BY MIKE WOOD

Television Lighting Consistency Index – TLCI

WE'VE TALKED ABOUT color rendering metrics in this column before (Winter and Spring 2010 issues of *Protocol*). Those discussions looked at the venerable Color Rendering Index (CRI) and the newcomer Color Quality Scale (CQS) and the pros and cons of using them. Although these metrics differ from each other, they have one important point in common: They are both metrics for the human eye and tell you nothing at all about how a light source might render colors on other sensors such as those used in video or TV cameras or on film stock.

> "All this makes the TV lighting director or director of photography's job that much harder."

Why won't CRI and CQS do the job?

You might think that a light source with a reasonable CRI or CQS value will render colors well when using a video camera, but that isn't necessarily the case. The response curves of video sensors vary significantly from those of the human eye, and the signals are then processed in a completely different manner. Additionally, the human eye (and the human brain) is very forgiving and continually adjusts to make colors look correct; video and film cameras have no such mechanism and, in fact, are designed to accurately reflect what they see and not to alter colors. **Figure 1** shows the response curves of the cone cells in the human eye while **Figure 2** shows those for the detectors in a camera using a CCD sensor. They are so different that it shouldn't be surprising that they see things differently. *The CCD curves are very similar to those used in standard light and color meters—another reason why such meters sometimes give results that don't match what we see.*

Another problem with trying to use existing color metrics such as CRI for video cameras is that some of the test colors used are outside the color gamut of the camera and are thus invisible. For example, the saturated red used for CRI R9 is outside the gamut of a television camera and thus is not a reasonable color to use to check camera color rendering.

Television Lighting Consistency Index

The Television Lighting Consistency Index (TLCI) seeks to address these problems and provide a color rendering metric

