Color Management White Paper 1

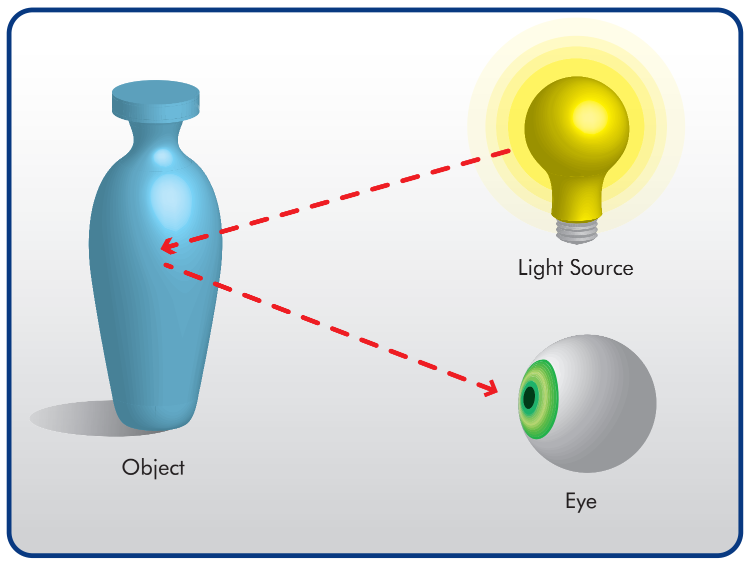
Introduction to Understanding Color

I. INTRODUCTION TO COLOR

Color vision is the capacity of an organism to distinguish objects based on the wavelength of the light objects reflect or emit. A ‘blue’ flower does not emit blue light; it simply absorbs all the frequencies of light shining on it except the frequencies we call blue, which are reflected. A flower is perceived to be blue only because the human eye can distinguish between different frequencies. The reflected light hits our eyes and stimulates the visual cells of our retinas. Our eyes send signals to our brains, which process the signals to create color.

Our impression of color results from interactions among three factors:

- The light source
- The object that reflects part of the emitted light
- The eyes and brain

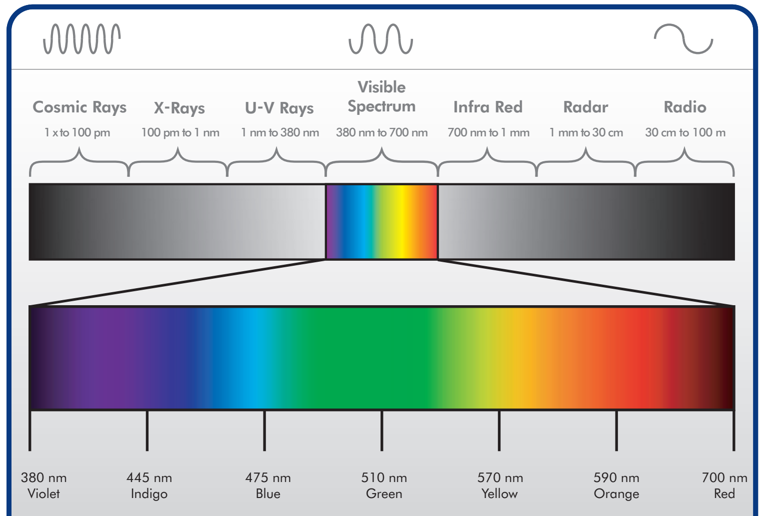


Let’s examine the role that each of these factors plays in the creation of the impression of color.

THE LIGHT SOURCE

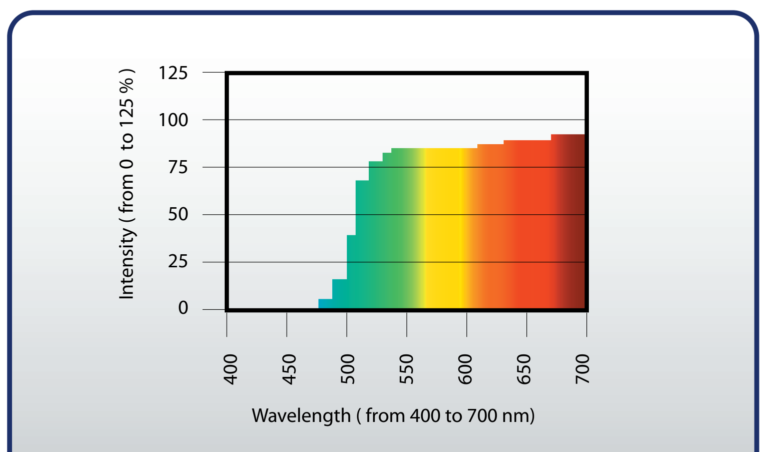
Light is a wave-like phenomenon. A light source emits waves that vibrate at a certain wavelength. Among these waves, those with a wavelength between 380 - 700 nanometers compose the visible spectrum. Waves with higher or lower wavelengths are not visible to humans.

