

## **Typical Procedure for Performing a Visual Color Match**

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A color match attempts to determine the degree of difference between two samples. The differences between light sources help to surface this, if they are significantly different in spectral reflectance. On the surface, performing a proper visual color match should be a simple straight-forward procedure. Once the procedure has been established, it should be fairly simple to determine if two colors match. The procedure will be different depending on the industry, the company's requirements and the samples that are to be compared. This should be expected due to the differing requirements of the color match.

There may be problems experienced when performing the visual color match. They could result from the improper choice or use of a light source, the spectral characteristics of the samples being compared or differences between the people evaluating the match, commonly called the observer. The differences between observers can be minimized by maintaining consistent backgrounds to the samples, verification of color perception differences (determination of color blindness) and following consistent procedures. However, if these aspects are minimized one should expect a high degree of confidence in the visual color matching process.

### **The Observer**

To match colors, or evaluate a match, you must have a sample, a light source and an observer. The observer can be an actual person or an instrument. Instrumentation is its own science and will not be discussed in this article. With visual color matching certain aspects and variables need to be made known so that the results of the match can be communicated effectively. Once these are known, the matching process and communication of the match can be much more reliable.

### **Color blindness**

Most people see color in some manner. There are very few people who see absolutely no color and could be considered completely blind to color. Color blindness is a catch-all term for people who have drastic or distinct biases in color perception. The vast majority of "color blind" people are men. This is due to a congenital defect and it runs in families. Even so, unless this condition exists, the ability to judge color differences is more an effect of training than gender.

There are different forms of color perception deficiencies. The most common are given below with their respective deficiency attributes:

Protanomaly (one out of 100 males): The redness seen in a color by a normal observer is seen more weakly by the protanomalous viewer, both in saturation and its brightness. Red, orange, yellow, yellow-green, and green, appear somewhat shifted in hue ("hue" being the "red, green or blue" attribute of color) towards green, and all appear paler than they do to the normal observer. The redness component that a normal observer sees in a violet or lavender color is so weakened for the protanomalous observer that he may fail to detect it, and therefore sees only the blue component. Hence, to him the color that is normally called "violet" may look only like another shade of blue.

Under poor or extreme viewing conditions, it is easily possible for protanomalous individuals to mistake a blinking red traffic light from a blinking yellow or amber one, or to fail to

distinguish a green traffic light from the various "white" lights in store fronts, signs, and street lights. They may rely upon position of the light to determine if they should stop.

Protanopia (one out of 100 males): For the protanope, the brightness of red, orange, and yellow is much reduced. This dimming can be so pronounced that reds may be confused with black or dark gray, and red traffic lights may appear to be extinguished. They may learn to distinguish reds from yellows and from greens primarily on the basis of their apparent brightness or lightness, not on any perceptible hue difference. Violet, lavender, and purple are indistinguishable from various shades of blue because their reddish components are so dimmed as to be invisible, e.g. pink flowers, reflecting both red light and blue light, may appear just blue to the protanope.

Deuteranopia (one out of 100 males): The deuteranope suffers the same problems of hue discrimination as the protanope person, but without the abnormal dimming. Red, orange, yellow, and green really mean very little to him aside from being different names used by others around him. Likewise, violet, lavender, purple, and blue, are too many names to use for hues that all look alike.

Of the several different kinds and degrees of color vision deficiencies, Protanomalous or deuteranomalous individuals can usually pass as a normal observer in everyday activities. They may make occasional errors in color names and encounter difficulties in discriminating small differences in colors.

There are color blindness tests readily available that are easy to administer and take. The two most popular are the Farnsworth-Munsell 100 Hue test and the Ishihara test. There are tests available to determine color vision deficiencies in children as young as three.

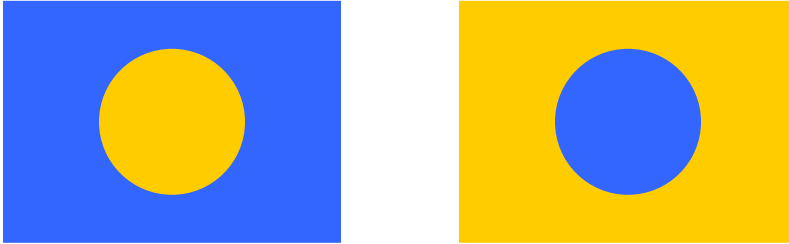
To perform color evaluations effectively requires the individual to have NO deficiencies as they not only need to see the differences, they also need to communicate them to other people (too red/blue/green, etc.). If the individual has any color deficiencies, their evaluations will always be suspect. Color perception deficiencies can easily be tested using either the Ishihara test or better still the Farnsworth-Munsell Test. Feel free to contact us about ordering these.