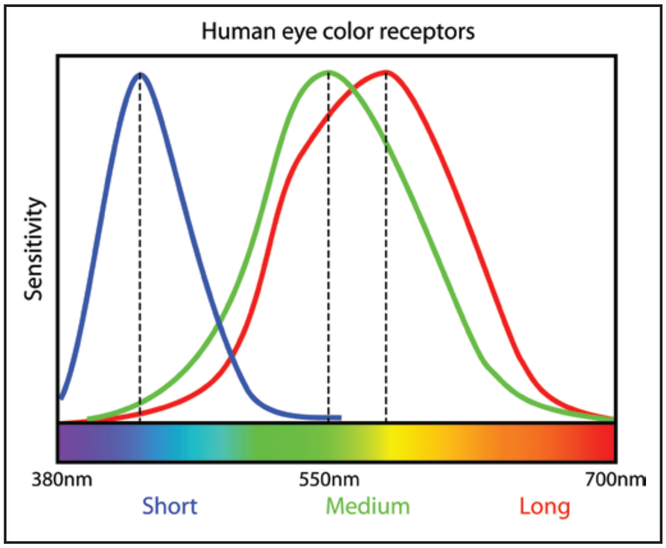

Figure 1 – Human eye color response curves

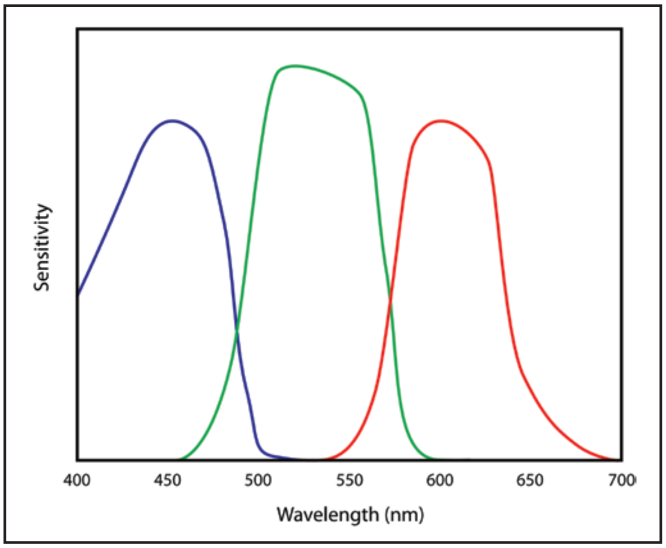

Figure 2 – CCD Camera response curves

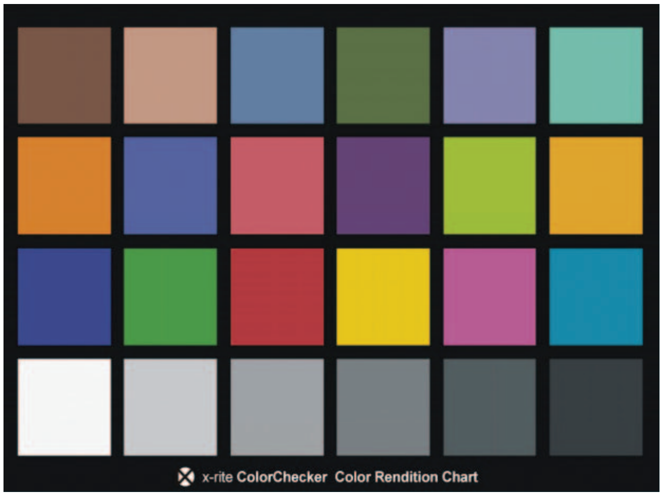

Figure 3 – ColorChecker test chart

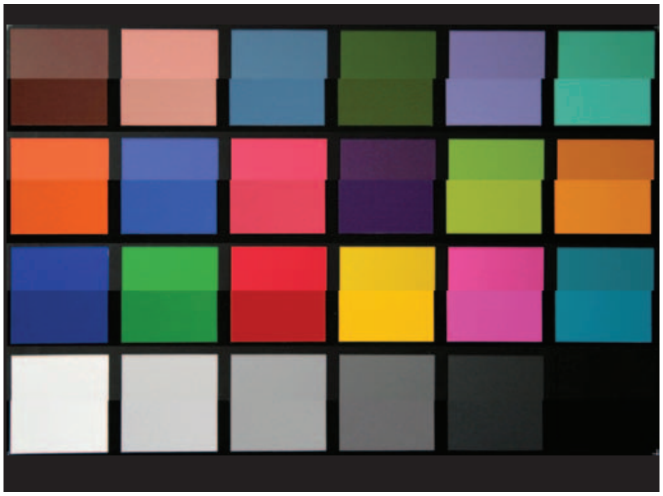

Figure 4 – Daylight (top) versus white LED (bottom)

for television and video cameras that is analogous to the CRI and CQS with human vision. The work on TLCI was started way back in the early 1970s at the BBC in the UK. However, the light sources in common use then, apart from the odd fluorescent, were mostly broad-band emitters, meaning that the need for it wasn't urgent and the research lapsed. Recently, the introduction of solid state lighting and, in particular, LED light sources has spurred it back into life. The rapid adoption of LED sources, many of which aren't that good at rendering colors, means that such a metric is needed now more than it has ever been! Alan Roberts, who is also an ex-BBC research engineer, has picked up the mantle and, after a huge amount of work, has developed TLCI to the point where it has been released as a European Broadcasting Union (EBU) recommendation. It is likely to become an SMPTE standard that, I believe, will then be adopted worldwide.

TLCI uses a methodology that is similar to that of CRI and CQS in that it uses a standard set of color test samples and compares their appearance in the test light source with that from a perfect black-body light source or daylight, depending on the color temperature. The choice of colors to use was a simple one; the television industry already widely uses the X-Rite ColorChecker chart shown in **Figure 3** as the standard for camera line-up (previously known as the Macbeth Color Test Chart).

As well as being very familiar to everyone in the video world, this chart also contains all we need in the first three rows of patches (the grey scale in the bottom row is irrelevant to color rendition). The first row contains natural colors such as light and dark skin tones, foliage, and sky, while the second and third rows contain more saturated colors that cover the entire gamut. There is one oddity with this chart, given its current use: the cyan patch at the end of the third row is actually just outside the gamut for television when illuminated at daylight color temperatures. This is because the chart was originally designed for photographic use, and color film stock typically has a wider color gamut. However, this errant cyan doesn't preclude the chart from this task.

