THE SECOND C: Lab Dips—The First Circle of Hell (Part 2)

By Keith Hoover

Light, Heat, & Despair

Before we get to those poor, unfortunate souls tethered to a lightbox full of lab dips, let's go to the LOO. While our friends at the Society of Dyers & Colourists (SDC) are snickering, recall I mentioned the LOO—Light, Object, and Observer—in the initial installment of this series. These three elements determine how we perceive color.

In the last installment, we covered the Object (Sample Preparation) and the Observer (Self-Assessment). So, let's finish them off by looking at the Light ("L"). Then, comes lab dip review.

Light, Color Inconstancy, & Metamerism

You know we're talking about Hell because this is all about light and heat. But, if you want to move out of Limbo, you must understand Figure 1. The sample on the left is *Killer Whale* viewed under Daylight (D65). On the right, it's the same sample under Incandescent. Figure 2 shows two mills' submits for *Limester* viewed under Daylight (D65) and the Ultralume 3000 (U30). Seems like magic—that is until your boss asks you to explain why a color manager is needed with so many color issues on the selling floor.

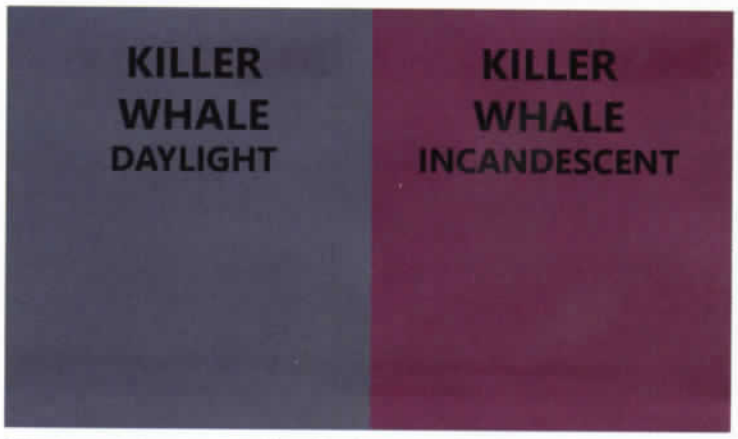

Figure 1. An example of color inconstancy.

When a *single sample* changes color under different lights is **color inconstancy**. However, when *two samples* match in under one light, but not another, that's **metamerism**. In fact, all color swatches display

