Importance of Illumination Rendering Index in Image Capture and Printing

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Abstract

Traditionally, the color balance of illumination in Degrees Kelvin has been of significant importance due to color sensitivity of film. Today, digital cameras including camera phones have an automatic white balance setting that reduces the importance of illumination color balance over film cameras. However, with the relatively fast pace of change of fluorescent and now light emitting diode (LED) illumination including camera strobes, the quality of light measured by Rendering Index (Ra) may be of more importance than Color Balance (Kelvin). Combining low rendering index values of some artificial light sources with the large color gamuts of inkjet printers versus traditional silver halide printers, increases the effects of color inconsistency and metamerism. While there is no immanent solution, it is important for imaging professionals to be aware this growing concern.

Introduction

Color film was introduced when the incandescent tungsten bulb dominated artificial lighting and photographers need only be concerned with daylight or tungsten light sources. They would select the appropriate film, tungsten or daylight, use a filter over the lens, or use the known miss-match between film and lighting color balance, using artistic license to create a deliberate affect. Because there were only two choices for color balance; tungsten and daylight, the importance of the Rendering Index value and quality of the light source has largely been of no interest to photographers.

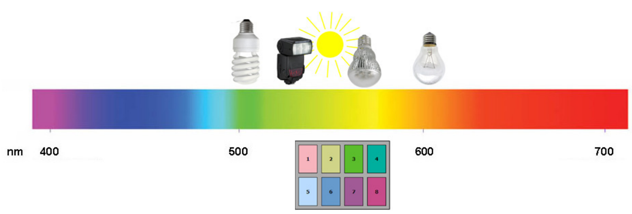

Figure 1

Kodak and Fuji dominated the film market at its peak in the year 2000. Traditionally, research and development goals for film emulsions was to create colors the way they were remembered and not necessarily their actual color. Consumers wanted deep blue skies and bright green grass - even though the skies were Robin's egg blue and the grass was more yellow/brown. Or did they? Then came Fuji's Reala film which changed marketing strategies by producing more accurate colors versus the way earlier marketing professionals and R&D engineers believed they should be rendered. Consumers and Professionals rapidly embraced Reala and its technology was incorporated to Fuji Professional films and finally all consumer films.

Figure 2: Reala's more accurate color rendering technology eventually moved to Fuji's consumer film lineup.

As digital cameras evolved, so did their operating software. Today, it is often difficult to turn off the automatic white balance setting to create the warm lighting appeal that artistic license offers. As illumination technology continues to evolve, there is now a vast array of incandescent, fluorescent and now light emitting diode (LED) illumination sources, all producing a very different quality of color, while producing the same color balance value.

Illumination

In early 1800's gas lighting emerged as an alternative for oil and paraffin light illumination. Approximately sixty years later in the late 1800's the advent of electricity introduced to the world a new lighting revolution, the tungsten light bulb. The world would never be the same after sunset as it once was. Electrical consumption costs for light bulbs continued to increase, sixty years later in the mid 1900's, a new more efficient form of lighting revolutionized office and retail lighting; fluorescence. In recent years fluorescent technology has improved even further in efficiency and lighting quality. In areas of developed countries, the availability of compact fluorescent bulbs has led to a ban on high output incandescence over 60 watts, due to their energy inefficiency. That is, they convert more electricity to heat via infrared wavelengths rather than visible light waves as compared to fluorescence.

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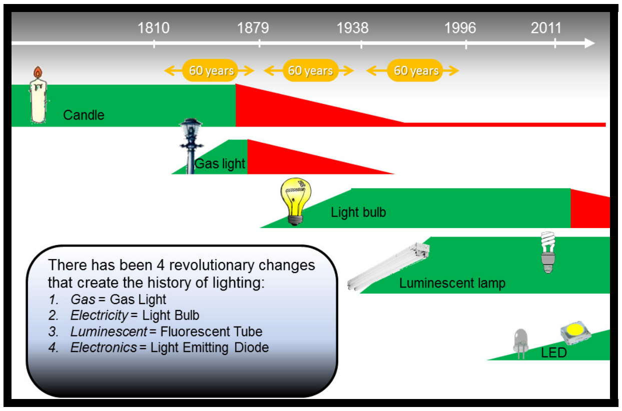


Figure 3: LED lamination is on the eve of a lighting revolution.

