 10-degree Standard Observer, the virtual colors might not *visually* match the physical swatches (unless the colorist *saw* color exactly like the Standard Observer).

Each colorist then used ColorWay to adjust every virtual color until it matched its physical standard as observed in LEDSimulator. The matches were associated with their master colorimetric data and stored. These data sets were used to create a GoldenEye matrix—a proprietary correction matrix unique to each colorist.

When colorists applied their GoldenEye matrix, all master spectral data imported into LEDSimulator matched their corresponding physical master standard—while maintaining identical L*a*b* values.

Capturing the Matches

Many studies have provided data describing how people perceive color differently. But, I wanted to *see* what those differences looked like. So, a high-resolution camera was installed in LEDSimulator [3] and a GoldenEye matrix was created for the camera by a colorist matching the 30 standards as seen through the camera image viewing software instead of direct observation in LEDSimulator.

The files representing the original L*a*b* standard colors, the six colorists' matches, and the camera's matches were retrieved, projected in LEDSimulator, and captured to provide images of what each subject deemed to be an exact match for each standard (see Figure 3).

With access to all of these images, we can now "see through someone else's eyes"—kind of.

The Results

The images presented in the next few pages show 30 rows of eight color variations. Each row is arranged chromatically with Subject 1's version of the color in the first spot followed by images of how the Standard Observer (labeled CIE) and the other subjects (including the camera, Subject 6) perceived that color. For the sake of consistency, I have used the same order for each row. Thus, you can look across to see variations on a single color and up and down to see how each colorist saw each color.

I am throwing caution to the wind here in trying to show discrete color differences in a print magazine. I saw the differences distinctly in LEDSimulator and the camera software. Going through an RGB and CMYK workflow will likely muddy up the results. Hopefully, you will get at least a taste of how color perception varies between different people.

