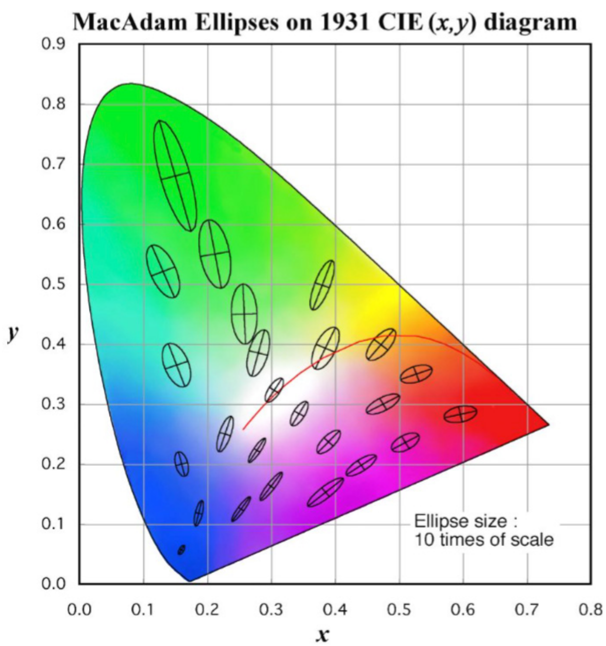
The Four Shades of White Light

Introduction

Most of us involved in lighting have experienced first hand how incredibly effective the human visual system is at spotting color differences. While we can easily adapt to color differences over time (think for example about the different tints of daylight), contrasting colors presented side by side tend to attract our attention.

Even though it is easy to spot color differences, it is not that straightforward to describe them. But we can effectively describe color differences in white light by breaking it down into four shades. Knowing and applying the thresholds for visible color differences for accent lighting, we can realize spaces of a higher quality, something that will be noticed both consciously and sub-consciously.



CIE 1931 xy color space

The First Two Shades: Yellow and Blue

The concept that white light can appear “cooler” or “warmer” is intuitive to most. Cooler light appears bluer and warmer light appears more yellow or orange. Correlated Color Temperature (CCT) describes the color of white light emitted by a black body that is heated to very high temperature (thousands of Kelvins). Ironically, a hotter body will appear “cooler” (bluer), while a cooler body will appear “warmer” (yellow, orange, or red).

- Yellow = warm white = low CCT.
- Blue = cool white = high CCT.

The Third & Fourth Shades: Pink and Green

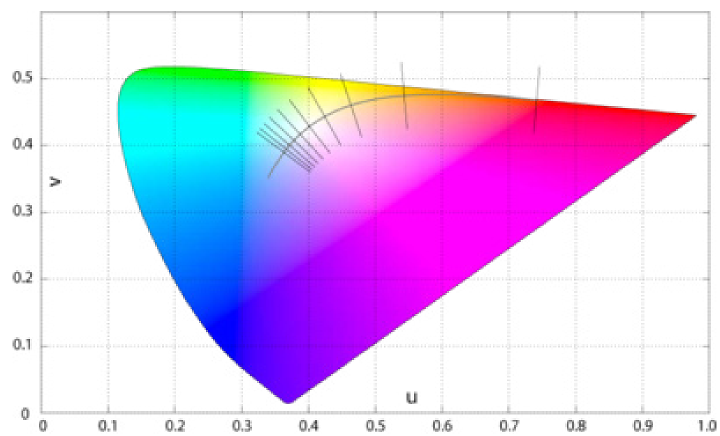
With the advent of gas discharge lamps it became clear that there can be other tint differences in white light than can be described by the blue vs. yellow of CCT. For example, fluorescent tubes from one manufacturer may appear pinkish, while tubes from another manufacturer may appear greenish, even though they are labeled with the same CCT. The problem lies in how CCT is defined in various color spaces. While a given CCT allows for no blue - yellow variation, it does not limit pink-green variation.