Now approximately sixty years later, the world is seeing a quick rise to yet another lighting revolution, the light emitting diode (LED). While on the heels of residential change from incandescent bulbs to compact fluorescent bulbs, LED lighting brings three important improvements; one well known, another of lesser awareness, and a third virtually unknown:

- *Well known* - Energy efficiency measured in Lumens per watt (lm/W) of electricity consumed
- *Lesser awareness* – No hazardous products such as mercury used in fluorescence
- *Virtually unknown* – High quality of light, more even spectral luminance with virtually no ultra violet light and minimal infrared wavelengths

The impact that various light sources have on colors is general not well understood by still image professionals and consumers. In the film era, this knowledge was largely insignificant as a power strobe flash had similar color balance and light qualities of natural daylight and was widely utilized in tungsten and fluorescence lighting conditions. As new light sources emerged along with the digital capture revolution, color inconsistency has increased while its awareness has not. The result in digital image capture has led to a vast color shade differential in digital image display and digital printing. While one shade may be consistent in multiple lighting technologies, another may have a noticeable inconsistence.

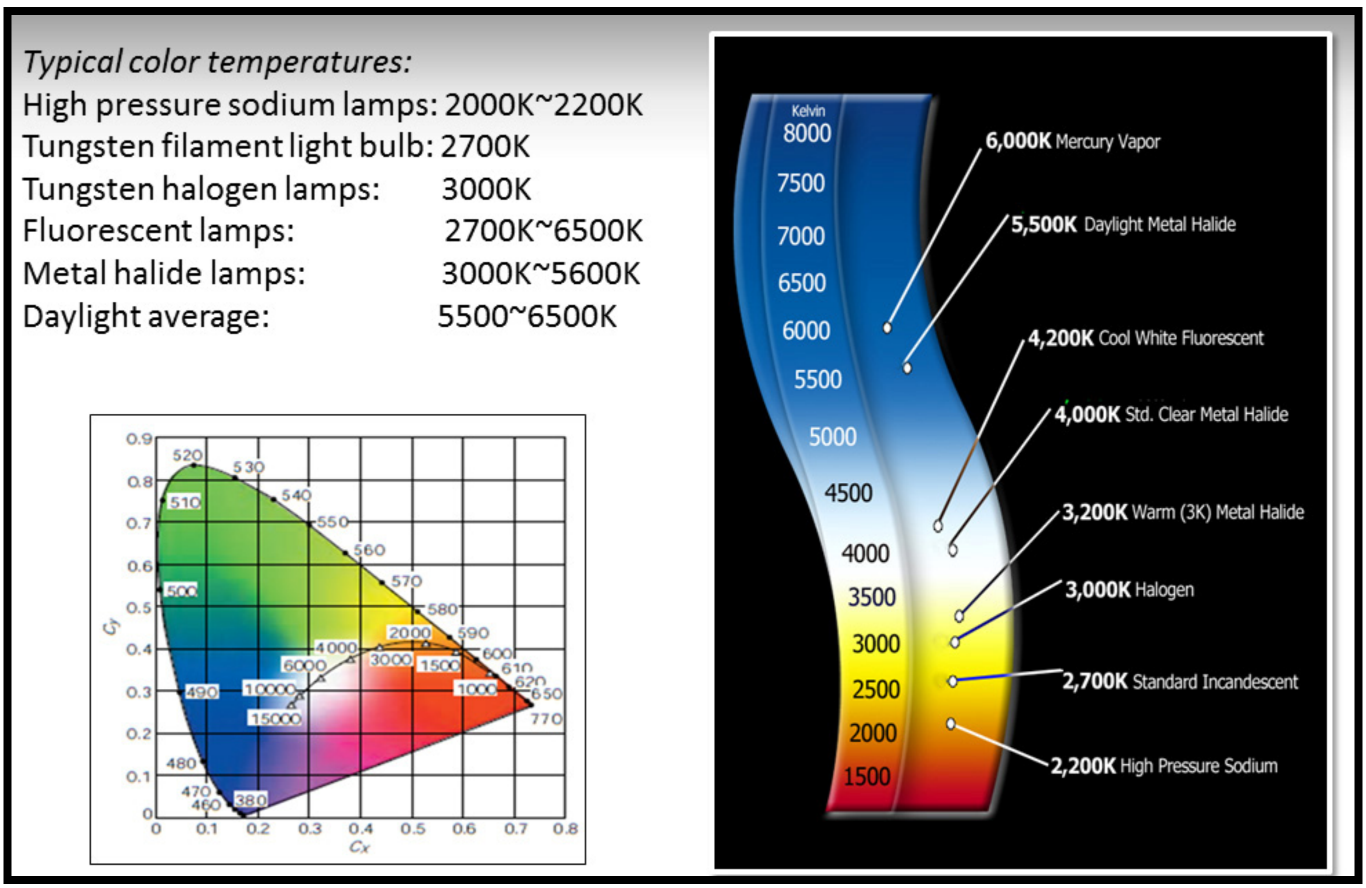


Figure 4

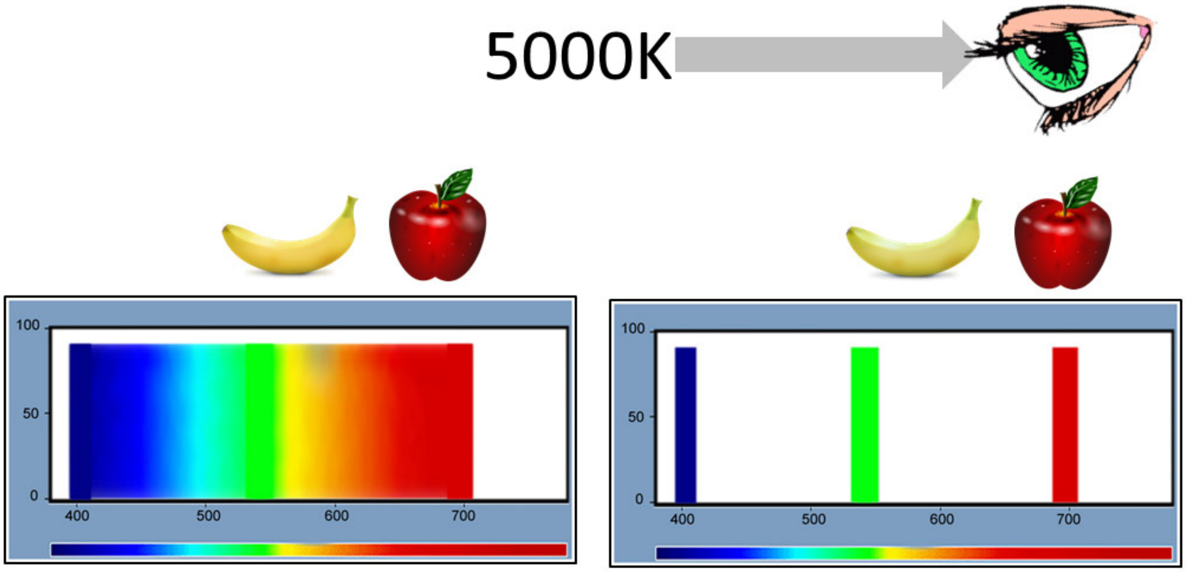


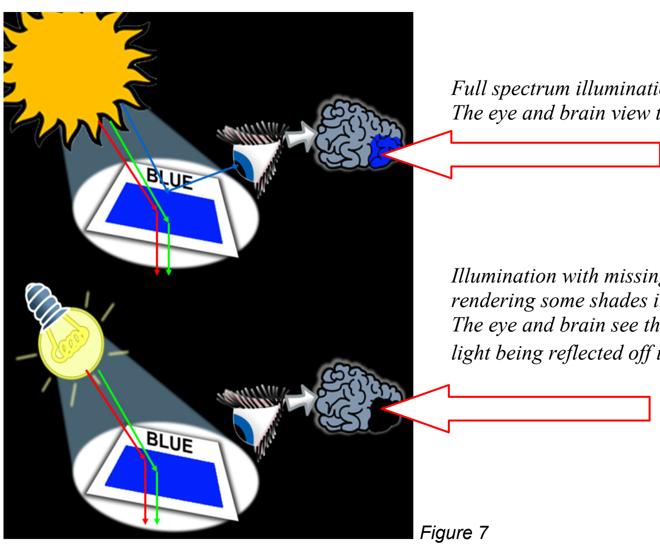
Figure 5: While two different light sources produce white light at 5000 Kelvin, the wavelengths s they emit may vary significantly. The result is a different Rendering Index value and color inconsistency with some shades. The red apple may appear the same shade in both light sources, the yellow shade of a banana may vary.