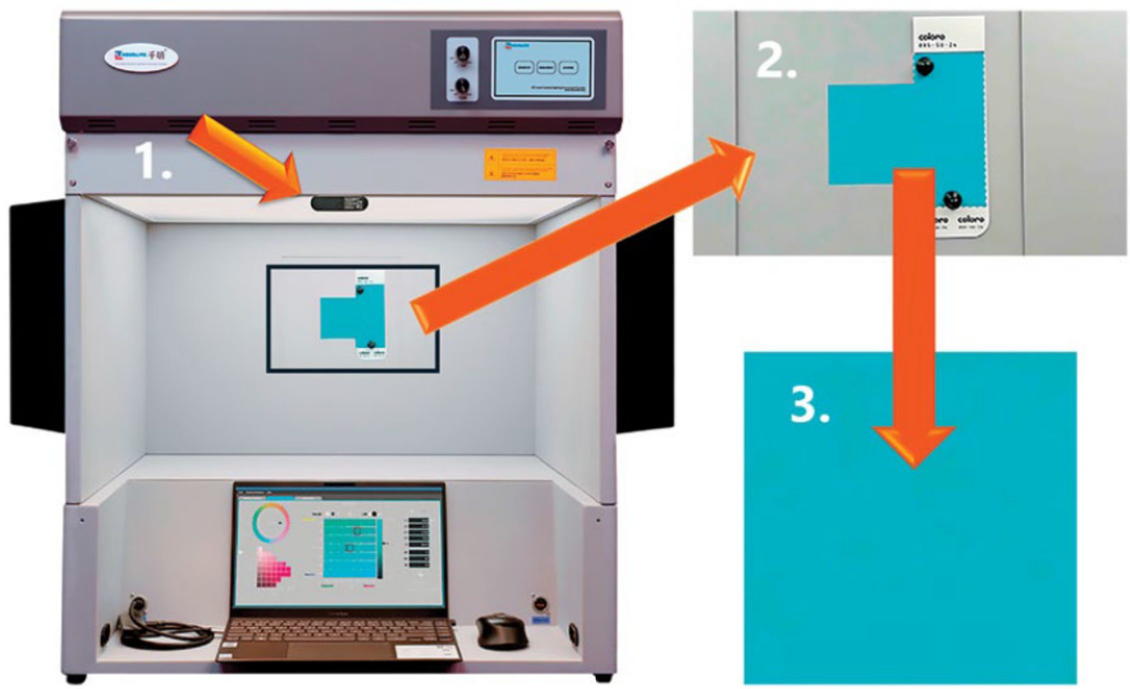
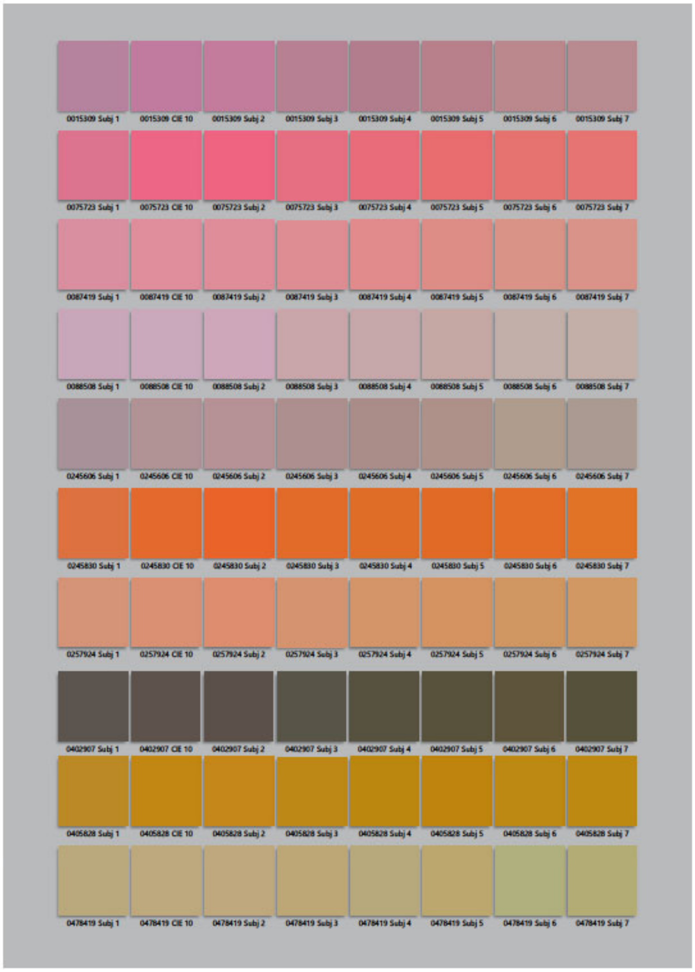
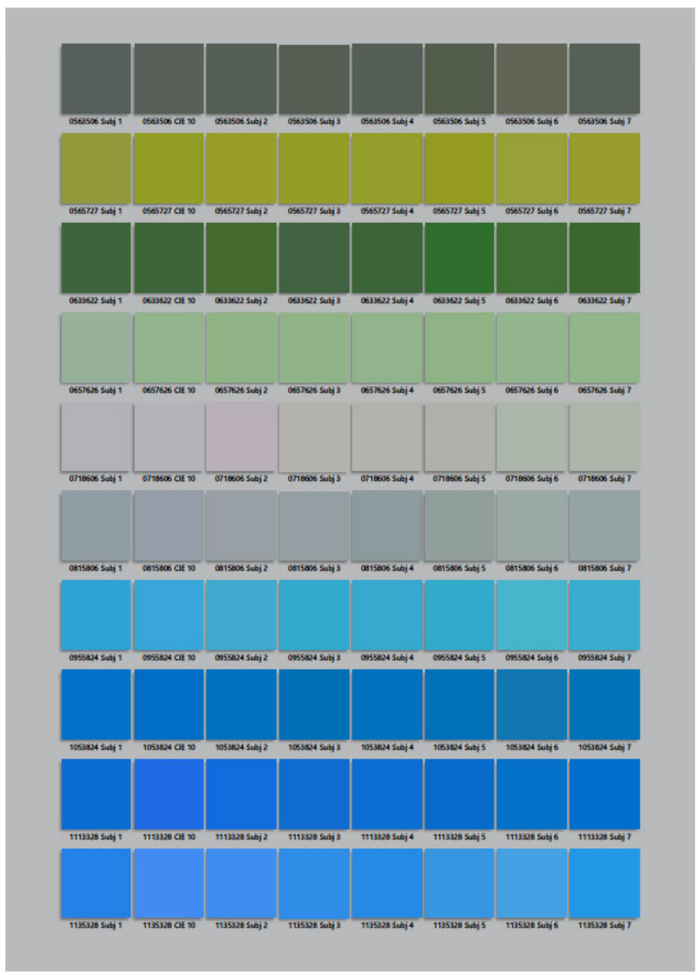
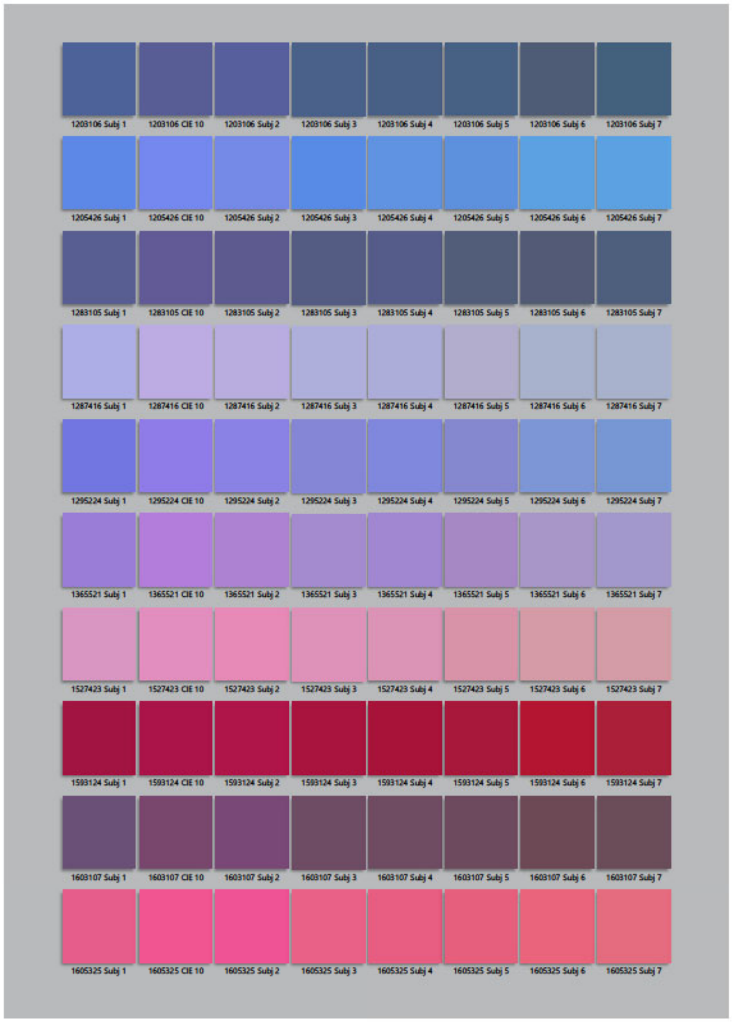


