Firenze, 22 gennaio 2019

An introduction to light and color in art.

Speaker:

Alessandro Farini

Evento:

DIAGNOSTIC TECHNIQUES FOR CONSERVATORS-SACI

CNR-INO

ISTITUTO NAZIONALE DI OTTICA

CONSIGLIO NAZIONALE DELLE RICERCHE

www.ino.cnr.it

Riferimenti

Alessandro Farini

Istituto Nazionale di Ottica-CNR

www.ino.it/home/farini

Blog: www.riflessioniottiche.it

alessandro.farini@ino.it

twitter.com/alefarini

www.facebook.com/alessandro.farini

instagram.com/opticalreader

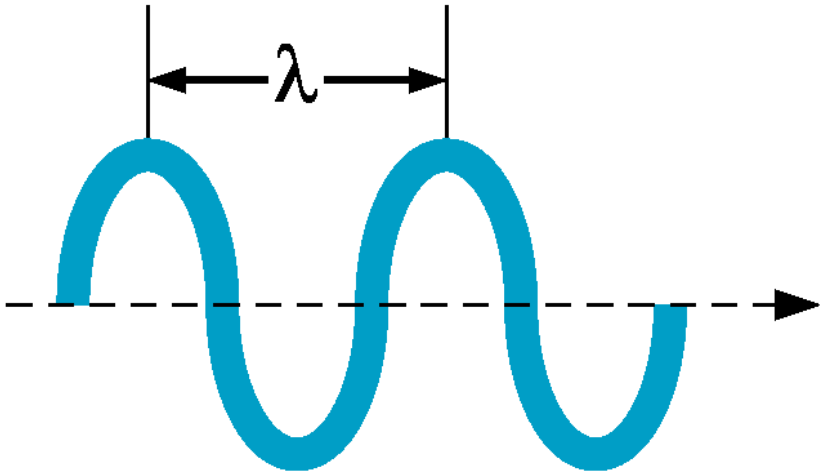
Summary

- 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?