### **Adjacency effect**

For people with normal color vision, the presentation of the sample, if not done properly or consistently, can create deficiencies in the color match process. Very seldom is a color seen completely by itself. There is always another color or tone within the visual field. If you sit in a darkened movie theatre, the screen is surrounded by the darkened theatre, black. The color surrounding the sample being viewed effects the way we see color.

The first consideration for backing materials is that they do not affect the color of the sample. Light colors should be backed by white, dark colors by dark gray or black. The next consideration is that the background and surround be neutral in hue. White, black or a tone of gray. Light booths generally use a mid-tone gray as the background. Since a viewer could evaluate samples in any range of tones from white to black, the gray becomes a reasonable compromise to accommodate the entire range. It is common for viewers to employ a special backing material to use within the booth if they consistently match tones in the extreme ends of the range.

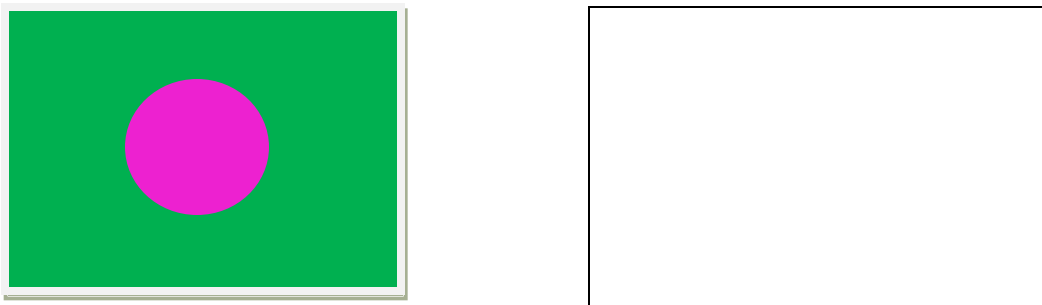
Other colors will effect the color perception of the sample's color. Below is an example of the "adjacency effect." The light color in the center of the blue field appears darker than the light colored field surrounding the blue center of the second sample. In actuality, the light colors are both the same. Adjacency effect makes them appear to be different.



Backing materials should be standardized for the color match process. They should be completely neutral in tone and if multiple colors are on the same sample sheet (as with textile swatch samples), each sample should be surrounded by backing material on all four sides. Finally, only samples of similar color or tone should be on the same backing sheet. Wide swings of hue or tone on the same backing will contribute to inaccurate color evaluations.

### **After Image Effect**

This problem is not as simple to demonstrate, but occurs regularly none the less. When the eye forms an image on the retina, the effect of that image remains for a period of time after the image has been removed. For very dark samples, this "after image" may only be a fraction of a second. If the sample viewed is very bright, the after image may last up to 30 seconds. The motion picture industry would not be possible without this effect, as it allows still images on film to be converted into a moving image on the screen. Below is a Magenta dot inside a White box. Look at the dot for ten seconds and then move your eye quickly to the empty box next to it and stare at the box for a few seconds. You will see an after image, but reversed, in the blank box. This is the effect we are discussing.



The after image effect can also degrade the color matching process. Looking at a color or sample for an extended period of time (a few minutes for very bright or saturated colors) and then looking at another color to make a decision can result in poor color perception.

To avoid this, either look at a neutral color of about the same tone (lightness to darkness) for a few seconds before looking at the new sample or look at the new color and take a few seconds for your color vision to adapt before you judge the color difference. The brighter or more saturated the sample, the greater the need to allow the visual system to adapt before a critical decision is made.

## Light Source Considerations

A light “source” is an actual emitting device. A conventional light bulb is a source, though it might not be a standardized or commonly used source for color matching. A light source is deemed “characterized” when its spectral output has been documented. Most light sources are characterized by the developer or manufacturer. By characterizing the light source, its spectral attributes can be incorporated with a sample and an observer’s spectral characteristics to predict color matches and metameric effects.

Light sources can also be specified. They can be specified by an industry, a company or an individual client. A retail store chain may specify a light source because it is used in their stores. An industry may specify a light source because it is commonly used or its spectral characteristics meet certain needs within the industry. The manufacturer of the light source can be specified along with any other attributes of the source. In reality it only needs to be accepted by the specifier.