Just to give an idea of the color rendering problem we are talking about, **Figure 4** shows a split chart where the top half of each patch is illuminated with natural daylight and the bottom half with a white LED of the same color temperature. The grey scale in the bottom row looks fine, but you can see enormous differences in other colors. In particular the first patch, dark skin tone, is completely different and renders much darker than it should.

Just like its CRI and CQS counterparts, a TLCI evaluation doesn't use a real test chart and camera; instead, the colors on the chart have been mathematically modeled and the entire test can be run in software from the captured spectrum of the test light source. The software also contains a model of a standard camera response created from averaging many commercial cameras. **Figure 5** shows a block diagram of the process with everything inside the colored box being modeled in software.

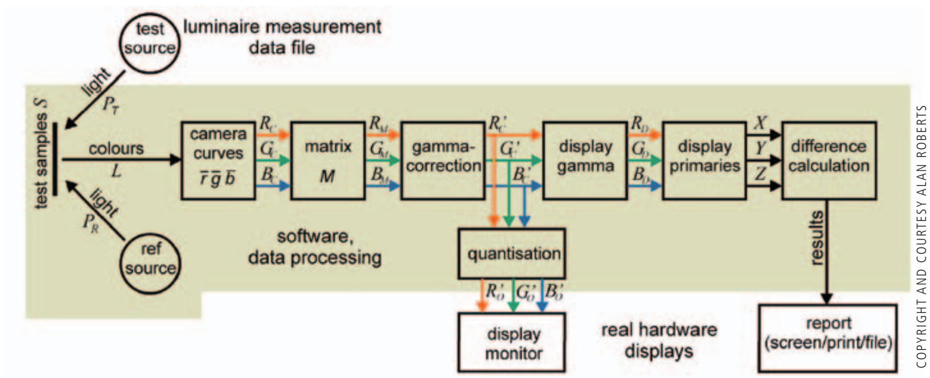

Figure 5 – TLCI process

The first step in the process is calculating the CCT (Correlated Color Temperature) of the test light source spectrum, once this is done a reference light source of the same CCT is generated. The algorithm uses a true Planckian black-body for CCT less than 3,400 K, a daylight source for CCT above 5,000 K, and a mixed illuminant interpolated between the two for CCT between 3,400 K and 5,000 K. This use of different test sources matches the real world use of lighting products where daylight and tungsten (3,200 K) are the most common CCTs used for shooting video.

The primary result from this process is a single number, ranging from 0 – 100, representing the TLCI of the test light source. As with CRI and CQS, in general the higher the number the better, with a perfectly rendering light source having a TLCI of 100. In practice, the scale is such that any light source with a TLCI of 85 or greater will likely be usable with a video camera with little or no adjustment to the camera. As we go down the scale, it is likely that sources with TLCI between 50 and 85 will still be usable but will need correction in the video chain setup to get acceptable results. Finally, a source with TLCI below 50 may not be usable at all, even with significant correction, particularly when used on sensitive colors such as skin tones.

