Color Vision
How We Understand and Communicate Color

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Color

Color plays a profound role in the way we act and react to our world

Our knowledge of color and our ability to communicate color information is important when treating our patients

There is a common language used for measuring, describing and communicating color information

This allows for accuracy in reproducing colors

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What Color is the Dress (2015)

Black and Blue

Gold and White

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How We Think it's Illuminated

If we believe it's in sunlight, we are more likely to see it as white and gold

If we believe it's illuminated by artificial light, it will look black and blue

If you get up and go to bed early – white and gold

If you're a night owl – black and blue

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Color

Color is a characteristic of light determined by the light's spectral composition and interaction with the human eye

Color is a psychophysical phenomenon

Perception of color is subjective

Color can make us feel happy or sad

Color influences our taste in food

We use color to judge a person's health

face color, the color of the retina

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Retinal Cone Cells

Respond differently to light of different wavelengths

This makes them responsible for color vision

They function best in bright light (less sensitive to light than rods)

S or short 2%

M or medium 33%

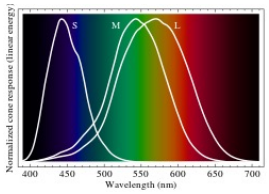
L or long 65%

peak wavelengths range

S: 420-440nm

M: 534-545nm

L: 564–580 nm



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How Do We Express Color

What color is the apple?

Red, Crimson, Bright Red, Scarlet

So color names are not very helpful when wanting to communicate how to reproduce the color
what color is a 15% blue tint

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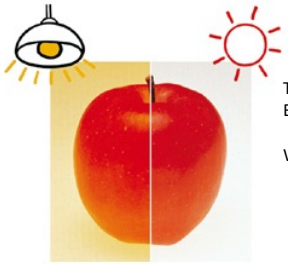
Conditions that Affect Color



The two halves are the same color
But they look different

WHY
light source differences
background differences
directional differences

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Light Source Differences

An apple may look delicious under sunlight at the farmer's market but not so good at home under artificial light

Each type of illumination such as sunlight, fluorescent light, or incandescent light will make the same apple look different

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Background Differences

The apple will appear dull when placed in front of a dark background

This is referred to as contrast effect

Directional Differences

If you view a car from a slightly different angle, it may appear brighter or darker due to the directional characteristics of the car's paint (high directional characteristics)

For accurate color communication
the angle of viewing and the angle from which the object is illuminated must be constant

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Observer Differences

Even with "normal" color vision a person may have some bias toward red or blue.

Eyesight changes with age affect color vision

Size Differences

Colors covering a large area tend to appear brighter and more vivid than colors covering a smaller area

This is called the area effect

Selecting objects which will have a large area (wallpaper) based on a small color sample or swatch may make you think you made a mistake in picking a particular pattern when the full wall or room is covered

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Describing Color

Hue — another word for color (red, yellow, blue, green)
can be represented on a color wheel

Saturation (chroma) — the intensity or purity of a hue, vivid vs dull, changes outward from the center

Lightness (value) — the relative degree of black or white mixed with a given hue, bright vs dark, changes vertically
a lemon is a brighter yellow than a grapefruit

Temperature — the perceived warmth or coolness of a color
2500K incandescent --- 5000K white, like sunlight

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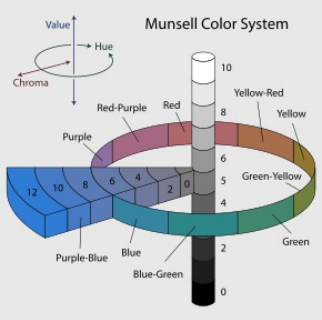
Munsell Color System

Artist A. H. Munsell devised a method of expressing colors by using a great number of paper color chips of different hue (Munsell *Hue*), lightness (Munsell *Value*), and saturation (Munsell *Chroma*) for visual comparison with a specimen color

Any given color is expressed as a letter/number combination (H/ V/C)



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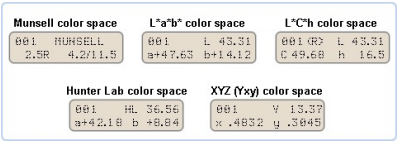
Quantifying Color

Colorimeters are used to quantify color

By creating scales for hue, lightness and saturation, we can measure color numerically

Color space is a method for expressing the color of an object or a light source using some kind of notation, such as numbers

This is the color of a red apple



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Features of colorimeters

Constant illumination / viewing angles

Constant "observer"

Elimination of area effect and contrast effect

Color difference measurement

Color difference from a target color can be measured and instantly displayed in numerical form

A colorimeter's measurements correlate to human perception

It is designed to see color the way we do

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Using a colorimeter may be important when utilizing different sources for phototherapy glass filters or checking tint color especially when a patient is sensitive to small differences or we want the tint to perform in a certain way to protect the patient's vision

Visual inspection is much less reliable and is influenced by ambient lighting, a person's age and even their overall physical condition

A colorimeter is designed to perform a type of psychophysical sample analysis, which means its measurements correlate to human perception. In other words, it is designed to see color the way we do

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Spectrophotometer

A spectrophotometer provides full spectrum color measurement. It measures spectral reflectance, absorption or transmittance at each wavelength

It can produce precise data beyond that observable by the human eye such as any UV transmittance of a pair of sunglasses

It calculates the tristimulus values from the spectral reflectance data. These tristimulus values can then be used to calculate values in other color spaces such as Yxy or L*a*b*

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Colorimeter vs Spectrophotometer

Metamerism occurs when two colors look identical in one lighting condition, but not another.

Two materials under fluorescent light might not match, even though they match to an incandescent "white' light source.

Colorimeters can't identify and adjust for metamerism

Spectrophotometers are capable of measuring metamerism

Spectrophotometers can account for apparent color differences caused by the light source (color rendering properties) and surface condition differences

Offer multiple illuminant/observer combinations

More precise than colorimeters

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The Human Eye

The human eye cannot differentiate some colors from others even if they are different.

The area of such colors on the chromaticity diagram is called the color discrimination threshold of the human eye.

In a diagram of the a*b* chromaticity diagram representing the CIE Lab color space, we can place ellipses that represent the color discrimination thresholds of the human eye concerning saturation and hue.

The human eye cannot differentiate the colors within the same ellipse.

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Four characteristics of the color differentiation ability of the human eye

1. The sensitivity to color differences is low for colors with high saturation (these colors are difficult to differentiate)

2. The sensitivity to the color differences in the direction of hue varies depending on the hue

3. The sensitivity to the color difference in the direction of lightness varies depending on the lightness. Sensitivity becomes highest around the lightness of 50 and decreases for both higher and lower lightness

4. For blue colors, the direction of the color discrimination threshold changes. It is this mismatch that causes differences in the color difference evaluation between color meters and the human eye.

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So How Do We Determine the Color of an Object

Determining the color of an object involves illumination, object and the perspective of the observer

When a color is created independently such as by a light bulb and the color is different and is called source color. For source color only two factors are involved - the spectral distribution of the light source and the perception of the observer

For object color, it is necessary to determine and evaluate the spectral distribution of the illuminants. This is because the color appears differently under different illuminants. The illuminants are not required when the light source color is measured because the color of the light source itself must be determined

Note: with LCDs hue varies depending on the viewing angle so the angle must be a set value

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The Importance of Color

Color is important in the real world

Color communicates invisibly

Color can affect our mood, can bring down blood pressure, enhance learning, and grab our attention

Because color is so powerful in our external world and for creating internal change through the visual system, it is important for us to know how to measure and communicate color information especially when it may affect our treatments and our patient's lives

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