Color and Light

The American National Standards Institute (ANSI) first developed standards for viewing hard copy in the late 1960s. These standards, which have been revised since that time, recommend light sources and viewing conditions. Anyone involved in evaluating color in a design studio, color separation shop, or printing plant needs to have a fundamental understanding of the science of color and light to see why these standards are so important. (For a more basic look at color, please refer to the Linotype-Hell technical information article entitled *Color in Printing.*)

Observer/object/light source

Most of you will be familiar with the observer/object/light source triangle. This model asserts that for color perception to take place, you need to have an observer, an object, and a light source. Change one corner of the triangle and you change color perception. Therefore you can't even begin to discuss the quality of a proof if you are looking at it under one set of conditions and your customer is looking at it under a different set of conditions.

Metamerism

You may have noticed how some item of clothing appears one color under the fluorescent or tungsten lights in the store, and yet seems different when viewed out in the sunlight. Metamerism is related to this, but must be considered in terms of pairs of objects. Say that you wanted to purchase a blue umbrella to match some blue deck chairs. If the items match in the store, but don't match when viewed in direct sunlight, then they are a metameric match. In other words they match under one light source, but not under another. In a metameric match, the objects' color coordinates match, but their spectral reflectance curves do not.[1] The concept of metamerism underlines the importance of a constant light source for viewing hard copy.

Metamerism may also occur where one observer says that a pair of colors match, but they do not match to another observer. This is called observer metamerism. (The observers could be machines as well as humans, and so this phenomenon can also be referred to as machine metamerism.)

[1]An excellent example of metamerism appears on the title page of *Principles of Color Technology*, 2nd Ed., by Fred W. Billmeyer Jr. and Max Saltzman (John Wiley & Sons, 1981). The concepts of color coordinates and spectral reflectance curves are also discussed in great detail.

Color temperature

Color temperature is a way of describing the color of a light source. It is related to actual temperature in the following manner. A blackbody[2] is heated up to extremely high temperatures. Unheated a blackbody is black, but as the temperature increases the color goes from a dull red to a bluish white. (See Figure 1.) At a temperature of 5000 degrees Kelvin, the light that a blackbody gives off looks like that of a 5000K light source. (5000 degrees Kelvin is about 8540 degrees Fahrenheit or 4727 degrees Celsius!)

There is a subtle difference between The terms 'degrees Kelvin' and 'Kelvin'. Degrees Kelvin describes the absolute color temperature (i.e., the

[2]A blackbody is a hollow chamber whose color depends on its temperature rather than its composition.

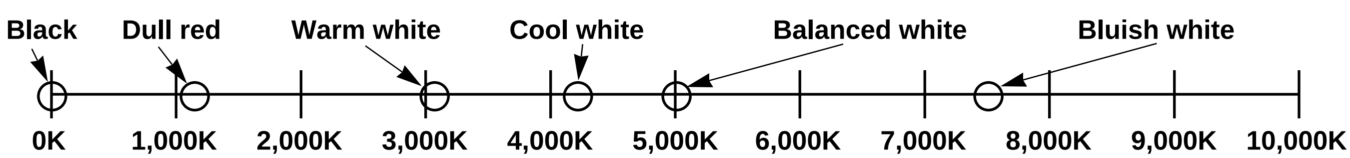

Figure 1 – Color temperature and the corresponding colors.

temperature of the blackbody). Kelvin, by itself, is used to describe the correlated color temperature (i.e., the color of the light produced by the blackbody). So unless you are talking about the temperature of a blackbody, don't use degrees Kelvin. If you are talking about a 5000K light source, it's actually 5000 Kelvins.

D5000

A 5000K light source is often called D5000, where the D stands for daylight because this light source simulates daylight. D5000 in the original ANSI viewing standard was specified for comparing for color quality, so-called color quality appraisal, while D7500 was recommended for comparing press sheets from the same press run so-called color uniformity appraisal. (The bluer light in the D7500 light source made it easier to see inconsistencies in the yellow printer.) Now D5000 is recommended for both color quality appraisal and color uniformity appraisal. Why was D5000 chosen?

- It is color balanced (i.e., it does not emphasize one color over another).
- It simulates white sunlight. (Even natural daylight isn't suitable for viewing originals because it constantly changes based on weather conditions.)
- It provides a single standard for the viewing of images so that people around the world can use the same conditions.
- Using D7500 in the pressroom and D5000 elsewhere inevitably lead to confusion.