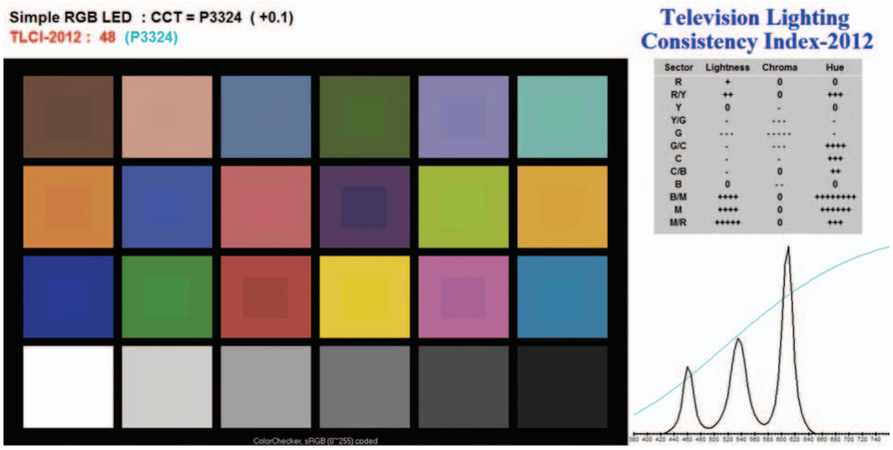

Figure 6 – TLCI report for RGB LED

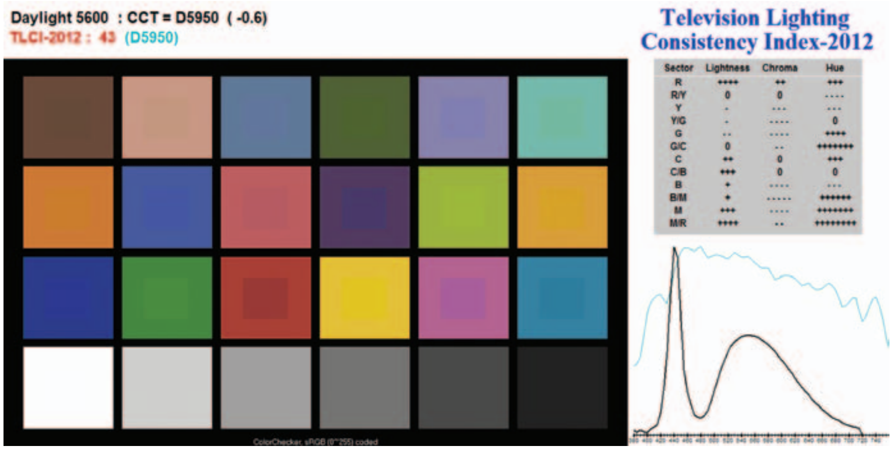

Figure 7 – TLCI report for phosphor white 5,600 K LED

Single number metrics

This is where CRI and CQS stop, with a single number. Single number metrics have a significant drawback in that the number tells you the size of the color rendering error, but it doesn't tell you where that error is. For example, if two lights each have the same CQS of 80, it doesn't mean they will look the same. One light might be deficient in the red while the other is deficient in the blue. They both get the same CQS value but will render colors very differently. TLCI takes this a step further in its reporting and, as well as the single TLCI metric, also provides information on where the light source is lacking and what correction might be needed to make it useful. **Figure 6** shows an example of the full TLCI test report for an RGB LED luminaire adjusted to produce a nominal 3,200 K white.

There's a lot of useful information here. In the top left of the chart, you get the calculated CCT of the light source, in this case 3,324 K, and the distance it is from the black body line (here +0.1) scaled such that anything less than one is acceptable, as well as the actual TLCI value itself. In this case, with a TLCI value of 48, this would not be a great light source for video or television if it were used to illuminate performers or color-critical costumes. Perhaps it would be okay for scenery. Below those figures is a representation of the ColorChecker chart showing each patch with an outer band as illuminated by the perfect reference light source and an inner square as illuminated by the test source. In this case, you can see that a number of color patches show significant errors. At bottom right, we can see the spectra of the reference light source, in cyan, and the test light source, in black. The three peaks of the RGB luminaire are clearly visible in this example. Finally—and very usefully for the user—the table in the top right of the chart shows the estimated correction that would have to be applied to the video chain to bring the pictures into broadcasting specification. In the example shown in **Figure 6**, it would take a very large amount of both hue and lightness correction around the magenta/blue and magenta/red area to bring the colors back into line.