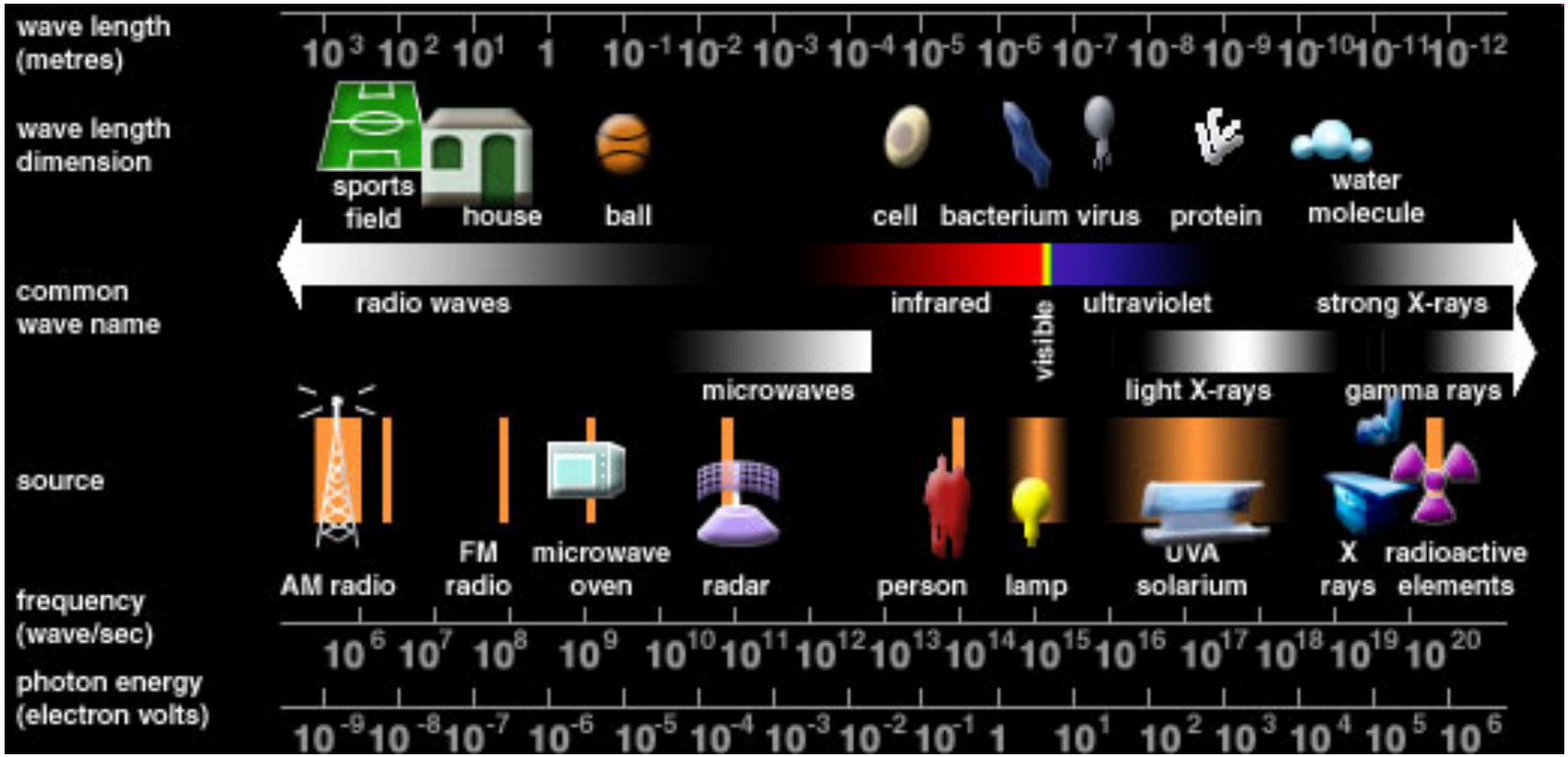
Electromagnetic radiation

Light is made by Electromagnetic waves

Different waves have different wavelength λ



What is light?



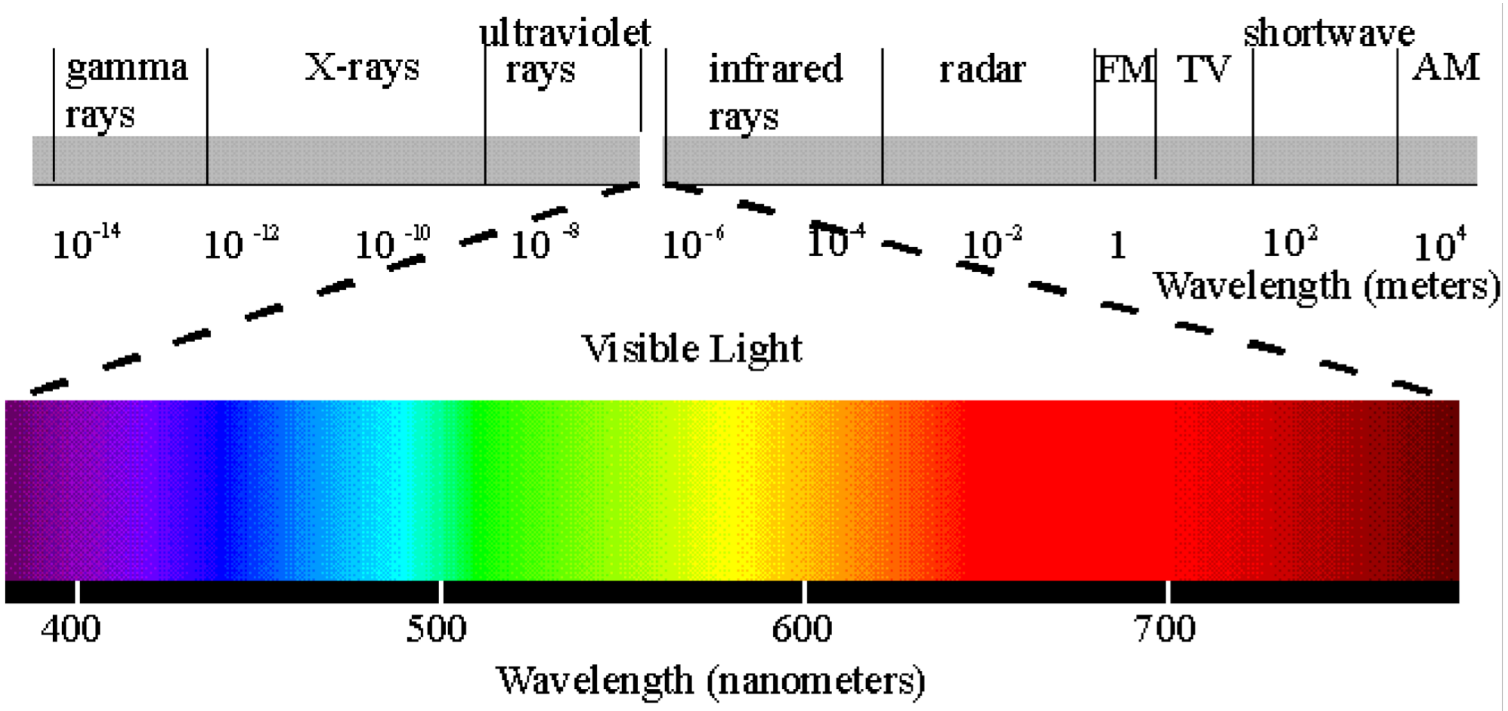
Light is a form of energy, visible with the naked eye, that can be transmitted from one point to another at a finite speed. Visible light is a small part of the radiation spectrum which ranges from cosmic rays to radio waves.

