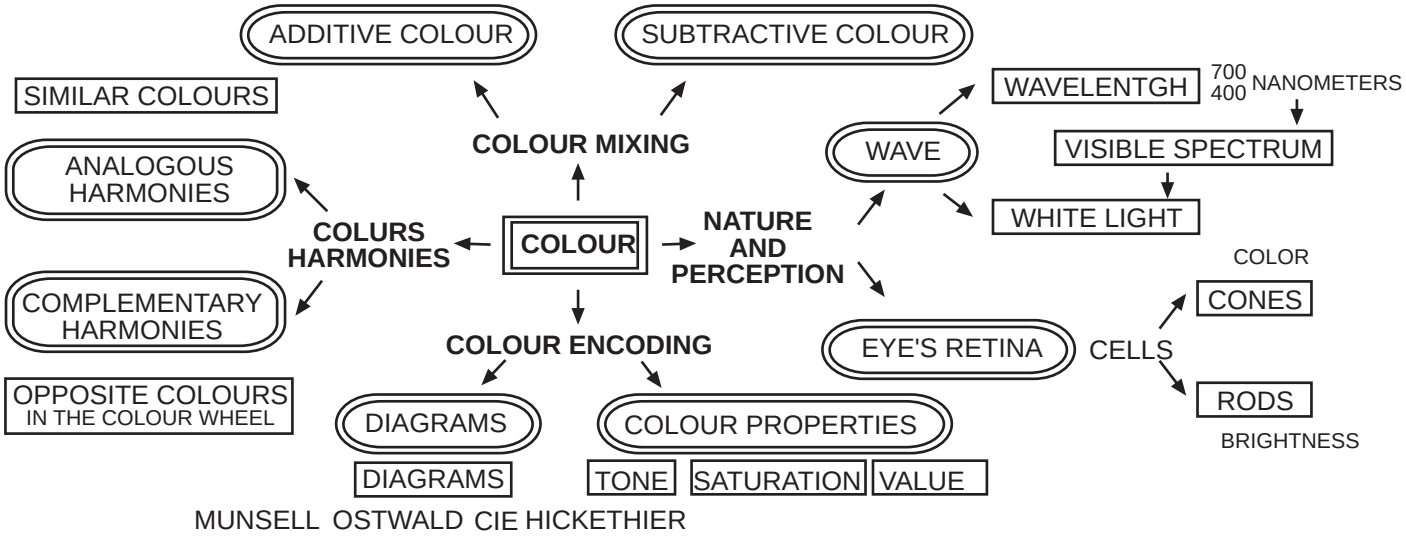
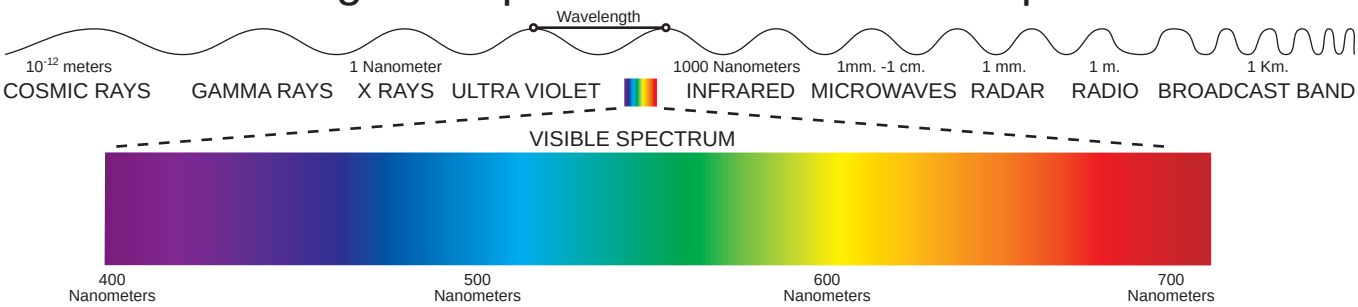


Electromagnetic spectrum versus Visible spectrum



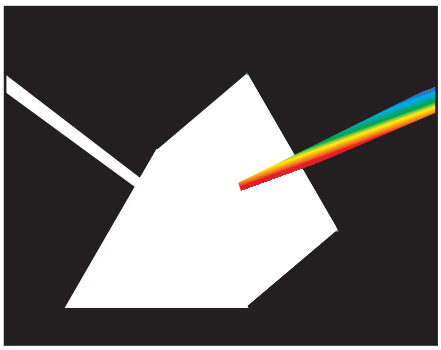
Colors in light, Newton's Prism and Additive mixing.