Digital camera white balance

A wonderful feature of all digital cameras and camera phones is its ability to automatically set a white balance in an instant while capturing, rendering and recording an image file.

Combining auto white balance technology with the low light sensitivity of current CMOS*1 and CCD*2 sensors and a dynamic range that exceeds the latitude of the highest quality color film ever made, an old phenomenon reemerges in greater scope than ever. Color Inconstancy and Metamerism.

Figure 6



Full spectrum illumination by the sun is rendered by the human brain accurately.
The eye and brain view this shade of blue in its correct, natural shade.

Illumination with missing visible wavelengths as compared to the sun, results in the eye and brain rendering some shades incorrectly.
The eye and brain see the same shade of blue as dark blue or even black as there is little or no blue light being reflected off it surface.

Figure 7

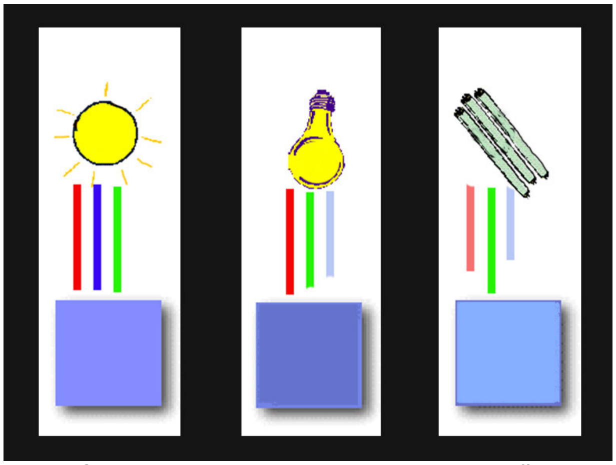


Figure 8 Color Inconstancy occurs when a shade appears a different color when viewed under various light sources that emit different wavelengths.

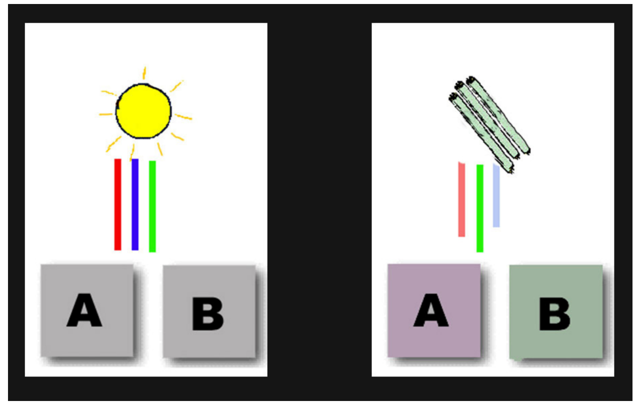


Figure 9 Metamerism is when two shades appear the same in one light source then different in another when each light source emits different wavelengths.

Large color gamuts of DRY printing technologies

The increasing color gamut of DRY printing technologies over traditional silver halide is compounding the effects of color inconsistency and metamerism, While silver halide (AgX) more closely represents sRGB color space, DRY printers produce shades well beyond silver halide approaching Adobe RGB color space. Dry printing technology is a closer match to a digital cameras sensors color gamut which is often reduced to sRGB by camera firmware when the image data is demosaiced and saved in a common file format. RAW often retains a significant portion of the sensors original color gamut.

Awareness of color inconsistency and metamerism due to illumination increased when photofinishers began to make black and white prints on traditional color silver halide (AgX) paper which uses an equal level of cyan, magenta and yellow color dye to create shades of gray. This eventually led to photofinishing labs installing 5000K white light bulbs. Prior to the color silver halide paper method to create a black and white print, shades of gray and black where created by black and white silver halide alone which has is less susceptible to color inconsistency due to various light sources.