Figure 7 shows the same report for a simple 5,600 K white LED. In this case, the LED is phosphor converted with a blue pump and a yellow phosphor which

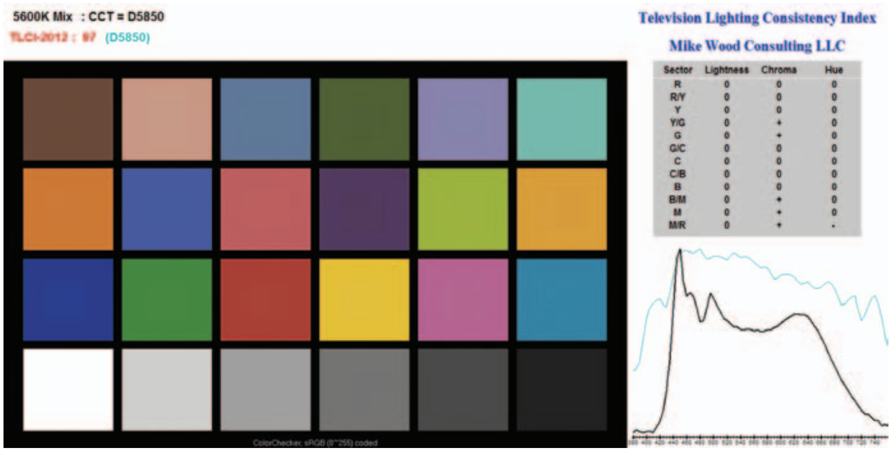

Figure 8 – TLCI report for LED mix 5,600 K

combine to give the illusion of white to our eye. The spectral plot shows that there is a lot of missing energy in the cyan area and that it tails off in the deep blue and deep red compared to the daylight spectrum shown behind. With a TLCI of only 43, this is a marginal luminaire for television use, with extreme correction needed in many areas of the spectrum. Note again that the grey scale looks just fine.

Finally, one more example just to prove that LEDs can do a good job with TLCI: **Figure 8** shows a mix of multiple colors of LEDs, including phosphor whites, which has been optimized for TLCI. This time we have a TLCI of 97, and almost no camera correction would be needed.

I've tested many current LED products for TLCI, and everything from 40 to the high 90s is both possible and available on the market. It's very hard to predict which products will have good TLCI and which poor. By its very nature, in that it uses the response of a camera rather than the human eye, there is no connection with what you or I see when we look at the light. It is very possible, and not uncommon in my experience, to have a luminaire that has good CRI or CQS but poor TLCI or vice versa. The only luminaire that is guaranteed to perform well with both metrics is one with close to a black body or true daylight spectrum. Anything with a discontinuous spectrum, missing wavelengths of light, will inevitably look different to the eye and the camera.

Figure 9 shows the results of some of Alan Roberts' tests. He measured 73 luminaires for both CRI and TLCI and then plotted the CRI and TLCI values against one another. If there were any kind of correlation, then we'd expect to see a straight line joining these points together. However, instead we see almost no correlation at all. For example, look in the pink band which shows luminaires with a CRI value of approximately 80. We can see that includes 14 luminaires, all with roughly the same CRI, whereas those same luminaires had TLCI values ranging from 45 – 95. This emphasizes the most critical point I'm trying to make here: CRI and CQS, or any other metric designed for the human eye, are no help at all when it comes to choosing luminaires for television or video. Similarly, TLCI tells you nothing about how a light will look to the eye.