It's said that Isaac Newton discovered the **white light** which contains itself all colours together by chance as the discovery of gravity. In the past it was believed that the eyes **emited** some short of **rays** that **scanned** reality for us to be seen.

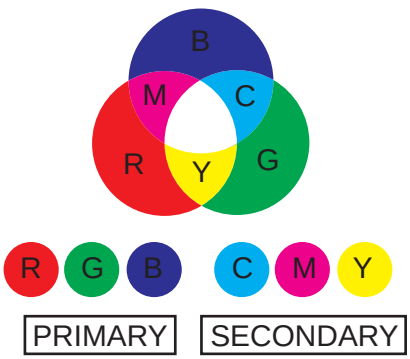
Later it was thought that light travelled to our eyes to show us what we see. By then Newton randomly realized a thin ray of white light was **decomposed** by a **glass prism** into the multiple colours that form the **visible spectrum**. That was the **Additive colors** theory seed.

Adding red light to green light a **yellow light** is obtained. A blue light and a green light produce a **cyan light.** And red and blue lights together form a **magenta light**. Adding all the three Additive **primary** colours (Red, Green and Blue) together produces the white Light.

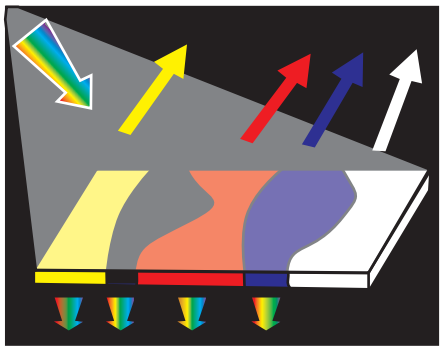
So white light comes into contact with the objects **surfaces** which **absorb** part of the colors contained. The rest of the colored rays are reflected and come into our eyes for us to **perceive** the colours of the objects. Those are the surface properties of **absorption** and **reflection** of light. The materials giving the colored **rays** different directions when the light goes through is called **refraction property,** and that's what happened to Newton's Prism as well as to the rainbow.



Newton's Prism and light refraction



Additive colours mixing

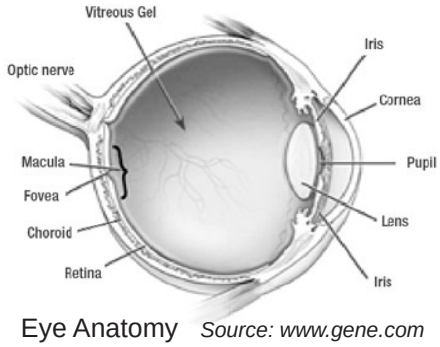


Absorption and Reflexion of light

Perception of color. The eye.

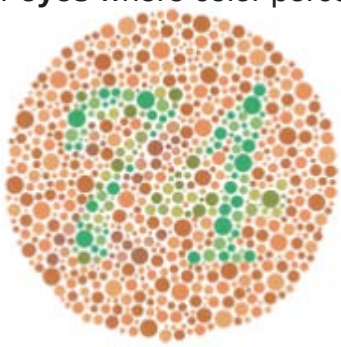
http://www.ted.com/talks/neil_harbisson_i_listen_to_color.html
Click here or scann the QR code on the right to watch a video about Neil Harbisson. A color blind person who can hear the colors. On the left you can see **Neil Harbisson's website**.
http://www.harbisson.com/

The process of **color vision** starts by a **source of light** that sends the **rays of light** to the objects. Once the **objects surfaces reflect** the light, or part of it, travels to our **eyes** where color perception starts.