A light source can also be “standardized.” There are specific requirements for standardizing a light source and all information must remain open to public review. The spectral characteristics of the source must be documented and reported. The source and the data from the spectral characteristics of the source must also be accepted by a national or international board of standardization. In some instances a “standardized” light source is an accepted compromise from a group of commonly found sources. Additionally, tolerances are established to help ensure the standardized source will remain specific enough without being restrictive to manufacturers. A standardized source can not be brand or company specific, though it could come from a single supplier source. Once standardized and mathematically characterized, this standardized source will be considered an “illuminant.”

Below is a table showing some of the more common standardized sources/illuminants:

Standardized source	Description	Details
Illuminant A	A tungsten source at a color temperature of 2856K	It emits high amounts of red and yellow energy and very little blue. Has virtually no UV.
Illuminant C	Daylight source at 6770K with no UV component	Specified for use by the paper industry.
D65 (Daylight 6500K)	Characterized by having higher blue than red energy. Spectrally complete (has all colors present) with energy down through the UV region of the spectrum.	Used extensively for color matches and the detection of metamerism. It is the source of choice for instrumentation applications (e.g., spectrophotometers).
D75 (Daylight 7500K)	Characterized by having higher blue energy than D65, otherwise similar.	Originally specified by the imaging industries to help viewers detect the yellow ink and for color matches in the USA. Now has been usurped by D65 for general industry use.
D50 (Daylight 5000K)	Equal energy daylight (equal amounts of Red green and blue. Includes UV energy.	Commonly used in the imaging industries where the sample has many colors to match (e.g., a photograph). No color can be accentuated or biased.
F2	Common “Cool White Fluorescent (CWF)”, single phosphor, broad halo fluorescent source at 4100K.	Commonly used source in the USA for general industry and facility lighting applications. Low CRI (below 70).
F4	Warm White Fluorescent source with higher red energy than F2 or F11 (2940K).	Commonly used in general lighting applications where a “warmer” lighting atmosphere is desired without the use of tungsten.
F11	Tri-phosphor fluorescent source at 4100K	Commonly used source in Europe for general lighting applications. CRI insufficient for color evaluation (it is below 85).
F12	Tri-phosphor fluorescent source at 3100K	Commonly used in the USA and elsewhere for general lighting applications. CRI insufficient for critical color evaluations.

## Choosing the light source

For everyday applications of living in the world, light is light. The spectral characteristics of the light source are not generally a concern. When performing color matches, however, the spectral characteristics of the light source used and the light levels of those sources are critical. Light sources can have a high amount of red energy, as with Incandescent or Illuminant A, Blue energy, as with D65 or D75 high Green energy, as with Cool White Fluorescent (CWF) or equal amounts of Red, Green and Blue, as with D50. The source may also have multiple peaks of energy.

### Choice of primary light source

Every color match should start with the primary light source, the source that is most critical. Sometimes the choice is easy. It has been previously specified by an industry or the applications of the products being matched dictate the source to use. Examples of this would be the use of D50 light source for the imaging industry. Industries outside of the imaging industry generally use D65 as the primary source in color matching applications. Retail chains may specify a source used in their stores (the Ultralume 30 lamp for example, used by one of the major retailers in the USA).

Once the primary source is chosen, a standard or reference is compared against a sample. It should be compared against a proper background as outlined previously and a determination of a sample's characteristics (lightness/darkness, hue shift, chroma or saturation) compared to the standard or primary sample should be documented. If the sample has a texture or structural attribute that is different from the reference, this should also be noted. Samples with a coarse weave or which are textured, like corduroy or canvas, should always be oriented in the same direction as the reference. This will be described further in the section discussing geometric metamerism.

### Choice of secondary light source

Additional light sources can be employed after the color match is determined under the primary source. Additional light sources are used if more than one light source is critical to the presentation of the sample and/or to visually detect problems of metamerism (see below). An example of the need for a secondary light source being critical to the sample presentation is clothing manufacturers, where garments are purchased in a store under a light source like Cool White Fluorescent and worn outside in daylight.

To choose the secondary light source that should be used, determine which is the next most critical source, as in the case of the clothing manufacturer. To determine the effects of metamerism, choose a light source that is significantly spectrally different from the primary source. If Incandescent or Illuminant A is used as the primary source, D65 would be a good choice for the secondary source. Incandescent has a great deal of Red energy, and D65 is high in Blue. They are significantly spectrally different.