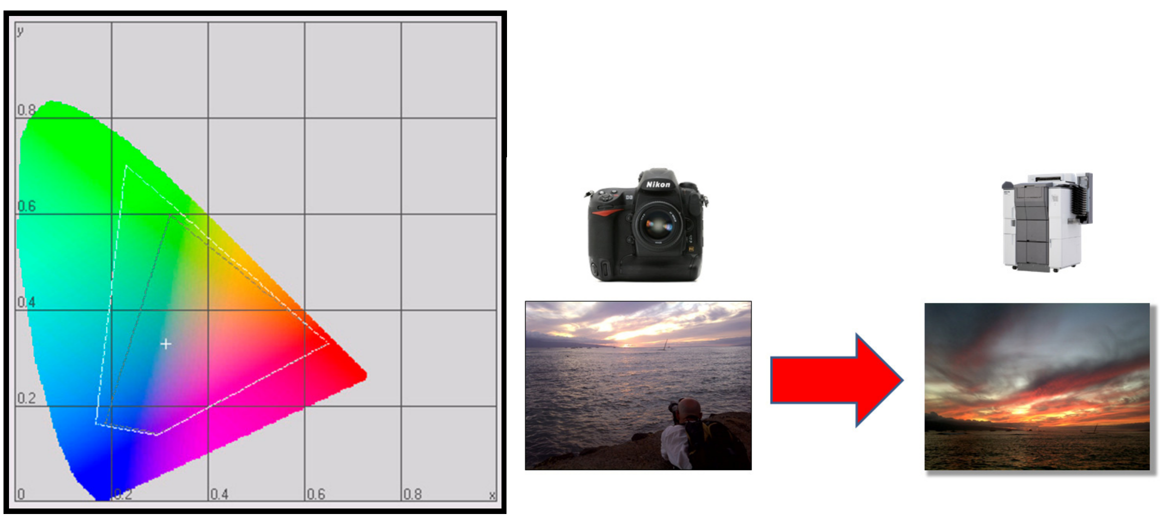


Figure 10 sRGB color space outlined in black as compared to Adobe RGB in white. A digital print capture printed by inkjet can produce impressive results.

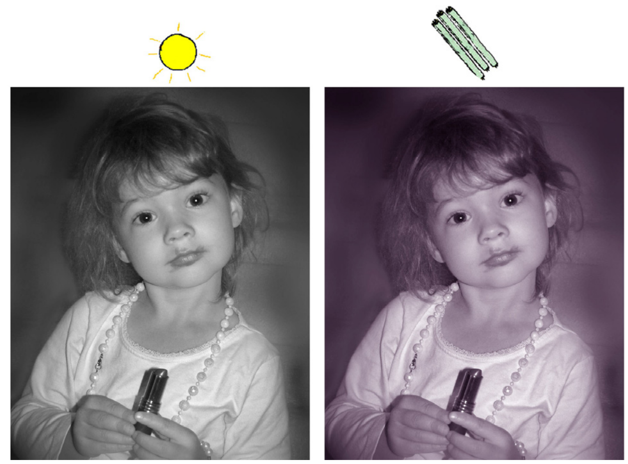


Figure 11
B&W AgX print under daylight *B&W AgX under traditional fluorescent*
Note: this effect is recreated for visual display

Resin Coated(RC) Photographic Print media

Traditional Silver halide (AgX) paper has a resin coated base as its foundation which gives the smooth plastic feel on the backside of the photo . While traditional silver-halide papers have a light sensitive emulsion coating, resin coated inkjet and dye sublimation photo papers have a similar construction except there is an inkjet or dye sublimation emulsion applied respectively, and there may be a back coating applied for curl control. As discussed, inkjet dry-photo prints have a much wider color gamut than the more traditional and dye sublimation. For this topic, inkjet paper will be discussed however both traditional and dye sublimation papers are subject to similar results.

Resin coated inkjet base paper is produced in essentially three major steps: the paper itself is made through a process called pulp bleaching, where kraft (brown) pulp is made bright white and then put through a paper machine to form a paper with a highly calendared smooth surface. The resin (polyethylene) is then extruded on the top and bottom side of this super smooth paper to form the resin coated base paper. Lastly, an ink jet receptive microporous coating (multi-layer)is applied in order to allow for ink absorption with instant dry characteristics.

To achieve a higher brightness or desired shade (generally blue white), optical brighteners (OBAs) and or dye can be added during the paper making process or later in the coating process. These optical brighteners may alter print characteristics under various lighting conditions as well as have certain negative affects in regard to light and ozone fade. The optical brighteners become more noticeable when UV radiation is absorbed and then re-emitted thus becoming fluorescent such as when being viewed under fluorescent and sodium vapor/mercury vapor lighting.