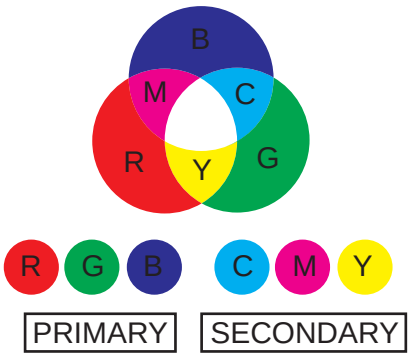
Eye Anatomy *Source: www.gene.com*

The **eye** is a sphere that lets the light get in through the **pupil**. The **iris** opens or closes depending the amount of incoming light to let in the right amount of light to be projected over the retina. The image gets projected over a layer called **retina** which is over most of the inside surface of the eye. The retina is composed by two kinds of cells.


Ishihara Test Plate 9 *Source: wikipedia*

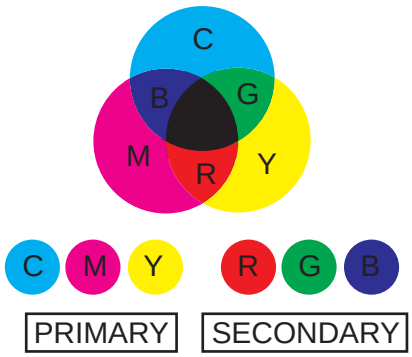
Rods are in charge of registering the light. Rods are the ones that work better at dark and they are not specialized in colors. **Cones** are the cells in charge of registering color. There are three types of cones, each of them has the task to register the amount of one of the **additive primary colours**. So there are cones that register the green, others that register the red and the ones that register the blue light. It is exactly the same system that old televisions used to show the images over their screens. Once the retina cells register, through chemical reactions, the **incoming colored rays** send the information as electrical messages to our brain through the **optical nerve**.
There are people whose **retina's cells** have different short of **defects or lacks**. Those people cannot get to perceive certain colours. Most of them cannot see red and green properly so they cannot tell the difference between them. There are other cromatic vision defects that don't let people see some other or any colors.This disease is called **color-blindness**.

Additive versus subtractive colors



Additive colours mixing

Subtractive colors, opposite to additive colors, work as we always thought colour combinations work. The **three primary: Magenta, cyan and yellow,** cannot be obtained through the mixture of any other color. These are the purest colors and by mixing them in equal parts we obtain the three **secondary: Red, Green and Blue.**



Subtractive colours mixing

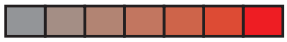
A **subtractive color model** comes from mixing different types of **dyes**, **inks**, **paint pigments** or **natural colorants** to create a wider **range of colors**. Each color is the result of absorbing some wavelengths of light (colored lights) and not others. The color that a surface shows depends on which parts of the visible spectrum are not absorbed and therefore reflected.

The primary additive colors (light) are the secondary subtractive colors (material) and vice versa. When we mix a primary and a secondary color we get the **tertiary colors** in both systems, additive and subtractive.

Subtractive is the given name to this type of colors because when we add more colors to the mixture we substract luminosity, so we obtain black. Black is the result of mixing the three subtractive primary colours in equal parts, even though that is sometimes difficult in real practice. Subtractive colors is the system we notice and experiment when we produce materials or we paint a surface using paint, dyes or coloured pencils. Let's say subtractive colours are the chemical aspect of colour. While Additive colours are the physical aspect of colours that travels through the air to our eyes as rays of light.

Color qualities

Besides Newton's discoveries and the additive and subtractive theories, color can be studied and clasified in a scientific way. This branch of science is called colorimetry and this teory is based on a method to describe colours by three features. While every color contains a specific amount of the three primary, and that is a way to describe them, colors can also be described by three other qualities:


HUE

SATURATION

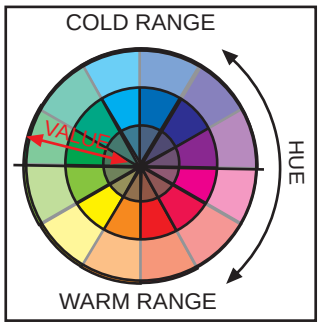
VALUE

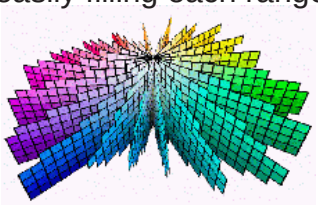
Hue: The specific quality by which a color is known, it is the color's name. Also called **tone or tint**. Each tone corresponds to a specific wavelength.
Value: Amount of lightness or darkness (black or white) a color has. Also called **brightness or lightness**.
Saturation: Degree of purity of a colour. The higher pureness (less mixing colors) the higher color saturation. The little saturated colors are seen like grayish. Also called **chroma**.