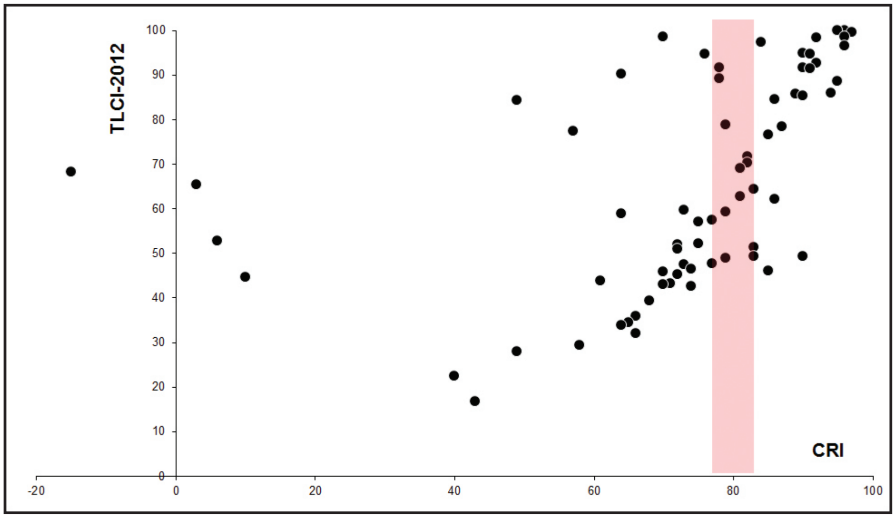

Figure 9 – TLCI report for LED mix 5,600 K

Television luminaire matching factor

All this makes the TV lighting director or director of photography's job that much harder. Those folks have always known that you cannot use your eye to judge lighting, and instead have to look through the monitor and thus through the eye of the camera. The use of LED sources with highly discontinuous spectra just makes that rule even more important.

> **"You'd drive yourself insane trying to line up the camera to make good pictures with this combination."**

TLCI has one more trick up its sleeve that should help with matching between lights. As I mentioned earlier, a single metric doesn't help with understanding how two lights compare with each other. If we have two LED light sources that both have a TLCI of 75, then we can be confident that we can make either of them work well for a video camera. However, what if we want to use both of them at the same time? What do we know about how one would look if the

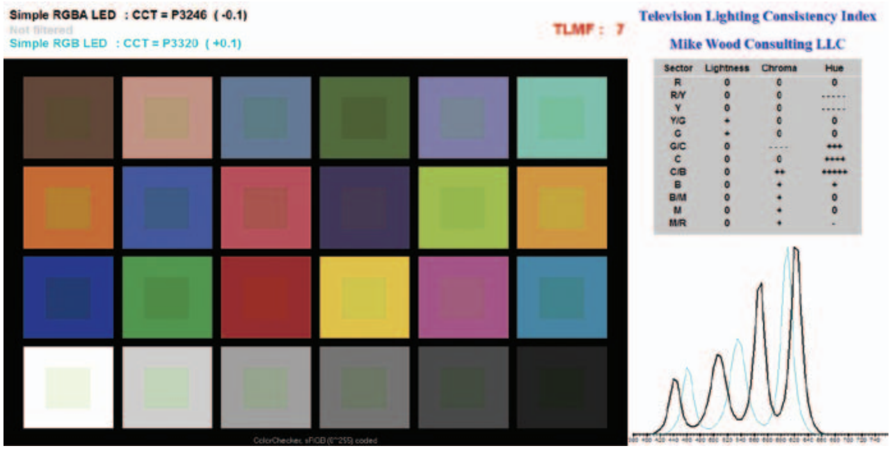

Figure 10 – TLMF report for RGB versus RGBA LED mixes both at 3,200 K

camera is adjusted for the other? Will they need the same correction or, perhaps, the opposite? There is a new companion metric to TLCI, the Television Luminaire Matching Factor or TLMF. The TLMF allows you to compare two different lights to each other, rather than to a perfect reference, and see if they will play well together. It also allows you to add a gel in front of them, in the virtual software world of course, and then see how that alters the match. If the TLCI is a tool for manufacturers to use in designing a product for television use, then TLMF is a tool for practitioners that allows the prediction of real world mixing and matching of different sources before getting in the studio, when it is often too late to change. I'll just show a single example of this, as I'm running out of space; **Figure 10** shows the TLMF comparing an RGB LED mixed to a 3,300 K white with an RGBA LED also mixed to approximately 3,300 K white. The RGBA on its own has a quite respectable TLCI of 67, while the RGB is 48. Either of them is usable on their own, but, as is clear from the color checker chart, it would be a mess if an attempt was made to use them both at the same time! The TLMF between them is only seven, which means they are an appalling match for each other. You'd drive yourself insane trying to line up the camera to make good pictures with this combination.

TLCI and TLMF are brand new metrics and in the early days of their adoption. However, there is no doubt that they are needed, and I expect all manufacturers will have to make TLCI values available for their products. What isn't clear to me yet is how useful the color correction values are going to be in practice, as I suspect that it's only the single metric that will get published.

Next issue, I want to take an overview look at all the options in color rendering and try to pull all the strands together. ■

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