Question

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)

Question

Where do brown and magenta fit in the electromagnetic spectrum?

It doesn't! In the spectrum we can't find mixture

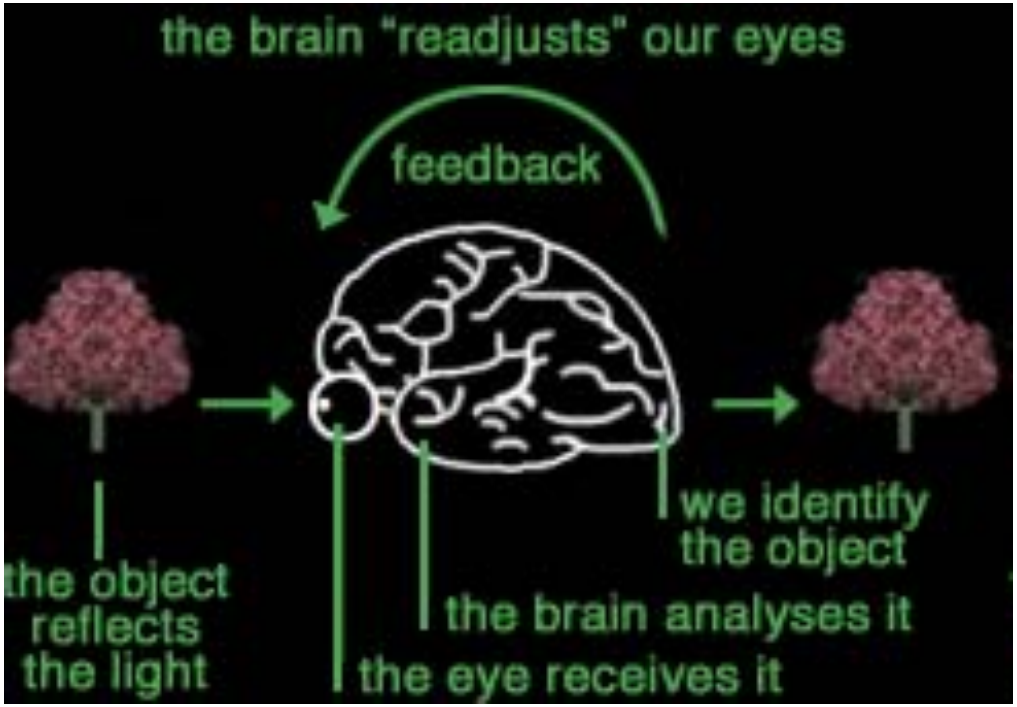
Color naming experiment

http://www.hpl.hp.com/personal/Nathan_Moroney/mlcn.html

http://www.hpl.hp.com/personal/Nathan_Moroney

What is vision?