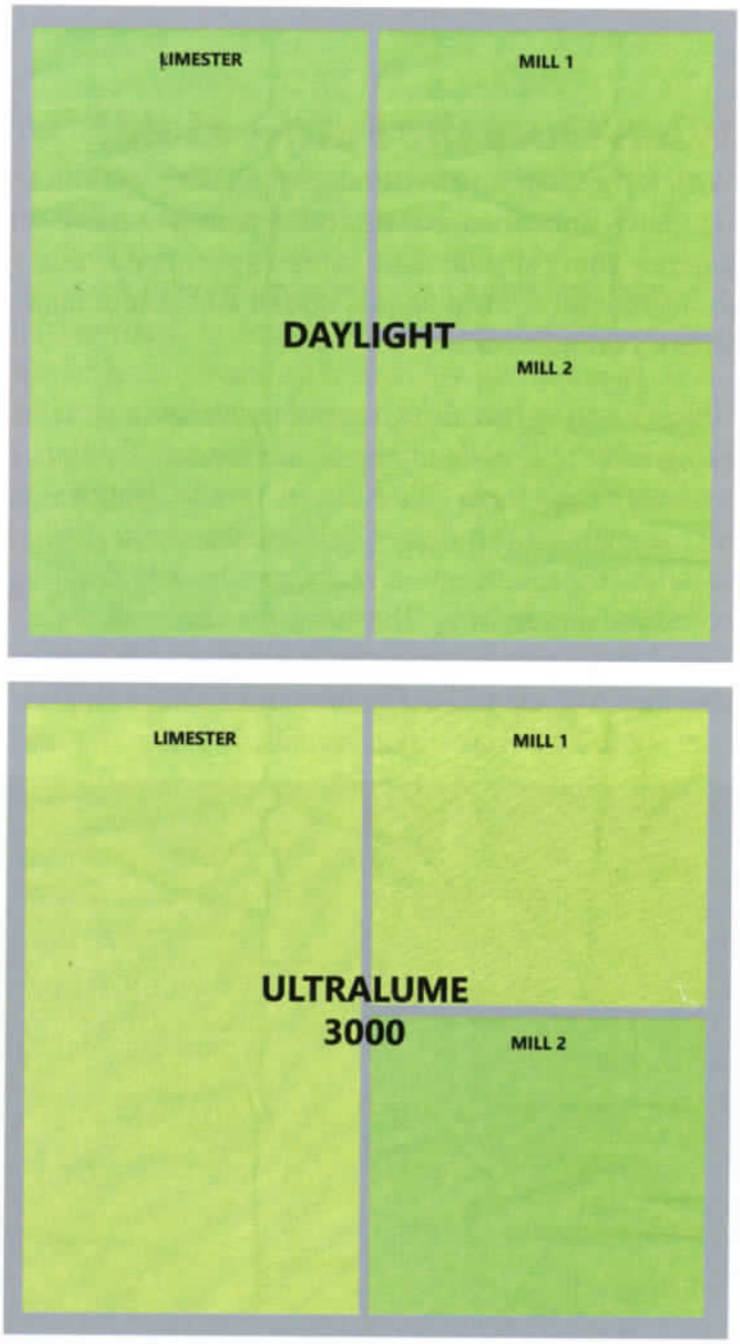

Figure 2. Examples of metamerism.

some degree of color inconstancy. Inconstancy can move in a variety of directions. A khaki shade can flare red or green under a secondary light. The trick in dyeing is to match the color standard's inconstant behavior as observed in multiple light sources.

Characterizing Light

But isn't light just light? I mean, you control it with an on/off or dimmer switch, right? Well, no, there are different ways to produce light and, within each of those methods, there are different qualities of light.[1]

First, when I say light "source," I mean the thing (bulb, tube, or whatever) that emits light. So, consider these four categories of light sources—incandescent, the sun (daylight), fluorescent, and LED. Incandescent and daylight are "continuous spectrum" sources, while fluorescent and LED are "mixed wavelength" sources.

Continuous Spectrum Sources

Incandescent light sources and daylight emit energy across the visible spectrum, which is broken into steps called wavelengths. A rainbow is one way of picturing the spectrum. It shows the hues of wavelengths continually changing from blue to green to yellow to orange to red. So, the light produced by a continuous spectrum source includes significant energy at all wavelengths.

Mixed Wavelength Sources

Fluorescent and LED lights are different. Similar to a TV using combinations of only red, green, and blue signals (RGB) to produce color, fluorescent and LED lights only emit energy at fixed wavelengths of the spectrum. The mixture of the energy from these select wavelengths produces different versions of white light.

Color Temperature

The color of white light varies on a continual scale moving from red to orange to yellow to white to blue. Think of what happens when a blacksmith heats up a horseshoe —it starts out "red hot," then turns orange, and then yellow. The temperature (using the Kelvin temperature scale with the "K" designation) required to heat the metal to each point on that scale describes the color of the light emitted by the source. So, as illustrated with the horseshoe, color temperature increases as we move from red to orange to yellow. Metal can only be heated so much before it vaporizes. However, it is possible to extend the color temperature scale beyond that point. After yellow comes white and then blue. Color temperature is used to place these white light variations on that scale.

Correlated Color Temperature, Color Rendering, and Spectral Power Distribution

Mixed wavelength sources mimic various continuous spectrum sources at different color temperatures. However, the color of the light they produce is a little different than their continuous spectrum counterparts at the closest color temperatures. So, these

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.**

lights are assigned a variation of color temperature called Correlated Color Temperature (CCT). CCT is used to describe the color of various mixed wavelength lights.

However, we're concerned with how product color looks under different lights (not just the color of the light itself). So, another term, Color Rendering Index (CRI), tells us how the color of a product viewed under a mixed wavelength light at a given CCT compares with the same object viewed under a continuous spectrum light at the same color temperature.

While CRI may not be a perfect index, a light source with a low CRI rating indicates that it will make the color of a product look different than a continuous spectrum light with the same color temperature.