You might say, "As long as my client and I use the same light source, why should we worry if it is D5000? In fact, if the final product is going to be viewed under the kind of lighting that exists in an average home, why should we use D5000 at all?"

There is one very good reason to use D5000. What you and your client are doing is making a comparison of an original to a proof, or a proof to a printed piece. As an example, the proof may be made out of toners and mounted on paper while the transparency is made from dyes on film. Because of this difference, an unbalanced light source may accentuate one color in the transparency but not in the proof. If transparency and proof are affected differently by the light source, how can you make a valid comparison? Even if you are comparing sheets from a press run (which obviously are made from the same materials), remember that you are trying to communicate color. A color balanced light source provides the best starting point for seeing and describing color. An unbalanced light source may not allow you to see subtle color differences, particularly in the highlights and shadows.

In the end, if you want to see what the final product looks under a given light source, then do so, but don't use that light source for any of the critical evaluation steps leading up to the final piece. Only a press proof (or more likely, experience) will allow you to make adjustments to improve the look of the final product under that light source.

Light sources

But what do you do if the result doesn't look good under your target light source? Obviously, once it's printed there is nothing you can do, but there are things you can do to anticipate how the final printed piece may be affected by the light source. Here are some generalizations about the two most common light sources:

Fluorescent light sources – These light sources are commonly used in stores and offices. They exhibit a green/yellow cast and will give images a sallow appearance that is deficient in red.

Incandescent light sources - These light sources are commonly used in the home. They emphasize reds, oranges, and yellows, and give images a warm appearance. However, purple, blue, and aqua shades appear washed out.

Many manufacturers offer viewing booths with multiple light sources. Users can see what an original, proof or press sheet looks like under an fluorescent or incandescent light, while still having D5000 for color comparisons.

Observer anomalies

One of the unsettling things about color perception is that if you are a normal observer, and your customer is a 'mildly anomalous observer', then you will never agree on a color match. (Even if you keep the objects the same and the lighting conditions the same.) While you can give color tests to your own employees, it is much more difficult to question the color judgements of your clients.[3] Gary Field makes these comments on identifying visual problems in his book *Color and its Reproduction* (GATF, 1988): "…proof markup behavior can sometimes provide clues. Confusion between light green, orange, turquoise, and pink colors often indicates anomalous color vision."

[3]Color blindness is relatively common, particularly among males. In addition, color vision deteriorates with age.

General tips on viewing color

The following tips have been summarized from an excellent document by GTI (Graphic Technology, Inc.) called the ViewGuide. While some of these items seem like common sense, it is very easy to overlook them.

- Be sure your equipment is in proper working order (i.e., no dirty or worn out light sources, no discolored surfaces, and nothing should be posted on the inside surfaces of a viewing booth but the things to be compared)
- Let your eyes adapt to the viewing conditions. Whether you are coming in from outdoors or perhaps from a dark area, your eyes need time to adjust.
- Allow the equipment to warm up. Since it may take 15 to 20 minutes for the light source to stabilize, it is best to leave them on during working hours.
- View transparencies with a 2 inch border of light.
- View transparencies with an overhead D5000 light source.
- Don't wear bright clothing. Colored light may be reflected onto the items being viewed.
- Check your vision with the Farnsworth-Munsell 100 Hue Test.[4]

[4]The Farnsworth-Munsell 100 Hue test, along with many other books, charts, and educational materials, is available from Macbeth. (For more information, call Macbeth at 1-800-MACBETH.)

On top of this, all surfaces should be painted gray, preferably with Munsell N8/. Stray light should not be allowed to hit viewing areas, and the viewing angle and angle of the light source should be carefully set. (Both the ViewGuide, and the ANSI Viewing Conditions standards provide a wealth of information on this topic. Please refer to the reference section.)

Viewing a soft proof

Comparing two pieces of reflective hard copy is relatively easy because you can control the light that falls on them. Comparing hard and soft copy[5] is more difficult because the viewing requirements are virtually opposite. To view a monitor properly you need dimly lit surroundings. To view hard copy properly it needs to be illuminated by 5000K lighting. How can you control the light falling on the hard copy if the soft copy is projecting light itself? You can always erect some kind of barrier, but you still have the problem of relative intensity of the monitor versus the hard copy.