For example, a photo paper that has low optical brightener content may appear rather normal in appearance in various lighting conditions while a paper that has optical brighteners (to add brilliance or to warm the white) may have a yellow cast when viewed under sodium vapor. Sodium vapor lighting has a strong warm color bias, it is widely used in warehouse and large retail stores with high ceilings. Viewing some print types under sodium vapor lighting may affect the colors of the print with the white being most noticeable.

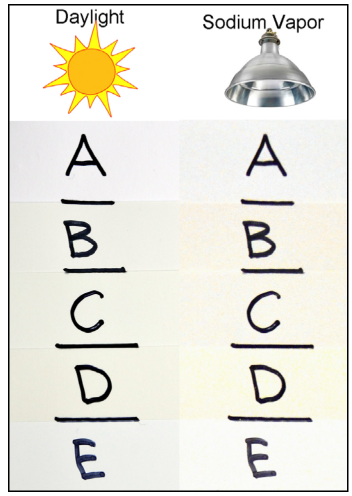


Figure 12: Five different inkjet papers are captured with a Nikon D7000 using auto balance in overcast daylight and sodium vapor lighting. Using sample A as a reference in both captures, color was equalized to R243, G243 and B243 (+/-1) in sRGB color space in PhotoShop.

While sample A has an inkjet emulsion, the white was not artificially adjusted with a coating therefore it looks relatively the same in both daylight and sodium vapor lighting.

Sample B,C & D exhibited a slight warm tone in daylight which was enhanced under sodium vapor.

Sample E exhibited a cool tone in daylight and appeared brighter under sodium vapor.

Note: Actual difference as seen by eye and captured on a Nikon D7000

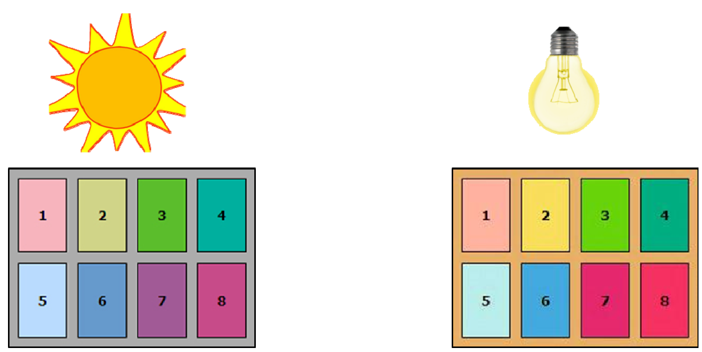


Figure 13: Ra values are confusing unless one understands that an Ra value is a comparison to a standard of the same color temperature. Ra = 100 is the highest value, the lower the index, the poorer the color rendering properties. Using a reference of daylight at 5500K, when the 8 colors of R1~R8 look different viewed under a 2700K bulb, the Ra value could be as low as Ra 50.

When the 8 colors of R1~R8 look the same when viewed under a 2700K bulb and compared to a black body heated to 2700K (color temperature standard,, the light bulb has an Ra value of 100.
The comparison reference is key to understanding Rendering Index values.

Color Rendering Index (CRI)

Color Rendering Index is a measure of how well colors can be perceived using light from a source, relative to light from a reference source. The CRI *Ra* value of a light source indicates the effect its light has on the appearance of persons or colored objects. To determine an Ra value, a minimum of eight color shades are used, often R1~R8 in the chart below:

Ri Value	Shade	R1 ~R8 are used to determine the Ra value
R1		Light grayish red
R2		Dark grayish yellow
R3		Strong yellow green
R4		Moderate yellowish green
R5		Light bluish green
R6		Light blue
R7		Light violet
R8		Light reddish purple
R9		Strong red
R10		Strong yellow
R11		Strong green
R12		Strong blue
R13		Light yellowish pink (human complexion)
R14		Moderate olive green (leaf green)

Figure 14 Fourteen shades of the color rendering index chart

Fluorescent tubes achieve CRI Ra values between 50 to 92. Fluorescent lamps such as compact florescent bulbs have a low CRI value as the phosphors that convert the UV light created by the filament and mercury vapor within the glass housing attempt to produce white light. They emit little red light and skin appears cool and "unhealthy" compared with incandescent lighting. Colored objects appear muted.

