Is there a Right White for Museum and Gallery Lighting?

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For the last two decades, the choice of light source for gallery lighting seemed straightforward. Specifying spotlights for a conservation gallery, I almost always used low voltage tungsten halogen.

The choice was obvious, the lamps had high colour rendering, small amounts of UV could be filtered, and relatively long life compared to mains voltage tungsten.

Colour temperature seemed simple too. The colour temperature of the lighting was usually just the colour temperature of tungsten halogen. So, around 3-3500K for undimmed lamps down to a sludgy brown 2,000K if it was dimmed too much.

In some isolated cases, the colour temperature of gallery lighting deviated from warm white. At The National Gallery in London in the early 1990's, a custom dichroic coating on standard spotlight lenses was used to create a 4,000K source from Erco tungsten halogen luminaires. This was done to better match the filtered daylight in some galleries.

Now the go-to technology in gallery lighting is LED and suddenly the goal posts seem to have shifted.

Colour quality

Colour temperature is now a positive choice. In most sources it is fixed, 2,700 up to 6,500K. But we can also specify white LED with tuneable colour temperature. Whichever option we choose, we need to decide what is right for our gallery. Previous experiments (Innes, 2011)[1] suggest that, at conservation light levels, even 150K difference between similar sources will affect the perception of brightness. (see figure 1)

Our long cherished metrics of colour rendering do not always represent our experience with white SSL. The quantification of colour quality has had to be rewritten to better deal with the spectral complexity of SSL. There is still much debate about the perfect combination of Colour Quality Scale, Gamut Area Index, extended 9 or 15 sample CIE Colour Rendering Index (R9, R15) and a plethora of other old and new metrics [2 3 4 5]

This amount of research activity around colour metrics suggests that there is still some way to go to find the perfect colour metric that will capture our visual response to white light. However, improved colour metrics may not be enough.

Quantifying light

Conservation advice from museums all over the world recommends minimising the damage from visible light by setting maximum illuminance levels for different exhibits depending on their likelihood to fade or degrade when exposed to light. However, Illuminance meters are not recording the total light energy (flux) reaching the artwork. Instead, the meter is reporting lumens, a metric based on the relative spectral sensitivity of a standardised human visual system in photopic conditions (many conservation galleries are far from photopic environments). The lumen is not an objective measurement, but what Kit Cuttle has called a "psychophysical measurement".[6]

Incandescent was the predominant light source used in gallery lighting in the 1950's and 60's, when these illumination recommendations began to be widely accepted (see Thomson (1957)[7] and (1963)[8]). Therefore, the 50 lux standard should really be qualified as being "50 lux of incandescent illumination". 50 lux of any other light sources can have a completely different potential damage profile.

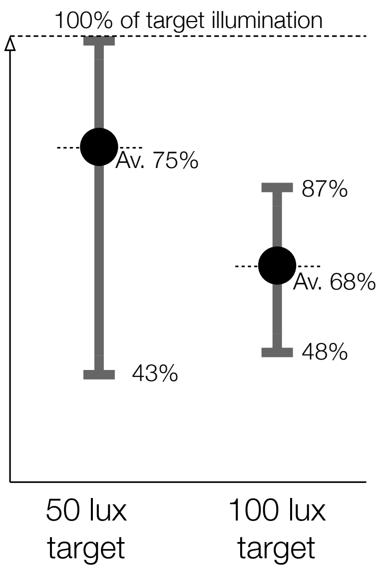

Figure 1. When asked to brightness match a cooler TH source against a 150 Kelvin warmer TH target, 20 test participants consistently saw a lower illuminance from the cool source as being equivalent in brightness to the target. At lower illuminance, there was a larger spread of results, but the cool source generally needed to be closer to the target illuminance to be seen as an equivalent brightness.

Shorter wavelengths of light carry more energy and are proportionally more damaging for most materials. Unfortunately, the illuminance meter provides none of this information as its peak sensitivity matches the CIE standard observer and it is relatively insensitive to the high energy shorter wavelengths.

Light meter errors (small inaccuracies tracking the CIE curve) can make significant variations in the recorded illuminance levels. At conservation lighting levels, we are always working on the edge of acceptable visibility, a very small reduction in illuminance due to inaccurate meter readings can be significant. Test by Pro-Lite Technology (2009) [9] looking at single colour LEDs demonstrated that even expensive illuminance meters can be problematic. Two illuminance meters under recorded the photometric flux of 460nm peak blue LEDs by 25-30%. For a 660nm red LED, one meter under recorded by 30%, the other over-recorded by 75%. Whilst the margin for error in the central part of the spectrum is much lower, white SSL sources often have peaks at the blue end of the spectrum.

Thinking outside the box

Kit Cuttle used a lighting workshop in 2007 for the American Institute for Conservation to demonstrate an alternative approach to conservation lighting.[10] Cuttle created experimental illumination that blended the light from four LED sources; red, green and blue LEDs close to the tristimulus peaks of the human visual system were combined with an amber LED to improve colour rendering. With this system, Cuttle was able to produce chromacities matching incandescent sources but, due to the non-continuous spectrum, there was 44% less damage potential. The conservation experts who viewed the test showed no preference between low voltage tungsten halogen and the RAGB LED source. It seemed that a discontinuous white could be visually acceptable, even to museum professionals.