Color systems or models

Code or chromatic system: They are maps of the coded color, sorted according to different criteria such as their position in the visible spectrum or their three qualities.

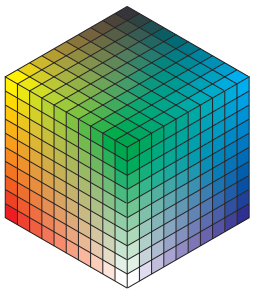
Color wheel: A circular diagram where the three primary colors are placed as far as possible from each other. Mixed the primary, secondary are shown in between each primary. Tertiary colors can also be observed between primary and secondary colors. It provides easy location of complementary colors, opposite to each other. Warm colors and cold colors can be determined easily filling each range half of the color wheel.



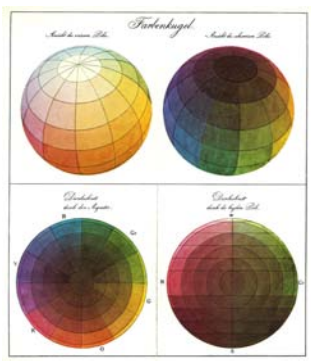


Munsell system: It is a solid that arranges the colors attending to three axes, each of them representing the three qualities of colour.

Spread Munsell Solid *Source: www.codeproject.com*



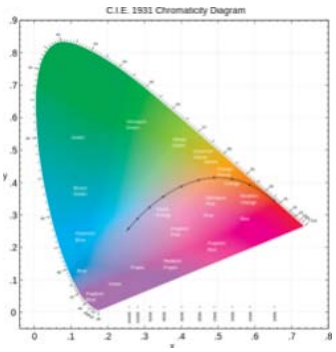
Hickethier cube: A three-dimensional color map in which the colors are distributed. Each edge contains ten divisions such that each square face contains 100 colors and the whole surface, formed by six squares, shows 999 colors. Vertices show the three primary, the three secondary, black and white. So all the surface shows variations in hues and values. Saturation decreases in the polihedron's inner part.



Otto Runge's Sphere: It has twelve pure colours around the equator, the three primary, the three secondary and six tertiary located between the primary and secondary. White and black, highest and lowest values, form opposite poles.

Philipp Otto Runge Sphere
Source: http://commons.wikimedia.org/

CIE Diagram: CIE is an acronym in French for "International Commission of Illumination" which is a organization that made a diagram in two dimensions like a triangle which reflects only two qualities of color: tone and saturation. In its three "vertices" we can find the green, red and blue violet, additive primary colors.



CIE DIAGRAM Lab space
Source: http://commons.wikimedia.org/

Ostwald double cone: Friedrich Wilhelm Ostwald was a Nobel Prize in Chemistry in 1909. His model shows the three color qualities: hue, lightness and saturation. The color wheel with saturated colors on the outside and less saturated colors on the inside is located in the middle circle. The vertical axis is formed by a gray scale from black to white that are located in the double cone vertices.

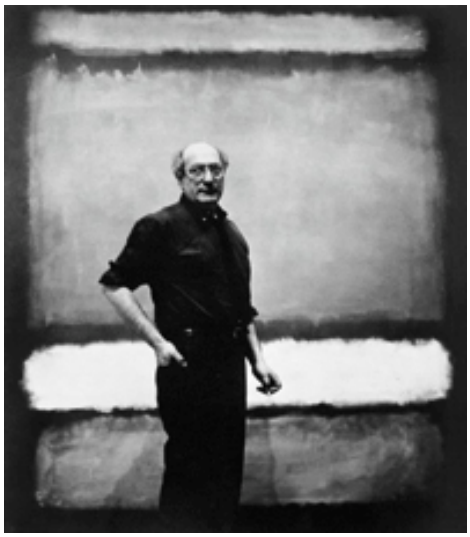
Ostwald double cone
Source: http://www.daicolor.co.jp/english/color_e/color_e01.html

More information about color models click **www.colorsystem.com** or scan the QR code.