Lamp type	Rendering index
Incandescent	52
High Volt Halogen	90
Low Volt Halogen	90
Metal Halide	80~90
High Pressure Sodium Vapor	20~40
Low pressure Sodium Vapor	20~40
Fluorescent	80~89
HF Fluorescent	80~90
Noritsu AdvancedLED	85~94

Figure 15

The color temperature of a lamp is often referred to as the “warmth” or “coldness” of the light that it produces. Lamps that produce a “warm” or “yellowish” light have a low color temperature. For example sodium vapor lamps used for street lighting appear orange. Lamps producing a pure white or bluish tinged light have a higher color temperature. Color balance alone is not an indication of the quality of the light.

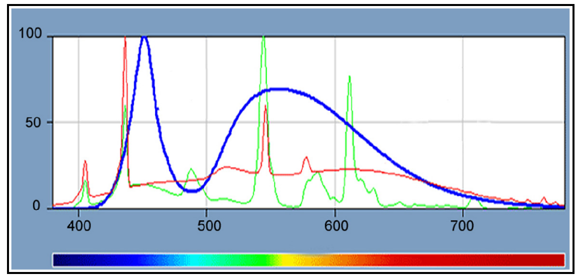


Figure 16 Noritsu 5000K LED lighting Blue provides a more linear level of wavelengths as compared to two manufacturers 5000K fluorescent tubes, Red & Green.

A Noritsu 5000K LED lighting fixture with an Ra value of 92 was installed side-by-side a fixture utilizing Sylvania HE Fluorescent Octron 5000K bulbs with an Ra value of 78. A Nikon D7000 with auto white balance captures the difference in light quality.

The light quality of LED versus fluorescence becomes evident as a more neutral white light appearance is seen with LED while the fluorescent fixture produced a cool-green cast. Increased market change to LED lighting will lead to more accurate image capture and print viewing conditions.

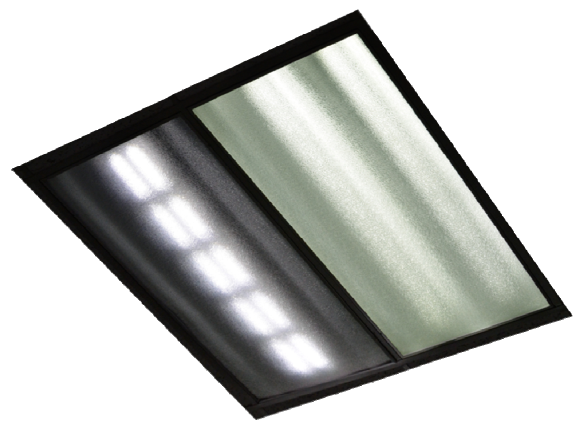


Figure 17 Neutral 5000K LED fixture & Cool 5000K Fluorescent fixture. Note about the image: Results displayed will be at the mercy of this readers display device (monitor) or if printed, printer color properties. Display properties of print will vary as LED does not produce any UV light.

Conclusion

Photographers, photo and lighting retailers, and image printing specialists must become more aware of how artificial lighting impacts image capture and printing color accuracy. Color Balance is no longer the main variable for color accuracy, the quality of the artificial light source as measured in Rendering Index may be of even more importance. Rapidly evolving LED technology and the popularity of LED lighting will reduce the impact of color inconsistency and metamerism.

References

Noritsu Koki Works Ltd.
Shimane Electronics Imafuku-Factory Ltd
Mitsubishi Paper Mills

Notes

*1 CMOS Complementary Metal Oxide Semiconductor
*2 CCD Charged Coupling device

Biography

Ron Kubara has over 37 years of imaging experience. With the emergence of digital imaging in the 1990's, Ron was established as leader producing interactive learning CD's for the photographic industry. Prior to joining Noritsu, Ron was with FujiFilm - starting his career in wholesale photofinishing quality control. Noritsu Koki Works development of traditional LED lighting and UV LED lighting products has expanded Ron's expertise of lighting technology and how it impacts image capturing. Combining his imaging capturing expertise and increasing knowledge in illumination technology, Ron is now a leader in bridging these two technologies for the educational benefit of the imaging industry. His education includes a Technical Diploma as a Photographic Technician. He is a worldwide communication liaison with Noritsu Japan International Sales, Marketing, and R&D divisions.