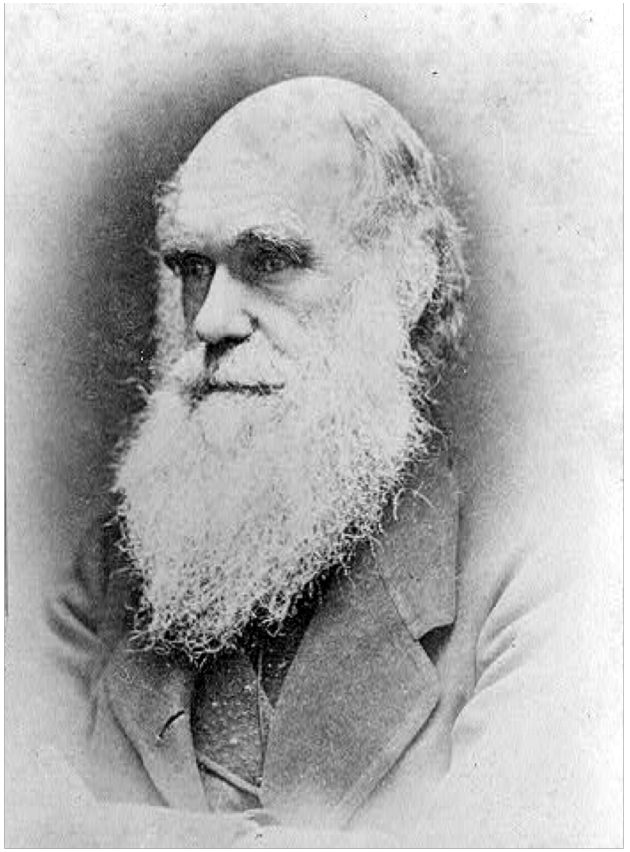
"...to know what is where by looking. In other word, vision is the process of discovering from images what is present in the world, and where it is" D.Marr "Vision" (MIT Press, Boston, 1980)



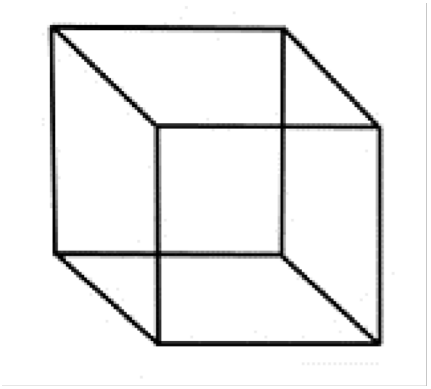
Darwin

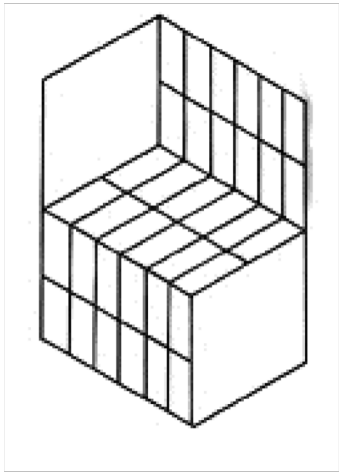
"To suppose that the eye with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I confess, absurd in the highest degree".