Cuttle's LED system was designed to match black body sources. Like other lighting designers, I seem to be pre-programmed to expect the best white to be on the black body locus. Now we have many high quality white LED sources that also appear on the BBL, the only decision should be which colour temperature to select?

A recent experimental trial by Colette Knight for Xicato [11] explored the white light preferences in a retail environment of 40 professional lighting designers and 20 shoppers. Looking at 6 different white LED modules with nominal CCT of 3,000K and CRI between 83 and 98, more than 80% of the participants selected sources that sat below the black body locus (BBL). Test subjects were consciously looking at a retail situation, and were asked to select a white which "would grab your attention most". It does not seem that this would translate well into the gallery environment where we expect to be maximising colour fidelity.

However, tests carried out in the Manchester Art Gallery (UK) by Kevan Shaw Lighting Design in July 2013 found that, even amongst an audience of museum professionals and lighting designers, the Xicato Vibrant module (with white point below the BBL) was preferred by some participants.

These results are perhaps less surprising when taken alongside Rea and Freyssinier (2012, 2012, 2013) work on finding a perceived 'neutral white'.[12] [13] [14]They discovered that, at most colour temperatures, the point at which participants see the light as being un-tinted, did not sit on the BBL. Joining these points at different colour temperatures produced what they have called, "the white body line". The line is above the BBL for CCTs above 4000K and crosses below the BBL for lower CCTs. (See figure 2)

In a natural extension of Cuttle's work, researchers in Vilnius have created a 'Tetrachromic' luminaire that can be dynamically adjusted to saturate or dull colours of illuminated objects. In tests that included fruit and paintings, the average preference of the 250 test subjects was for slightly increased saturation, rather than hi-fidelity neutral white light. [15]

Galleries and SSL

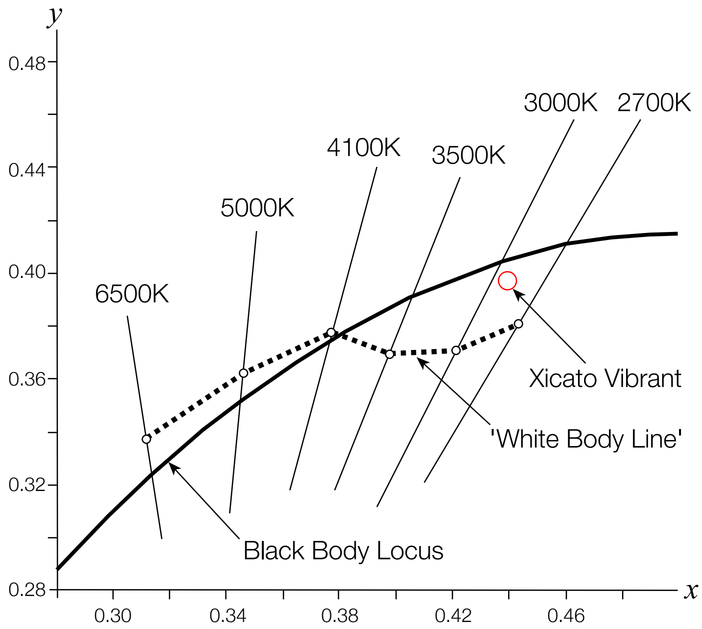

Figure 2. Rea and Freyssinier's 'White Body Line' is a line joining the points where white light of various colour temperatures is seen by test subjects to be 'un-tinted'. It does not follow the black body locus, the traditional gold standard for white SSL sources.

(illustration modified from Rea & Freyssinier, 2013)

SSL is a new landscape for museum and galleries. To navigate this new world, we need to create new maps. Our existing colour metrics and measurements have been proven wanting and we cannot think of SSL as simply a replacement for tungsten, it requires a whole different approach. We are not unique in finding the SSL world a very unfamiliar place, cinematographers have great difficulty in finding SSL sources that behave correctly on film [16]. In response, they have created a Studio Tungsten Simulation Index (STSI) with which to measure the similarity of LED to a 3,200K studio tungsten source when recorded on film. It seems that all realms of lighting need new metrics to deal with SSL.

Is there such a thing as a right white for gallery lighting? Well, that may depend on factors such as ambient tonal and colour qualities of the display surfaces, the illumination level, the spectral composition of the artwork itself and on our personal preference for vibrant or muted colours. There may be a perfect white for me, but it could be different for each artwork in each gallery and it may even be different tomorrow.

Is the right white the light source that renders the colours of the artwork best? If so, how do we quantify that? It is clear that colour metrics have a difficult time capturing our visual response to light? Is the right white the source that produces the minimum damage to the artwork whilst still allowing us some visual acuity? If so, museum professionals should probably abandon the historic psychophysical standards like 50 lux (of incandescent illumination), and adopt new damage based metrics that can allow creative lighting designers to improve visual acuity at low light levels.

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