A light source can be characterized by its spectral distribution. The spectral distribution of a light source describes the proportion of the energy it emits in various areas of the spectrum.



The visible color spectrum

A light source that emits most of its energy in wavelengths of 570 nm (nanometers) can be described as emitting mostly “yellow” light. A light source that has a flat spectral distribution (equal energy emitted across the entire spectrum) will be described as gray.



A yellow patch and its spectral distribution

THE OBJECT

When light waves strike an object, its surface absorbs some of the waves’ energy, and reflects some other parts of the energy. In effect, the object subtracts part of the light originally emitted by the light source[1]. The part of the original light that is subtracted depends upon the nature of the object’s surface and in particular on the pigments, dyes, and inks that might be present.

For example, red paint contains pigments that reflect mostly the ‘reddish’ wavelengths situated around 650 nm, and attenuates (subtracts) other wavelengths.

THE HUMAN EYES AND BRAIN

The light that is reflected by an object strikes our eyes, which contain light sensors called rods and cone cells.

- Rods are mostly sensitive to the intensity of light. They enable us to distinguish between light and dark under low light conditions. Thanks to rods we can see at low levels of light and detect different gray tones. Under normal lighting conditions our eyes only use cones.

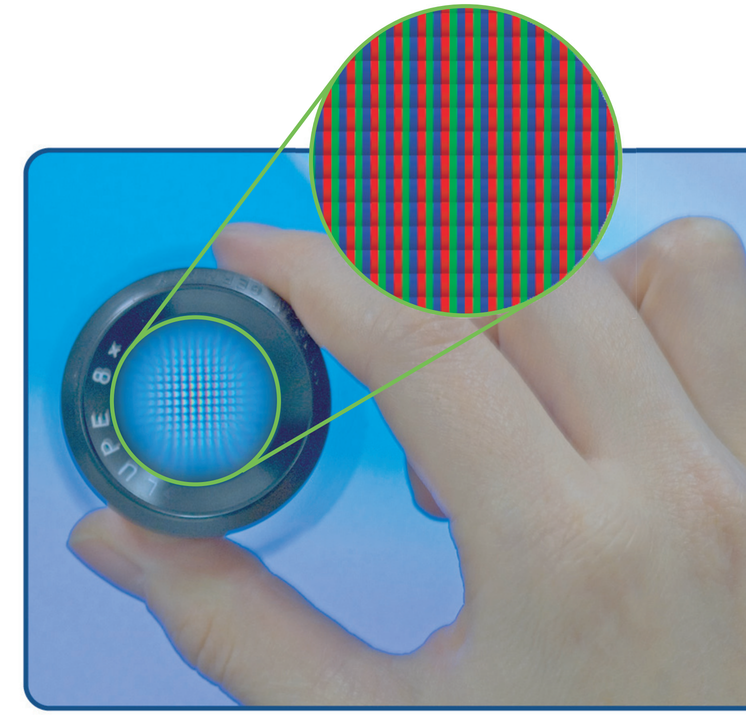
- There are three types of cone cells. Some are more sensitive to the red areas of the color spectrum, some to the green areas, and others to the blue areas.

Depending on how they are stimulated by light striking the eyes, rods and cones send signals to the brain, which process the signals to create a perception of color.

Exactly which color is perceived depends on the composition of wavelengths in the light waves. If the sensors detect all visible wavelengths at once, the brain perceives white light. When our visual system detects a wavelength around 700 nm, we see “red”; when a wavelength around 450-500 nm is detected, we see “blue”; a 400 nm wavelength looks “violet”; and so on. If no light is present, no wavelengths are detected and the brain perceives black.