Mark Rothko's expresiveness

Marc Rothko, born in 1903, started to paint in his twenties. He took about twenty years painting **figurative images**. But in the fourties he lost his interest for painting the **appearance** of the world based in his thought that art is an experience for the artist and the **viewer**.He wasn't really interested in **abstract images** or in colors but in the experience he lived when painting an artwork as well as in the viewer's **impressions** when apreciating it. He thought his current world subjects needed to be **depicted** that way to be explained properly. And with that purpose he used colors and **abstraction**.

Rothko did not like his audience to know much about the observed artworks in order to have them taking their own experience and conclusions without outer influences. He painted what the art critics called "**multiforms**" which were **colored spots** painted on big format **canvases**, sometimes about three meters tall. These **colored shapes** seem to be integrated with the **canvas** and need to be **observed**, because of their big size, creating view directions, Rothko called "**plasticity**" this feature of his art.



Mark Rothko

Source:pictify.com

Scann the QR code to watch **Mark Rothko's collection in MOMA**.

http://www.moma.org/collection/artist.php?artist_id=5047

Black and Gray. 1969

Source:wikipedia.com

Homage to Matisse 1954

Source:www.thecityreview.com

Rothko's Color stages

In the first stage of Rothko's abstract painting, **saturated or bright colors** were the main characters, later he focussed on **warm ranges** such as reds, oranges, and yellows but keeping the strategies of highly **contrasted colors** using sometimes **cold and warm contrasts**. After those two stages he started using **darker hues**, such as grays, dark warm colors or **coffee tones** but still making use of **contrasts and analogies**. Finally, late sixties, and beginning of the seventies, during the last two years of his life, he ended up painting in black, gray and very dark tones. Rothko's artworks are really difficult to be appreciated in **prints**, being the originals as big as they are and showing such a delicate and accurate use of color.

Rothko's artworks have broken records of selling prices. In 2005 "Homage to Matisse" was auctioned for 22.5 Million Dollars. In 2012 "Orange, Red, Yellow" was sold for 86.9 Million

Orange, Red, Yellow. 1961

Source:wikipedia.com

COLOR HARMONY

Harmony: It deals about the way to combine colors that match well with each other. There are different ways to combine colors in a good way that the final result looks good, mainly contrasts and analogies (analogous colors). Most of the harmonies are based in chosen colors out of the color wheel.

Contrast: This is the opposite concept of analogy, it is the relationship between different colors in which mixtures colors are not repeated so they look way too different. The most striking contrasts are those formed by complementary colors and these combinations are also called **complementary color harmonies**.

Ananologous colors harmony: They are achieved by using colors close in the color wheel. These harmonies can be created with pure colors varying degrees of saturation, tone or value.

EXPRESSIVENESS OF THE COLOR

Warm colors: Besides warmth they convey feeling of liveliness and closeness.

Cold or cool colors: In addition to the cold feeling, they transmit calmless, stability and distance.

Visual sensations: It is said that human vision distincts better yellow among other colors, as opposed to red and green that seem better integrated or confused with the chromatic surrounding.

Perception of color contrasts: Dark on light hues are better perceived than light on dark. A contrast that seems to be the most striking is the black on yellow.

COLOR

Color: It's a perteption. It is the result of the light received on the retina cells, sent through the optic nerve as electrical stimuli that interpret the brain.
Retina: Layer of photoreceptor cells inside the eye, rods and cones, which are responsible for registering the light that comes from the outside.
Cones: Cells in the retina of the eye that transmit to the brain the sensations of color. There are three types of cones, one for each primary color of light, cones that record red, cones that register green and cones that record the blue .
Rods: They are the cells in the retina responsible for recording and transmitting light sensation to the brain.