Figure 3 *The camera (1) mounted in LEDSimulator captures an image of the virtual match next to the Coloro standard (2) and the virtual match image (3) is saved and stored.*







OBSERVATIONS

I noticed a few chromatic trends across all colors that can be seen in the order in which I placed the subjects.

- Subjects 1 and 2 have the highest level of agreement with the CIE Standard Observer, although Subject 1's matches seem to be consistently bluer.
- Subjects 6 and 7's matches are consistently similar.
- Subjects 3 and 4 track similarly and fall in the middle between the first three subjects and the last two.
- Subject 5 waffles in cast between Subjects 3 and 4 and Subjects 6 and 7.
- The visual order of the subjects moves along a hue angle sequence for chromatic shades and a chromaticity sequence for achromatic shades Subjects 1 and 3 see reds bluer, oranges redder, greens bluer, and blues redder than Subjects 6 and 7. Subjects 1 and 3 also see neutral shades brighter than Subjects 6 and 7.
- One row of color particularly baffles me; 0718606. It is a very pale light green shade that varies from pink to green across the observers.

I propose no explanations for these variations. The number of participants was small and certainly not representative of global demographics. I will state that most of the participants were under 35 with another participant nearly twice that age (Subject 7). Given the chromatic consistency, I would venture to guess that lens yellowing over time does indeed tend to have a noticeable effect on color perception. It likely reduces the gamut of perceptible colors and shifts their cast. Younger observers may well perceive a wider range of colors than their elders. It is interesting to note, however, that the camera (Subject 6) perceives color much like Subject 7.

No, I Don't See What You See—But So What?

Before you get too carried away and conclude that younger candidates make better colorists, consider this. Various matching exercises capturing inter-observer performance (agreement with the other subjects) and intra-observer performance (individual repeatability) were executed by the six subjects. Subject 7 was an outlier in inter-observer agreement but was vastly superior in *intra-observer* agreement—repeatable color match precision. So, perhaps experience and acquired skills trumps clearer lenses.

The thing to remember is that this exercise in attempting to see how others see can be misleading. Each one of us relies on our own visual system (the eyes capturing sensations and the brain processing them). Any gradual change over time to the lenses is offset by experience and acquired skills. What does matter is a person's interest in—and passion for—color. The will/way thing.