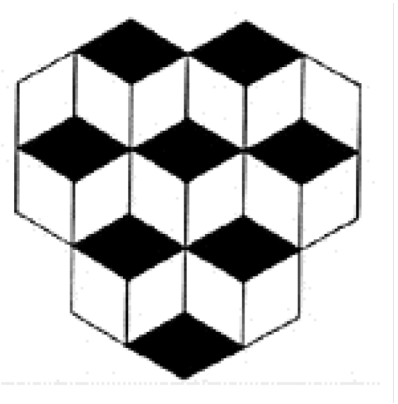
Charles Darwin, The Origin of Species, John Murray, London, 1859



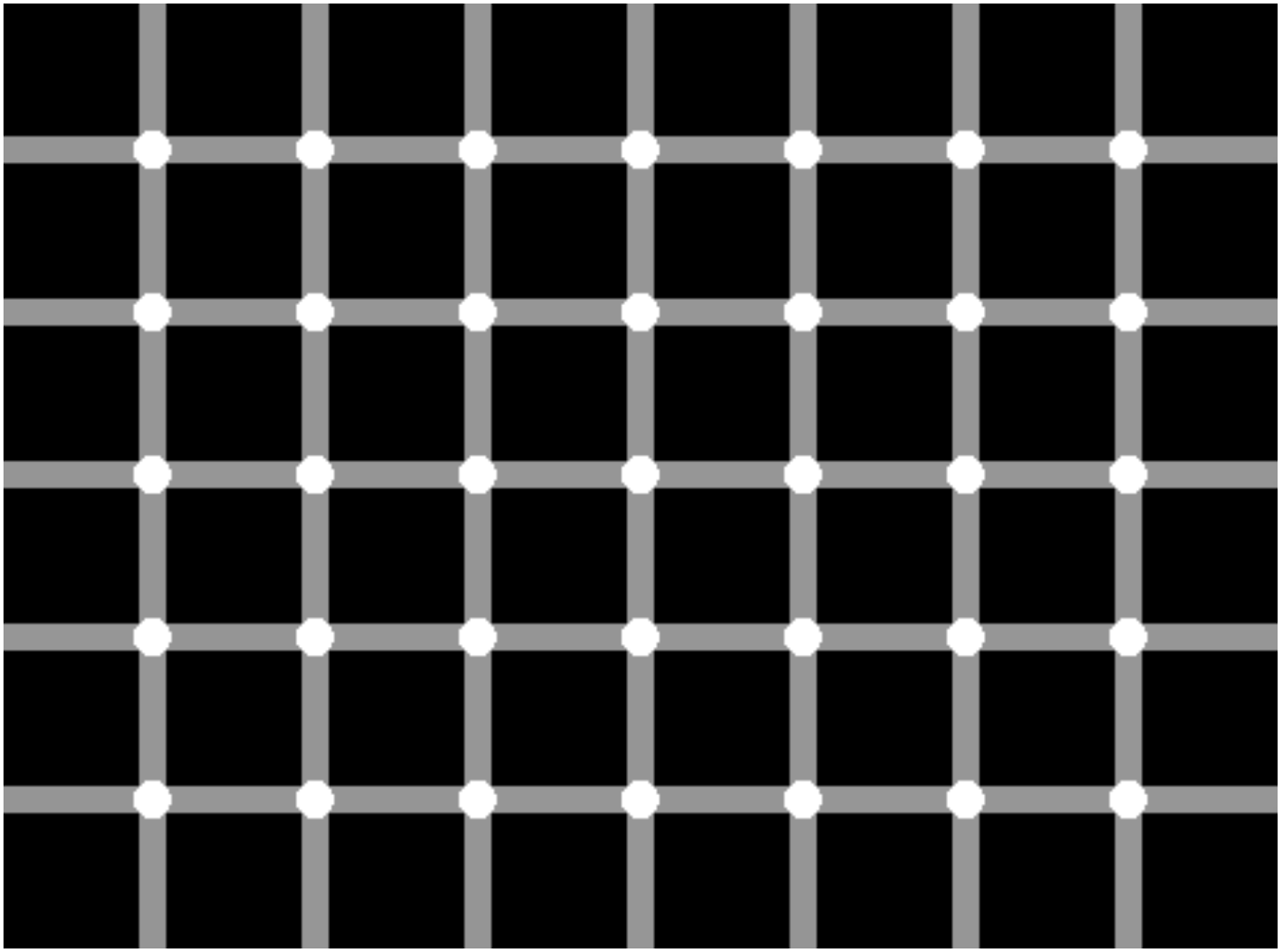
Same image, different perception



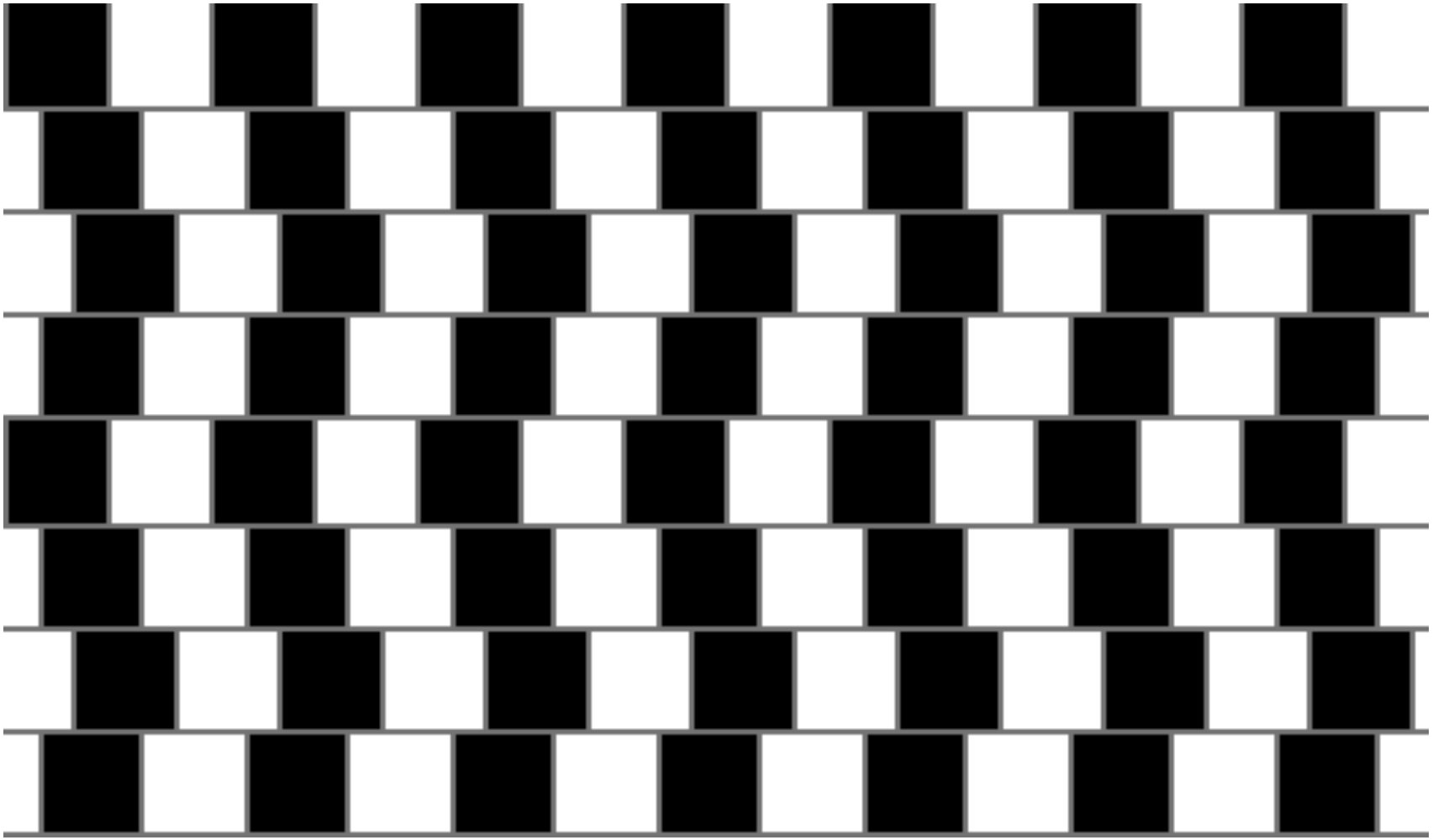




Count the black dots!