LIGHT AND COLOR

Electromagnetic spectrum: The set of electromagnetic waves that travel through the air.
Visible spectrum: The set of electromagnetic waves that the human eye perceives.They are perceived as colored lights and the color depends on the wavelength. For a wave to be visible its wavelength must be between 400 and 700 nanometers.
White light: Sunlight is considered the ultimate white light. The white light meets all visible wavelengths by the human eye. In conclusion, it is composed by the mixture of all the colored lights.
Newton's Prism: It is also called a dispersive prism. An experiment conducted by the scientist who gave it its name. He demonstrated that the white light passing through a triangular prism of glass is decomposed (refracted) in all the spectral colors.
Refraction of light: The change of direction of a wave passing from a material medium to another. This happens in Newton's prism when white light passes through it artificially. In a natural way, when sunlight travels through the atmosphere and turns into a rainbow which is a visible spectrum that arises naturally.
Light absorption: The physical property which has the object surfaces to absorb part of the received light. Depending on the surface physical qualities these absorp certain wavelengths and reflect others. A surface that we perceive as black actually absorbs all wavelengths (all colored lights).
Reflection of Light: The physical property which have the surfaces of objects to reflect some of the received light. Depending on the surface physical qualities these absorb certain wavelengths and reflect others. A surface that we percieve as white actually reflects all wave magnitudes (all colored lights).

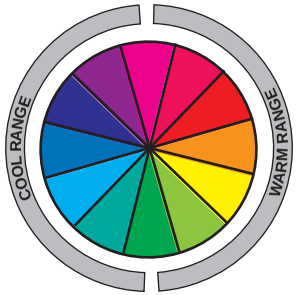
ADDITIVE MIXING AND COLOR LIGHT

Additive colours: The name given to the mixture of all the colored lights resulting in white, it is so named because the colors added to the mix add light to the result.
Primary additive colors: Red, Green and Blue. In English this mixture of colors is called RGB and this name is found in many electronic devices and software related to images. These lights cannot be obtained by mixing others. The mixture of the three primary additive colours results white
Secondary additive colors: They are the Magenta, Cyan and Yellow and they are the result of mixing equal parts the three primary lights in pairs. Red + Blue = Magenta, Blue + Green = Cyan, Green + Red = Yellow.
Color filters: Filters let through the radiation corresponding to the color we see the filter. A green filter lets through the green (yellow and green radiation) and a red absorbs all but red and orange to get through the filter.

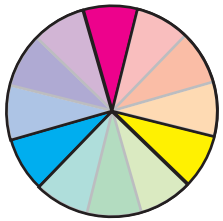
SUBTRACTIVE COLOR:

Pigments: dyes, normally in powder form, which are extracted or achieved by chemical or natural proceses from mineral, vegetable and various materials or substances which are used for dying or printing paint.
Binder or binding medium: These are substances used to amalgamate or bind and give unit the pigments in the paint. The binder for oil paint is lineseed oil, tempera is yolk, watercolors is gum arabic, ect.
Susbtractive colours: Are material colors. If you add them to the mixture, light is subtracted achieving black.
Primary subtractive colors: Are Cyan, Yellow and Magenta. These can not be obtained by mixing other subtractive colors.
Secondary subtractive colors: They are the result of mixing equal parts of the three primary colors in pairs; Cyan Yellow = Green, Yellow, Magenta = Red, Cyan+Magenta = Violetish blue.
Tertiary colors: They are always the result of mixing a primary color and secondary, on the color wheel they are arranged opposite ways (in front).
Complementary colors:They are pairs of colors such that the complement of a primary color is one which is composed of mixing the other two primaries. The mixture of two additive complementary colors approaches to white, while the mixture of two subtractive complementary approaches to black.