Notes

[1] The Second C: Going To the LOO, Part 1: Dips, Diapers, and the Standard Observer, *AATCC Review*, **2024**, *24* (5), 40-43, The Second C: Going To the LOO, Part 2: Oedipus Meets the Standard Observer, *AATCC Review*, **2024**, *24* (6), 24-28, and The Second C: Going To the LOO, Part 3: Chromalucense & the Golden Eye, *AATCC Review*, **2025**, *25* (1), 24-30.

[2] **www.gtilite.com/store/shop/scv**

[3] Although device metamerism (the way the camera captures color) is comparable to observer metamerism as a risk, we found that the camera adequately and consistently captured the difference between the color pairs.

Keith Hoover, President of Black Swan Textiles, implements manufacturing-centric digital processes for color and fabric development. He has implemented digital color management programs for Ralph Lauren, Target, Lands' End, JCPenney, and Under Armour, ultimately leading to a process that eliminated lab dips altogether. At Under Armour, Hoover championed the UA Lighthouse, driving digitalization and advanced manufacturing processes to explore local-for-local sourcing. He has worked hands-on in mills worldwide and is a frequent AATCC presenter.

Articles from The Second C: Series

- Hoover, K. The Second C: Color with a Purpose. *AATCC Review*. **2022**, *22* (1), 36-39.
- Hoover, K. The Second C: From Inspiration to Replication. *AATCC Review*, **2022**, *22* (2), 28-32.
- Hoover, K. The Second C: Lab Dips—The First Circle of Hell (Part 1). *AATCC Review*, **2022**, *22* (3), 26-30.
- Hoover, K. The Second C: Lab Dips—The First Circle of Hell (Part 2). *AATCC Review*, **2022**, *22* (4), 32-36.
- Hoover, K. The Second C: Leaving Limbo. *AATCC Review*, **2022**, *22* (5), 34-39.
- Hoover, K. The Second C: The Sixth Circle of Hell—Heresy, Part 1. *AATCC Review*, **2022**, *22* (6), 34-39.
- Hoover, K. The Second C: The Sixth Circle of Hell—Heresy, Part 2. *AATCC Review*, **2023**, *23* (1), 26-33.
- Hoover, K.; Merritt, R. The Second C: The Ninth Sphere of Paradise—Primum Mobile, Part 1. *AATCC Review*, **2023**, *23* (2), 22-28.
- Hoover, K. The Second C: The Ninth Sphere of Paradise—Primum Mobile, Part 2. *AATCC Review*, **2023**, *23* (3), 22-28.
- Hoover, K. The Second C: The Ninth Sphere of Paradise—Primum Mobile, Part 3. *AATCC Review*, **2023**, *23* (4), 26-31.
- Hoover, K. The Second C: The Ninth Sphere of Paradise—Primum Mobile, Part 4. *AATCC Review*, **2023**, *23* (5), 34-39.
- Hoover, K. The Second C: The Cost of Color. *AATCC Review*, **2023**, *23* (6), 34-43.
- Hoover, K. The Second C: The Truth About Color Revisited. *AATCC Review*, **2024**, *24* (1), 26-33.
- Hoover, K. The Second C: A Higher Class of Problem. *AATCC Review*, **2024**, *24* (2), 24-28.
- Hoover, K. The Second C: A Higher Class of Problem, Part 2. *AATCC Review*, **2024**, *24* (3), 32-36.
- Hoover, K. The Second C: Two World Views, *AATCC Review*, **2024**, *24* (4), 32-39.
- Hoover, K. The Second C: Going To the LOO, Part 1: Dips, Diapers, and the Standard Observer, *AATCC Review*, **2024**, *24* (5), 40-43.
- Hoover, K. The Second C: Going To the LOO, Part 2: Oedipus Meets the Standard Observer, *AATCC Review*, **2024**, *24* (6), 24-28.
- Hoover, K. The Second C: Going To the LOO, Part 3: Chromalucense & the Golden Eye, *AATCC Review*, **2025**, *25* (1), 24-30.
- Hoover, K., Kiser, K., The Second C: Intentional Color Loss, *AATCC Review*, **2025**, *25* (2), 24-29.
- Hoover, K., The Second C: Modeling Fabric Hand for the Apparel Industry, *AATCC Review*, **2025**, *25* (3), 26-33.

This textile series will share technical insights and wisdom of AATCC members. The "Second C" series will focus on color. If you wish to contribute your own technical insights on topics of interest to AATCC members, contact Communications Director, Maria Thiry; thirym@aatcc.org.