[5]Hard copy is a transparency, a print, a proof, a press sheet, etc. In short, it's anything that you can walk away with without needing a battery or a plug to continue to see it. Soft copy is something that you would view on a monitor, television, computer screen, or other device. Soft copy disappears once you turn the device off.

Better results can be had by setting the white point of the monitor (i.e., white that the monitor displays), to be as close as possible to the white that you see reflected or transmitted off of the proof or through the transparency by a 5000K light source. Similarly, the dynamic range of the monitor may have to be adjusted to reflect the range of colors that the proof can reproduce.

The importance of the surrounding areas is particularly critical for the soft proof. You must prevent reflections from reaching the screen, and eliminate other illumination that might reach it. This may be accomplished by placing a black curtain behind the operator, as well as painting the areas behind the operator to prevent reflected light. The angle of the monitor is also important because of the chance that light may reflect off of it.

Conclusion

The scientific technicalities of viewing color can be overwhelming. Look for help from some of the sources mentioned in this article or in the following list of references. As of now, no ANSI standard exists for comparing soft and hard copy, but much research work is being done on this topic. The list of measuring equipment is also provided for your reference.

References

Viewing and Defining Color, from the 3M Technical Communications series, contact the 3M Printing and Publishing Systems Division of the 3M Imaging Systems Group, 3M Center Bldg. 223-2N-01, St. Paul, MN 55144-1000

ViewGuide, A Guide to the Evaluation, Implementation and Maintenance of D5000 Standard Color Viewing Conditions. GTI Graphic Technology, Inc. (914-562-7066).

The ANSI viewing conditions standard is PH2.30 and is called *Viewing Conditions - Graphic Arts and Photographic Color Transparencies, Prints and Photomechanical Reproductions*. It is available from ANSI (212-642-4900).

Measuring equipment

There are a wide range of devices that may be used for measuring color and light. This list gives a brief description of many of them:

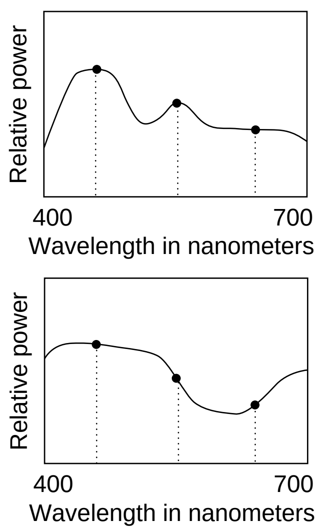

Figure 2 –A spectroradiometer measures the SPD at numerous points. A colorimeter only does so at three points. This is why colorimeters are potentially inaccurate. There are many potential curves that would go through those three points, but only one SPD that accurately represents a light source.

Spectroradiometers – Sophisticated (and expensive) lab instruments which can essentially fingerprint a light source. This fingerprint, the Spectral Power Distribution Curve (SPD),describes the relative proportions of each color of the spectrum that occur in the light source. Numerous measurements (one every two nanometers through the spectrum) allow spectroradiometers to calculate Correlated Color Temperature (CCT), the Color Rendering Index (CRI) and the chromaticity (i.e., CIE XYZ) values of the light source.

Spectrophotometers – Like a spectroradiometer except that it measures reflected rather than emitted light and has its own light source. Spectrophotometers are used for measuring color on swatches of ink, paint, etc.

Colorimetric meters – Can be used to measure the color-balance of a light source via color corrected RGB CIE filters. They can be thrown off by the ‘spikes’ of energy in the color spectra of fluorescent lamps and therefore lack the accuracy of a spectroradiometer. Also known as **Colorimeters**.

Color temperature meters – Measure color temperature via red and blue filters. Relatively accurate for incandescent light sources, but not so for fluorescent ones. (See Figure 2.)

Light meters – (Also known as **photometers**) measure the intensity of a light source or reflection (not the color). However they can be helpful in determining if a light source needs to be replaced.

Elapsed time meters (ETM) – Measure the time that a light source has been illuminated. Another helpful tool for spotting aged light sources.

Densitometers – Densitometers equipped with filters can be used for measuring dot percent on color press sheets.

Because of the complexity of color measuring, the most accurate measurements can only be made under lab conditions by experts.

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