For commercial color management, we need more than color temperature or CRI. We need to know the spectral power distribution (SPD)—exactly how much energy a light source emits at each wavelength. SPD is to a light what spectral data is to a color. SPD data is used to build "illuminant tables" (digital models of a light) in color QC software.

Light, More Light!

Incandescent

Incandescent light is produced by heating a metal filament in a sealed bulb.

Types of Incandescent Lights:

- ***Horizon light***: Red/orange in color (2300K)
- ***Edison bulb***: Yellow/orange in color, the old-fashioned inverted pear-shaped bulb (2856K, modeled as Illuminant A)
- ***Halogen***: Yellow in color, the hottest commercially available incandescent light (3000K)

Higher color temperature incandescent sources are possible by filtering out part of the light they produce.

Daylight

Daylight refers to the color of the sky in four standardized variations, again using color temperature to distinguish them.[3, 4]

Types of Daylight:

- D50 (5000K): White in color, used in the graphics industry
- D55 (5500K): Okay, I'll admit it. I don't know what industry uses this.
- D65 (6500K): Blue in color, used in the textile industry and the US military (after 2021).[2]
- D75 (7500K): Bluer in color, used by the US military prior to 2021

Fluorescent

Fluorescent light is created using tubes coated on the inside with phosphors and filled with a mercury vapor. Introducing electrical current in the tube creates a reaction causing the phosphors to glow and emit light. Varying the amounts of different phosphors produces different colors of light.

Types of Fluorescent Light:

- ***Cool White Fluorescent (CWF)***: Greenish white in color, no longer produced in its original form (4156K)
- ***Tri-band Fluorescents (TL and U series)***: Produced in a variety of color temperatures from 2700K to 6500K, intended as energy efficient substitutes for other lights
- ***Daylight Fluorescent***: Produced in various grades most notably as a cheaper daylight source in lightboxes (5000K, 6500K)

LED

LED lights use integrated diodes that emit specific colors of light (Light Emitting Diodes). When mixed, they produce variations of white light. This technology is the most energy efficient of all types described.

Types of LED Light—The CIE recently published nine LED standard illuminants. However, the technology is capable of producing a huge variety of lighting products, each with different CCT's, CRI's, and SPD's.

So What?

I can hear you saying, "This seems pretty technical—do I really need to know all that?" Yes, you do. The introduction of LEDs and the outlawing of many of those old lights has seriously challenged our ability to manage product color. Whereas before, we only had a handful of lights to consider, now we have hundreds, each rendering product color differently. Since the specific energy make-up of a light source determines the color of a lab dip, we must know what lights to consider.

Choosing Lights for Evaluating Color

Fifty years ago, this was easy—the primary light source had to be store light since colors had to match at the point of sale. And all stores used CWF. Then, Westinghouse (thanks to Bill Thornton), introduced Prime Color tri-band fluorescent lights. They required much less energy and looked like CWF, but product colors viewed under them looked different than under CWF.

Then, lighting companies introduced advanced tri-band technology in "better" lights with a variety of correlated color temperatures. The CIE (the international group that standardizes lights) had a hard time keeping up. Soon, brands introduced their own "custom illuminants" to characterize their own new lights. Then high-tech skylights were introduced in stores to save energy. Then came LED lights. And finally, e-commerce started supplanting retail stores, and the home became the first place that customers saw their purchases.

One light source isn't adequate for color matching. To assure that product colors matched when customers left the store, daylight was selected as a secondary light source. Some brands chose incandescent as a third light source to make sure colors matched at home. Incandescent sources traditionally used at home, however, have given way to either tri-band fluorescents or LED sources.

So, the concepts of uniform "store lighting" and "home lighting" are obsolete. Thankfully, daylight isn't threatened since Mr. Sunshine remains the same.

What should replace the obsolete specs for the store and home? That's a tough question. Therefore, the AATCC research committee addressing color measurement test methods (RA36) recently set up a subcommittee to identify and evaluate light sources actually in use in the commercial space to help answer it. Let's look at a few different scenarios in retail today.