### Choice of tertiary light source

A third light source is commonly employed if it is critical to the color match, to see additional color match characteristics or to see additional effects not normally seen with the first two light sources. Examples of this would be the Automotive industry where a car or truck will be displayed in a showroom having Cool White Fluorescent (CWF) lights, driven in full daylight and stored in a garage with Incandescent lights. Metameric effects can be further determined through the use of a third light source.

Choose the third light source based on the needs of the color match or to augment the detection of metamerism. For instance, if the primary source is D65 (high blue energy) and the secondary source is Illuminant A (high Red energy), a good choice for the third source would be Cool White Fluorescent as its output peaks in the Green area of the spectrum.

#### Using additional light sources

Additional light sources can be employed to verify the color match under these sources or to see other metameric attributes. The use of an Ultraviolet light source is an example of this. Many garments and plastics employ optical whitening agents to “brighten” colors or make them appear more saturated. A new white shirt will glow under Ultraviolet light because of these whitening agents. These agents absorb light energy in the Ultraviolet region of the spectrum and re-emit them in the visible region. Most of them currently re-emit only in the blue region, though industry is developing agents to re-emit in other areas of the spectrum. To detect the effects of them easily, the use of an Ultraviolet source, along with the use of Primary, Secondary and Tertiary sources is necessary.

#### Light Intensity

For most industries, procedures for the visual evaluation of color have been documented. This includes the standardization or specification of light sources and the light levels required, usually expressed in *lumens* or *footcandles*. These light levels should be strictly adhered to. If a light booth is used, the booth should be manufactured in accordance to industry standards. Two that are very important across industries are the CIE Publication 51 and ASTM 1729-96. To reduce differences substantially using the same type of booth in different locations is advised (same booth size or lighting configuration).

#### Color References

Color references are those samples that will be used to compare other samples against. These can be representative samples from a previous batch or run, or samples specifically made up to represent the norm or preferred color of the production run.

Choosing the reference samples will involve a series of color matches as they are decided upon. They should represent a normal or repeatable process and be reproducible in a production run. Sometimes, the reference sample must be “adjusted”, in that, it is found that the original reference cannot be reproduced in the production run. In such a case the closest match from the run is chosen to become the reference.

Reference samples should be placed on a stable, unchanging backing material. For paints, metal is usually a good backing material because of its stable characteristics. For cloth samples, a card stock that will not degrade the reference over time (perhaps an acid free card stock) would be a preferred choice. Sometimes the backing material is specified for an industry. Such a case would be the use of opacity cards in the ink industry. The backing material, whatever it is, should not show through the sample, thereby affecting the color match process, unless this effect is part of the matching process. The ink industry, because of the transparency characteristics ink can have, routinely creates reference samples over both a white *and* a black backing material to help see the effects of transparency.

If a physical sample is thin or transparent, the backing material will become critical and great care should be made when choosing it. Choose a backing material that will have the *least* effect on the

color of the sample itself. For light colored samples, a white backing would probably be best. For dark samples a gray or black backing might be the best choice. Whatever backing is used, it is most important to make certain it is used *consistently* for the reference *and all samples that will be compared against it*.

Once decided upon, the long-term effectiveness of the reference will be determined by how well it is stored and how it is used. Usage will be covered next under *Performing the Color Match*. Storage of the references samples, if not done properly, will severely degrade the color match process. Samples should be kept dry but at normal humidity levels (20 to 80%RH). They should be stored away from direct light and away from severe heat or cold. Some samples actually change as they are heated or cooled, they are *thermochromic*. Others can change due to exposure to light and are *photochromic*. If exposed to light long enough, most colors will fade so maintaining proper storage conditions will help to minimize these effects.

### **Performing the Color Match**

As with many procedures, if the basics have been taken care of, the actual procedure should be simple. Such is the case with performing a visual color match. First make certain the samples are oriented so that any surface characteristics are the same (see *Geometric Metamerism* below). If the reference is matte and the sample glossy, or visa versa, angle the samples away from you to eliminate the effects of gloss. In this way you minimize or eliminate the *appearance* attributes of the samples. You can have the colors match perfectly, but the samples appear different because of these surface characteristics. This may not be avoidable.

If the samples are dark, more light might be necessary to determine a proper match. Simply hold the sample and reference closer to the light source. Each should be at the same level. Document how far above the base or below the source the samples are held. One of the objectives is repeatability so others can perform the same match at another time or location.