So, if CCT is the measure for blue - yellow, what should be the metric for green - pink?

Different color spaces provide options.

CIE1960 is very suitable because points of the same CCT lie on a line that is perpendicular to the BBL. The two axes in CIE1960 are referred to as u and v respectively, and distance from the BBL as Duv.

- Green = positive Duv.
- Pink = negative Duv.

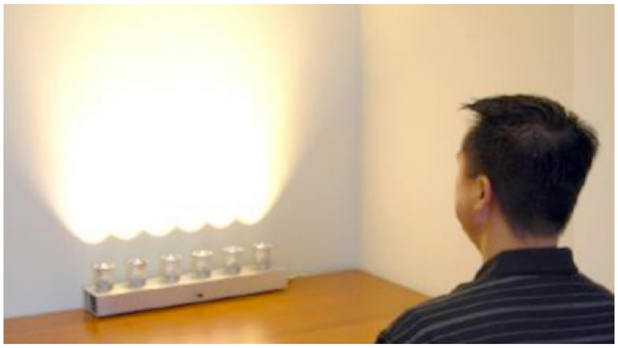


CIE 1960 uv color space

What is Good Enough?

This mostly depends on your application and the amount of spatial contrast. Accent lighting aims to achieve to high spatial contrast and is therefore one of the most critical applications for avoiding color differences. Because of their high brightness, small size and emission in one direction, LEDs are particularly suitable for accent lighting. But as is clear in many places around us, LED lighting presents a major color uniformity challenge.

When Xicato was founded, one of its key objectives was to solve the color non-uniformity problem with LEDs for accent lighting. Xicato conducted application research to determine the minimum visual threshold for observing color differences on both the green-pink and blue-yellow dimensions.

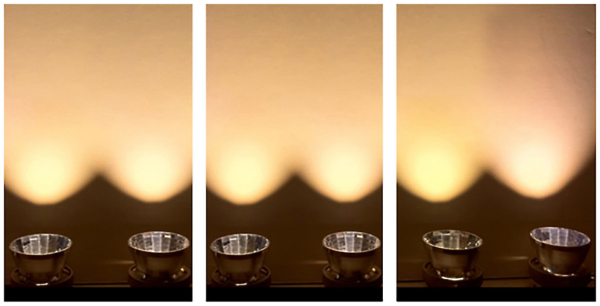


Application research to determine thresholds for non-visible color differences

We found that Standard Deviation of Color Matching, or SDCM, was a very accurate measure for describing color differences. SDCM is an improved version of the famous MacAdam ellipse that dates back to the 1930s. SDCM can also be converted to the blue-yellow measure CCT, and the pink-green measure Duv.

By presenting observers with light sources of slightly different color with high spatial contrast, we found that, for accent lighting, the threshold of 1SDCM for pink-to-green (Duv) color differences is appropriate.

We also found that the eye was a bit more forgiving of differences along the blue-yellow (CCT) dimension, and that for these shades 2SDCM is appropriate.



In other words, it is important to distinguish the different thresholds for these different shades. We are more sensitive to green-pink variations (Duv) than we are to blue-yellow (CCT) variations. So in specifying color consistency, we need to maintain tighter tolerances for Duv than for CCT.

This is what Xicato does.

The transformative effect of uniform lighting color

Imagine that you ask a painter to paint a wall white, but he uses two different tints. No doubt, you would think it looked messy and would ask the painter to redo the work and make it look uniform.

We have similar expectations with lighting. Color non-uniform lighting gives a messy, cluttered impression. On the other hand, color uniform lighting elevates a space with an impression of clarity and serenity. That will not go unnoticed!

Xicato Initial Color Consistency

Xicato warrants that its light sources meet the specifications described above:

Blue-Yellow (CCT)	2 SDCM	± 40K at 2700K ± 50K at 3000K ± 70K at 4000K
Pink-Green (Duv)	1 SDCM	± 0.001 Duv at all CCT