Primary Light Source

Owned stores: If you're managing color for a company that owns its stores (like a big box or boutique shop), then find out the type of lighting used in the store. If you're lucky, there will only be one type in use (such as a tri-band fluorescent, halogen, or an LED source). You will likely find that there are at least two light sources in use. Choose the one that illuminates most of the products. And, considering where purchase decisions are made, the dressing room and checkout area lighting should be the same. Check with your lightbox suppliers to see if they offer that light source. Don't get fancy by building a lightbox with several lights on at the same time. It's just silly.

Department Stores: If you're managing color for products sold in department stores or other brick-and-mortar retailers, then, well, good luck. Each brand selling products through department stores has a spec for a primary light source, but does it make sense? Few retailers follow standard guidelines for lighting other than color temperature (3500K), illuminance level, and efficacy. Several lighting configurations are likely in use (even across stores in the same company). And then, there's those pesky windows and skylights. Some lighting specs are obsolete. Neither CWF nor daylight are used in your store (the first, because it hasn't been manufactured in years and the second, because the store has a roof). It's tragically surprising that some multi-billion-dollar brands still spec CWF for color matching.

eCommerce: If you're managing color for products to be sold exclusively via eCommerce, then the home becomes the "selling floor." Since variations of LED sources are replacing other types of light both at the store and in the home, it makes sense to focus here. Again, the new AATCC Research Committee will tackle this, so stay tuned.

Secondary/Tertiary Light Sources

All scenarios: In order to avoid metamerism, you will need to choose a second and possibly third light source for color evaluation. Daylight makes sense (except for sleepwear and lingerie). Some type of LED make sense for home—see above.

Unless you are using color standards that have been vetted for feasibility (see "The Second C: From Inspiration to Replication"[5]), then expecting a match in more than two light sources may be a fool's errand—especially when different fibers (like cotton, polyester, nylon, and acrylic) are in play. You may also need to set a higher acceptability tolerance for the second and/or third tolerance.

Beyond Standard Illuminants

Since new light sources have proliferated like mayflies on Lake Winnebago, we may have to re-think the role (or ranking) of standard illuminants in color matching. We know that if the reflective curves of two samples are the same, then they will match under any light source. So, the curve shape of a color standard optimized for feasibility may lessen the impact of uncontrolled lighting. Again, more research is needed.

Strictly Visual Color Evaluation

So, let's get to those lab dips. We'll start by assuming a strictly visual process—no spectrophotometer or color QC software. Just you, pretty colors, and the lightbox. Here comes the "despair" part. Reviewing lab dips and sending comments back to the mill without the benefit of data is a waste of your time and the company's money.

You saw in the third installment of the series that visual color assessment is unreliable.[6] It's also slow. You don't need to be a Black Belt in Six Sigma to know that an unreliable process is worthless. Your company would probably get better results (and save money) by adding a color quality clause in the vendor contract, foregoing all lab dip review.

Ouch. I know it sounds cruel, but it's the truth. All is not lost, however. In the next installment, I'll cover how implementing a digital color process will add value, cheer you up, and protect your job. And maybe, get you out of Limbo.

References

1. Note that this presentation of light is a simplified version intended to provide a basic understanding of its impact. I have taken certain liberties and introduced unorthodox terms for the sake of clarity and simplification. However, I have found over the years that many claiming a technical grasp of the subject don't really understand it at all. However, if you are well-versed in the subject, please bear with me while I introduce the basic concepts to an audience for whom it is extremely relevant.
2. Shade Evaluation Light Source Change, U.S. Army Combat Capabilities Development Command—Soldier Center, Briefer: John Kirk, Project Officers: Rachel Matuszek and Brenda Zarate
3. Judd, Deane B.; MacAdam, David L.; Wyszecki, Günter (August 1964). "Spectral Distribution of Typical Daylight as a Function of Correlated Color Temperature". *JOSA*. 54 (8): 1031–1040. doi:10.1364/JOSA.54.001031.
4. Note that for daylight, I am mixing light source (the light itself) with illuminant (the theoretical model of a light source). Since the source is the sun itself, daylight has been driven by the CIE D illuminants, which have been difficult to simulate as controlled light sources (thus the ASTM daylight simulator ratings).
5. Hoover, K., AATCC Review, Vol. 22, No. 2, March/April 2022.
6. Hoover, K., AATCC Review, Vol. 22, No. 3, May/June 2022.

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