Take the reference sample and place it down first. Next, place the sample to be matched next to, but not on top of, the reference sample. Placing it on top may change the color characteristics of the sample. Determine if the color matches. If it does not, determine why. Is the sample light compared to the reference? Is it bluer, or redder? Use words associated with color, not emotion. Using phrases such as, “it’s less glitzy...” can lead to confusion. Be specific about the color differences. Document what is observed so you can easily communicate it later on.

Take your time on the color match. Rushing the match can lead to rash judgments and wasted time and materials.

### **Problems associated with the color match**

#### **Metamerism**

Metamerism is a very common problem, though most people do not realize this. It occurs when a sample is viewed under one light source and is deemed to match, but when viewed under another source, the colors shift and it is determined they do not match. This happens most frequently when comparing samples from different media types (paints and plastics for instance) but can also occur in media of the same type if different pigments or dyes are used to obtain the color mix. Whatever the

reason, metamerism is a real phenomenon and its absence or presence can significantly effect the determination of a good color match.

Metameric effects are best observed using three light sources. Incandescent for its high Red energy content, D65 for its high Blue energy and CWF for its high Green energy. If the effect can be seen or detected it can be minimized or eliminated. And if it is found, a meeting with your color mixer or dye house is probably in order.

#### Appearance Differences

Although not as severe as Geometric Metamerism, which is discussed below, the surface *appearance* attributes of a sample can affect the color match. Not all samples have the same surface characteristics. Samples can be *glossy*, *matte*, or something in between. Textiles come with velvet surfaces, leathers come in smooth and suede. There are many more than can be listed here. All of these appearance characteristics are separate from the color of the sample. Care must be taken to minimize these appearance attributes when performing the color match, even with samples having the same appearance characteristics. If a glossy reference is viewed with a hard reflection directed to the viewer and a glossy sample is angled to eliminate the reflection, a color mismatch *will* occur.

To eliminate the gloss of the sample, angle it away from the observer (the front side is higher than the back of the sample). Make certain both the reference and sample are viewed at the same angle each time an evaluation is made.

#### Geometric metamerism

This is another problem associated with the color match but it has to do with the orientation of textured samples. An example would be corduroy, which is highly textured. When viewed looking down the length of the texture the sample will appear to be one color and when viewing the sample across the texture, the sample will appear to be another tone. As the sample is rotated, the tones change. If the sample has a grain or knap, like wood or carpet, this will also effect the visual perception of the color.

To avoid this problem simply make certain all samples are oriented in the same direction. Knap, grain and textures should all be observed and documented beforehand and their proper orientations determined. The sample can then be compared more accurately and the effects of the texture can also be taken into account as part of the color match. For instance, it is possible for a textured sample to match in one direction but not match in another.

#### Communication

You may be doing everything correctly, but is the person you are communicating with doing it the same way you are? Are they using the same light sources, methods, etc.? To communicate color differences in a color match effectively, make certain the person or people you communicate with have or use:

1. The same illuminant you are using.
2. A documented procedure on how the samples were viewed including:
  - a. Orientation of the samples
  - b. The distance from the lamps if this can be varied.
  - c. A common background.
3. A documented list of what was seen (the samples was lighter/darker; redder/greener; bluer/yellower, etc.).

## **In conclusion**

Performing a good visual color match is a process which must be documented and performed consistently to be effective. Documenting the process allows others to follow the same process to assure good communication of the effectiveness of the color match and to ensure the color match is successful. Years ago manufacturing and design were done in the same factory, or at least the same city. A person could be on-site for a color match fairly easily. Now it is a global issue with design and specifications taking place in, say, Paris and the manufacturing of the materials being done in a continent away, say India. To be on-sight for color matches on a regular basis would be prohibitive. Good procedures and practices will save countless hours trying to obtain a good match and also save countless amounts of money, from both the efficiencies of the color match process and the avoidance of waste caused by poor color matches.

### Additional references:

- |                    |  |
|--------------------|--|
| ASTM D1729-96      | Standard Practice for Visual Evaluation of Color Differences of Opaque Materials |
| ASTM D2616-94      | Standard Test Method for Evaluation of Visual Color Difference With a Gray Scale |
| ASTM D4086-92a     | Standard Practice for Visual Evaluation of Metamerism                            |
| ASTM E1499-94      | Standard Guide to the Selection, Evaluation and Training of Observers            |
| CIE Publication 51 | A Method For Assessing The Quality of Daylight Simulators For Colorimetry        |

### Resources:

The American Society for Testing And Materials - ASTM - <http://www.astm.org>  
International Commission on Illumination - CIE - <http://www.cie.co.at/>

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