An introduction to light and color in art.

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Summary

• What is light? (a very short introduction to the physics of light)
• What is vision?
• What is color? Is it possible to measure a color?
Light is made by Electromagnetic waves

Different waves have different wavelength $\lambda$
Light is a form of energy, visible with the naked eye, that can be transmitted from one point to another at a finite speed. Visible light is a small part of the radiation spectrum which ranges from cosmic rays to radio waves.
Where does sound fit in the electromagnetic spectrum?

It doesn’t! Sound is a wave propagated through compressions and rarefactions of the medium. Electromagnetic waves are propagating via electromagnetic induction, and travels in air at about a million times as fast as sound.
Visible part of the spectrum

From 380 to 780 nm (1 nm is one billionth of a meter, one millionth of a millimeter)
Where do brown and magenta fit in the electromagnetic spectrum?

It doesn’t! In the spectrum we can’t find mixture.
Color naming experiment


http://www.hpl.hp.com/personal/Nathan_Moroney
“...to know what is where by looking. In other word, vision is the process of discovering from images what is present in the world, and where it is” D. Marr “Vision” (MIT Press, Boston, 1980)
“To suppose that the eye with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I confess, absurd in the highest degree”.

Same image, different perception
Count the black dots!
Are the horizontal lines parallel or do they slope?
To create your own

http://illusionetc.blogspot.com/2006/05/how-to-create-your-own-colorization.html
The Checkershadow Illusion
web.mit.edu/persci/people/adelson/checkershadow_illusion.html
Anderson e Winawer (2005)
What is color?
Are we equally sensitive to all wavelengths?
Is color an objective or subjective phenomenon?
Photometry measures light from the point of view of our visual system. It must take into account that our eyes are not equally sensitive to all wavelengths. We see yellow-green far better than red and blue.

Fig. 16.7. Eye sensitivity function, $V(\lambda)$, (left ordinate) and luminous efficacy, measured in lumens per Watt of optical power (right ordinate). $V(\lambda)$ is greatest at 555 nm. Also given is a polynomial approximation for $V(\lambda)$ (after 1978 CIE data).
Almost all colors disappear under low illumination (for example under the light of a quarter moon)

For some observer objects that appear very different in color for the normal observer may appear hopelessly alike

Objects that are seen as highly colored, and easily discriminable in daylight, lose their colors when viewed under sodium vapor light
The rendering of an object color depends on
• visual mechanism of the viewer
• object’s composition
• the spectral qualities of light sources
• size (colors covering a large area tend to appear brighter and more vivid)
• background differences
The importance of the surround

The Appearance Of A Colour Changes According To Surrounding Colours
This is caused by the local adaptation of the retinal response. The neural systems “fills in” the area to be consistent with its perception of the edge contrast.
Because the appearance of any color depends on the color of its surround, the change of just one color in a geometric design changes the appearance of the overall design.
The macula is at the center of the retina, the light-sensitive wall of the eyeball. Though only two millimeters square, it contains thousands of photoreceptors—the rods and cones—that transfer visual information to the brain.
Relative sensitivity of the eye: three cones
Cone Distribution

L 50.6% M 44.2% S 5.2%
L:M=1.15

L 75.8% M 20.0% S 4.2%
L:M=3.79

Roorda e Williams Nature 397, 520 (1999)
What are the three primary colors?

Blue, yellow and red (blue? Probably blue green, cyan, turquoise) (Red? Bluish red, Magenta)
Red, green, blue
What is white? (a mathematical point of view)

White is the sum of all the colors.

False!

The sum of all the colors of light add up to white.

True!
Physics’ world (very theoretical): any color at all can be made from three different colors (but using also the minus sign)

Real world: it is impossible to obtain every color using three colors
Additive synthesis

With red, green and blue a wider range of colors is available (in the real world, not in the physics world) for some of the combinations
Examples of additive color effects

Lamp in stage productions, TV screen, computer monitor
Subtractive synthesis

Examples: ink, paint, dye
Unsolvable problem
To obtain all the colors using only the plus sign the CIE in 1931 defined three imaginary colors X,Y,Z.

A color can be specified using three numbers.
CIE chromaticity diagram
In the CIE 1931 diagram (old, but still used in artworks conservation) a color is represented by three numbers, x, y (coordinates in the diagram) and Y (luminance, the amount of light that is reflected or is emitted from a particular area)
Colors may appear to match under one light source, but not under another: is the metamerism. Two colors that have the same appearance but different spectral reflectance distributions are defined as a metameric pair.
Color constancy
Color constancy
It is green, no doubt
Do you believe? It is cyan...
Color constancy

Appears red

Same color, different perception?

Appears white-bluish
#thedress
March 2015
Kuvankappaus data

The original (black-blue) dress

% of men / women

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<th>Category</th>
<th>Men</th>
<th>Women</th>
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<td>38</td>
<td>35</td>
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<tr>
<td>Light blue-gold</td>
<td>27</td>
<td>24</td>
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<tr>
<td>White-gold</td>
<td>22</td>
<td>20</td>
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<tr>
<td>Blue-brown</td>
<td>4</td>
<td>5</td>
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<tr>
<td>Light blue-brown</td>
<td>1</td>
<td>2</td>
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1. Start with a card half red, half white.
2. Fold it so that red faces white.
3. Light reflects from red onto white.
4. The visual system “knows” about the reflection and knows to discount it.
5. Now, fool the visual system into thinking the card is folded like a roof.
6. Without the reflection explanation, the white side now looks quite pink.
Black body
When the light of a radiator has the same chromaticity coordinates as a blackbody at temperature $T$, the radiator has color temperature $T$.

Correlated color temperature: when the chromaticity of a radiator is not equal to any of the chromaticities of a blackbody radiator.
Is a candle a cold or a hot light source? Has it a low or high color temperature?

A candle is a hot source (psychologically speaking) and it has a low color temperature (physically speaking).
Color rendering index

Color rendering of a light source is the effect the source has on the color appearance of objects in comparison with their appearance under a reference source.

For calculating the CIE CRI a set of eight test-color samples is specified.
Light and color

White light

Yellow light

Seen magenta

Seen red
Nothing like the sun?
in a sense

**Color doesn’t exist**

For convenience we may talk about a yellow light, but we really should say “a light that we perceive as yellow” In fact light of a variety of different spectral compositions can evoke the same color perception
When we see a color......
Light and art: experiments
Aim of the experiment

Evaluating subjective preferences regarding lighting in front of a painting
“Madonna del Granduca”
Raffaello (1504)
Olio su tavola 84,4 X 55,9 cm
Paintings selected for the experiment

“L’Assoluto della luce”
di Giovanna Rasario (2010)
Preferences for Raffaello

- New LED Cold: 50
- New LED warm: 50
- Halogen: 20
- Old LED: 10
Lighting preferences

Opera di Giovanna Rasario (2000)

- New LED Cold
- New LED warm (highest)
- Halogen
- Old LED

The chart shows the preferences for different types of lighting in the Opera di Giovanna Rasario (2000) presentation.
Measuring the inmeasureable
The experiment
Elizabeth Chaplin
Botticelli
Giovanna Rasario

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The champion and the worst
Expert or not

Memoria della Luce

Sant'Agostino nello studio

Figura di donna
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