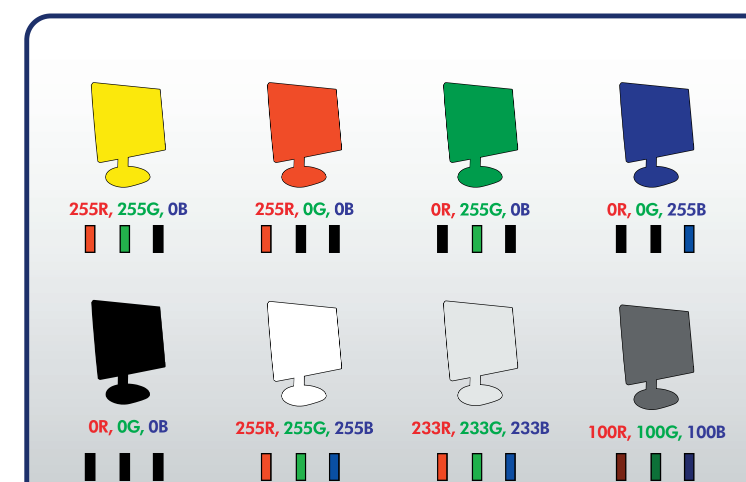
II. COMPUTER DISPLAYS AND COLORS

Computer monitors display images as pixel matrices where each pixel is made up of three tiny light sources commonly called dots. A LaCie 321 Monitor, for instance, displays a matrix of 1600X1200 pixels. A close-up view of such a matrix can be seen in the following illustration.



Each of the three dots that make up a pixel is responsible for emitting a shade of red, green or blue light. Each dot’s intensity can be adjusted with a value from 0 - 255[2]. When the dot’s intensity is set to 0, the dot emits no light, and when it is set to 255 it emits its maximum intensity. By setting a given intensity for each of the three dots, one creates an individual color such as: Red=100, Green=100, Blue=100. A large palette of colors is available, which comprises 256x256x256 equaling 16.7 million colors.

The following illustration shows a variety of combinations of RGB and the resulting colors.



Examples of additive RGB color mixing

1- Some objects, such as a printed piece of paper are mostly reflective. Others, such as film or a transparency are transmissive objects: part of the original light goes through the object. This document refers to the basic context of reflective objects.

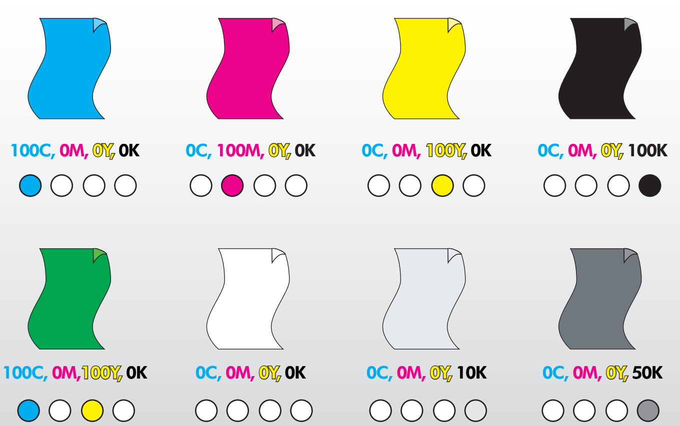
2- This is called 8-bit color because in the binary system, these 256 values can be coded with 8 bits.

The three dots are so close that at a normal distance from the monitor, the naked eye cannot distinguish them from one another and their colors appear blended – added together.

The complexity of color perception by the human eye combined with color display on a computer and related peripherals is the reason why an accurate color management system is necessary.

PRINTERS - CMYK

Professional commercial printers, on the other hand, produce colors by layering semi-transparent inks over each other. The four inks most commonly used are cyan, magenta, yellow and black[3] (abbreviated CMYK). The range of colors that a particular printer is capable of producing is obtained by varying the concentration of the inks, between 0 - 100%.
As we saw in the first section, the pigments present in each of the inks will absorb certain wavelengths from the light that strikes them and will reflect only certain wavelengths. The combination of which wavelengths are absorbed by the pigments determines the composition of the reflected light, and therefore the perceived color of the printed area. This is a subtractive process.
The following illustration shows a variety of combinations of CMYK and the resulting colors.



Examples of subtractive CMYK color mixing

100, 100, 100, 0 = in theory this mix results in black but for economical and quality reasons printer manufacturers prefer to print black and gray colors by using the fourth pigment –called K – rather than the three other ones. Hence, black will more often be printed as follows: 0, 0, 0, 100. 0, 0, 0, 0 = no added pigments, the reflected color is that of the paper.

> "Through a combination of cutting-edge technological engineering and a rich history of unique design aesthetics, LaCie continues as a firm leader in the color display industry. Established in the United States, Europe and Japan, LaCie is a leading worldwide producer of PC and Macintosh compatible peripherals, including a new generation of color LCD monitors. By providing top-of-the line tools for multimedia innovation, LaCie anticipates the needs of creative professionals such as graphic designers, photographers and filmmakers, who require genuine, practical solutions for accurate color management."

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3. Theoretically, adding cyan, magenta and yellow at maximum concentration should produce black. For various technical, economic and practical reasons, the 'black' generated by mixing the primaries is not ideal; this is why a fourth color "K" (or Black) is used in a four-color printing process in addition to the subtractive primaries.