COLOR WHEEL



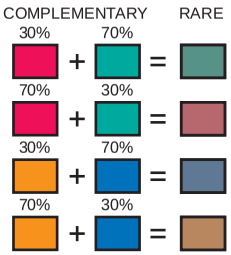
PRIMARY



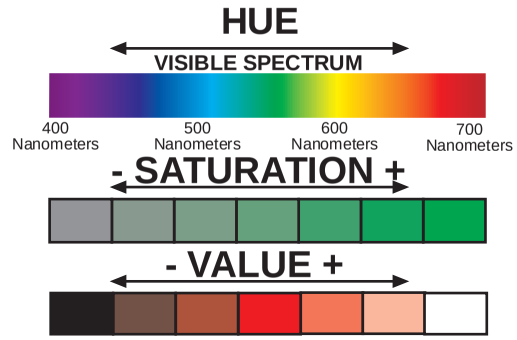
SECONDARY

TERTIARY

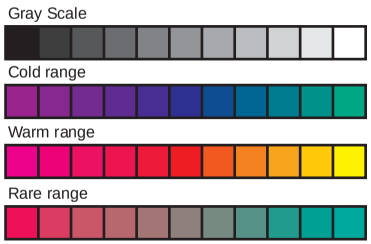
RARE COLORS



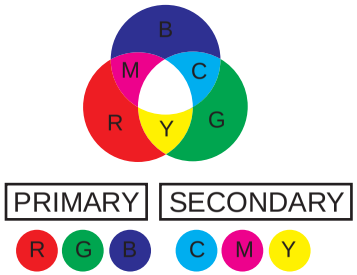
HUE



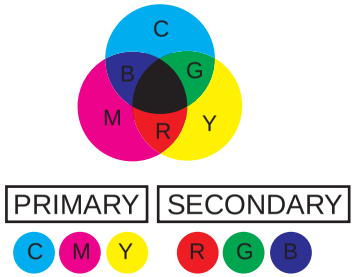
RANGES



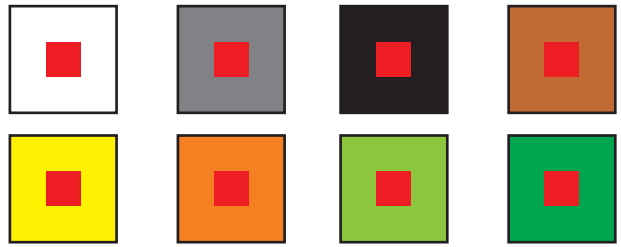
ADDITIVE:RGB



SUBTRACTIVE: CMYK

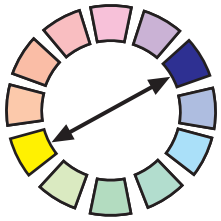


CONTEXT / SIMULTANEOUS CONTRAST

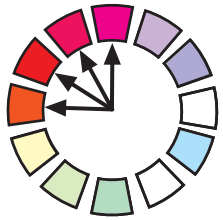


COLOR HARMONY

COMPLEMENTARY

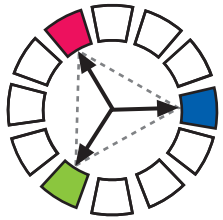


ANALOGOUS

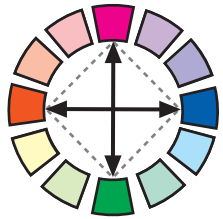


SPLIT COMPLEMENTARY

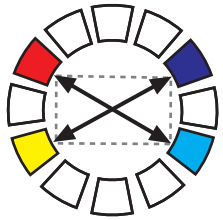
TRIAD



DOUBLE COMPLEMENTARY



SQUARE



RECTANGULAR

COLOR SUBJECTIVE SYMBOLISM

RED: Intense, fire, blood, energy, war, danger, love, passionate, strong, ambition, agression, alertness, braveness, dominating, dramatic,emotional, energetic, erotic...
PURPLE: Royalty, power, nobility, wealth, ambition, dignified, mysterious, aristocracy, art, anxiety, beauty, compassion, conflict, dream, dignity, enigma, extravagance...
YELLOW: Sunshine, joy, cheerfulness, intelect, energy, attention-getter, activity, aspiration, alertness, brightness, richness, happiness, idealism, imagination...
BLUE: Sky, sea, depth, stability, trust, masculine, acceptance, authority, balance, calmness, coolness, cooperation, culture, depression, distance, honesty, ...
GREEN: Nature, groth, fertility, freshness,healing, safety, money, adventure, balance, efficiency, cleanliness, faith, freedom, generosity, good luck, poison, health,outdoors...
ORANGE: Warm, stimulating, enthusiasm, happiness, success, creative, autumn, action, appetite, assurance, exagerated, competent, cheerful, tiring, outrageous...

Scann the QR on the right or **click here** to access the COLOR playlist in laslaminas.es youtube channel.

Scann the QR on the right or **click here** to access the COLOR gallery in laslaminas.es/Pinterest

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COLOR THEORY QUICK GUIDE