Are the horizontal lines parallel or do they slope?



To create your own

To create your own

http://illusionsetc.blogspot.com/2006/05/how-to-create-your-own-colorization.html

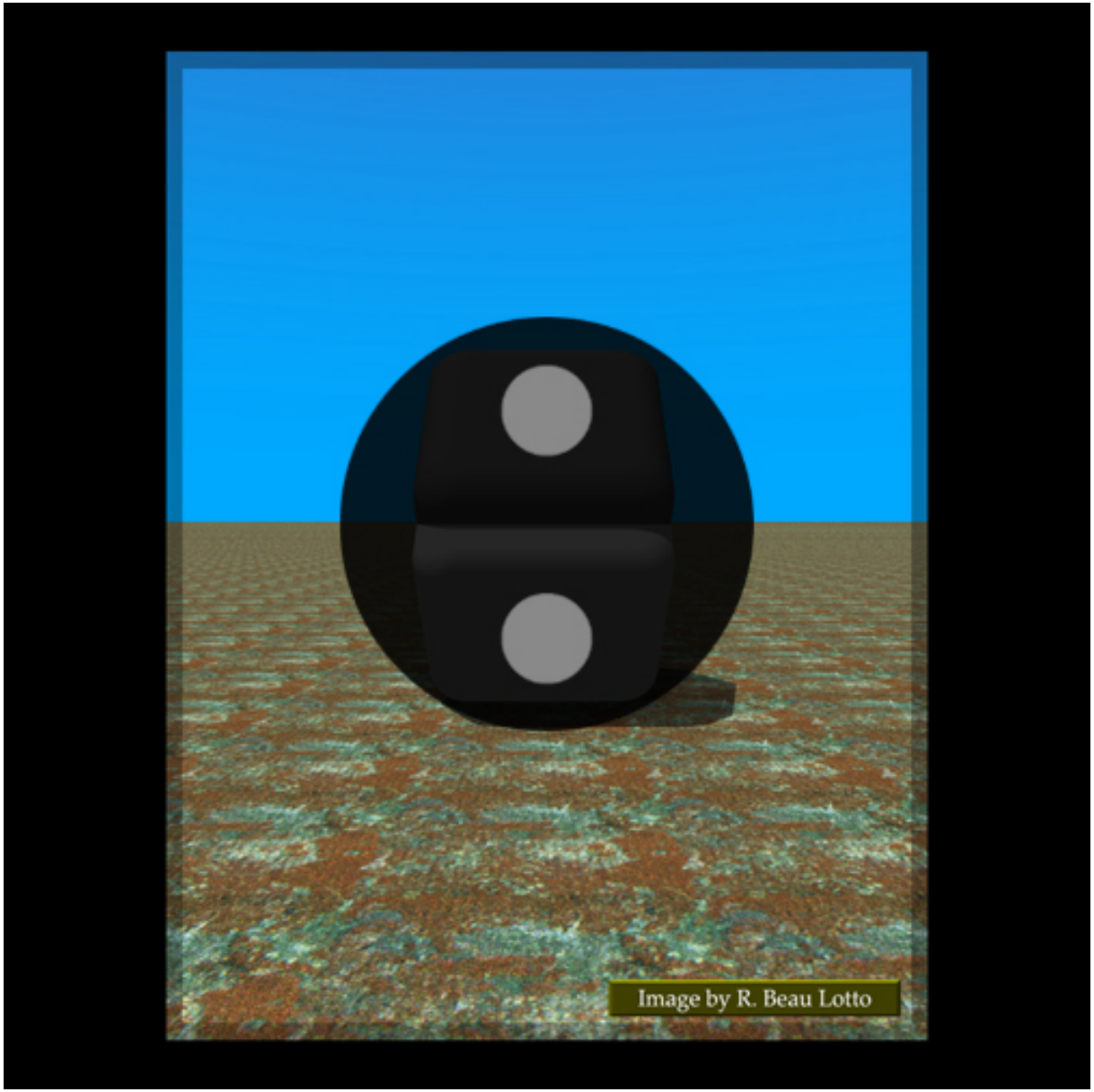
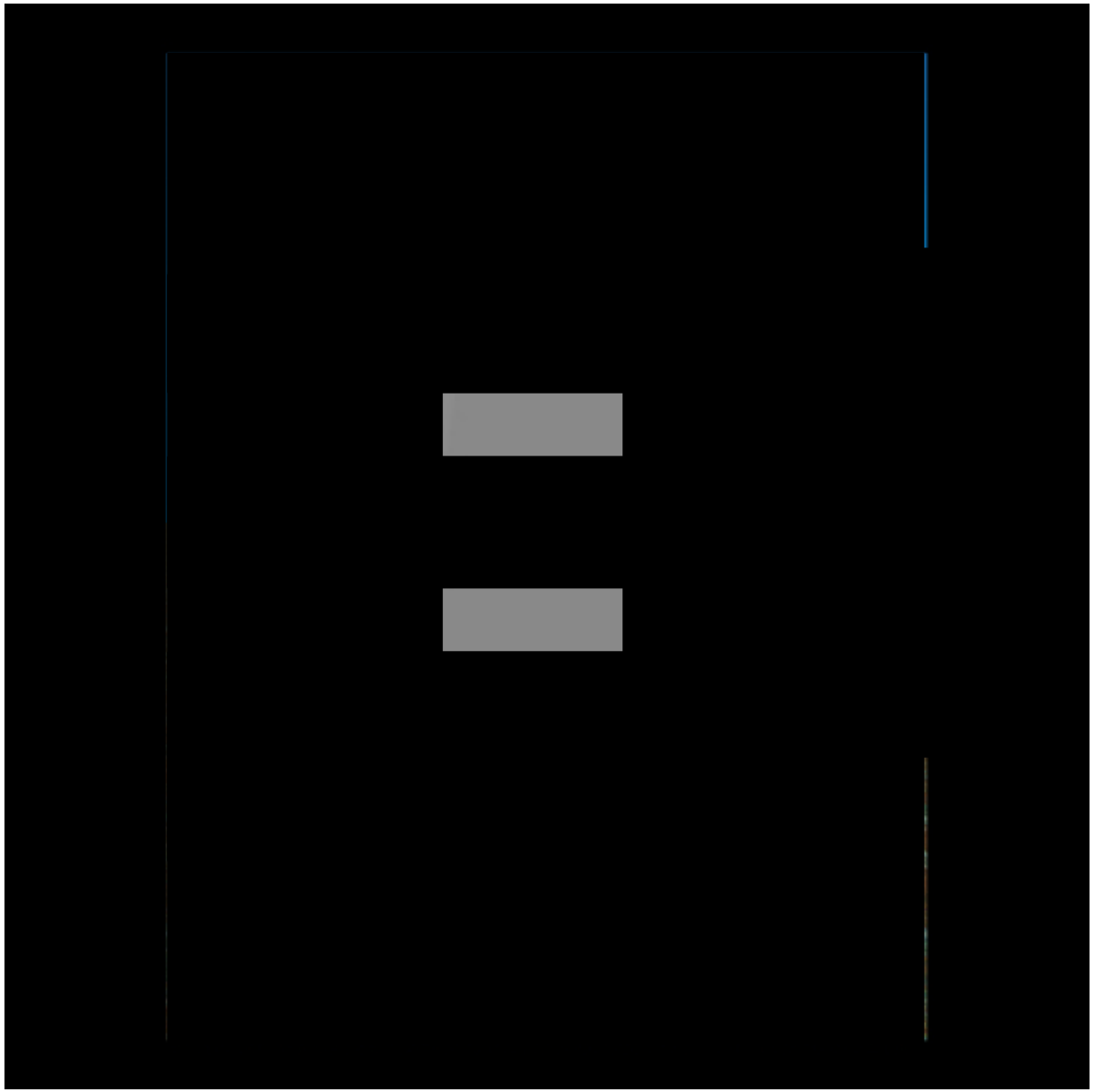
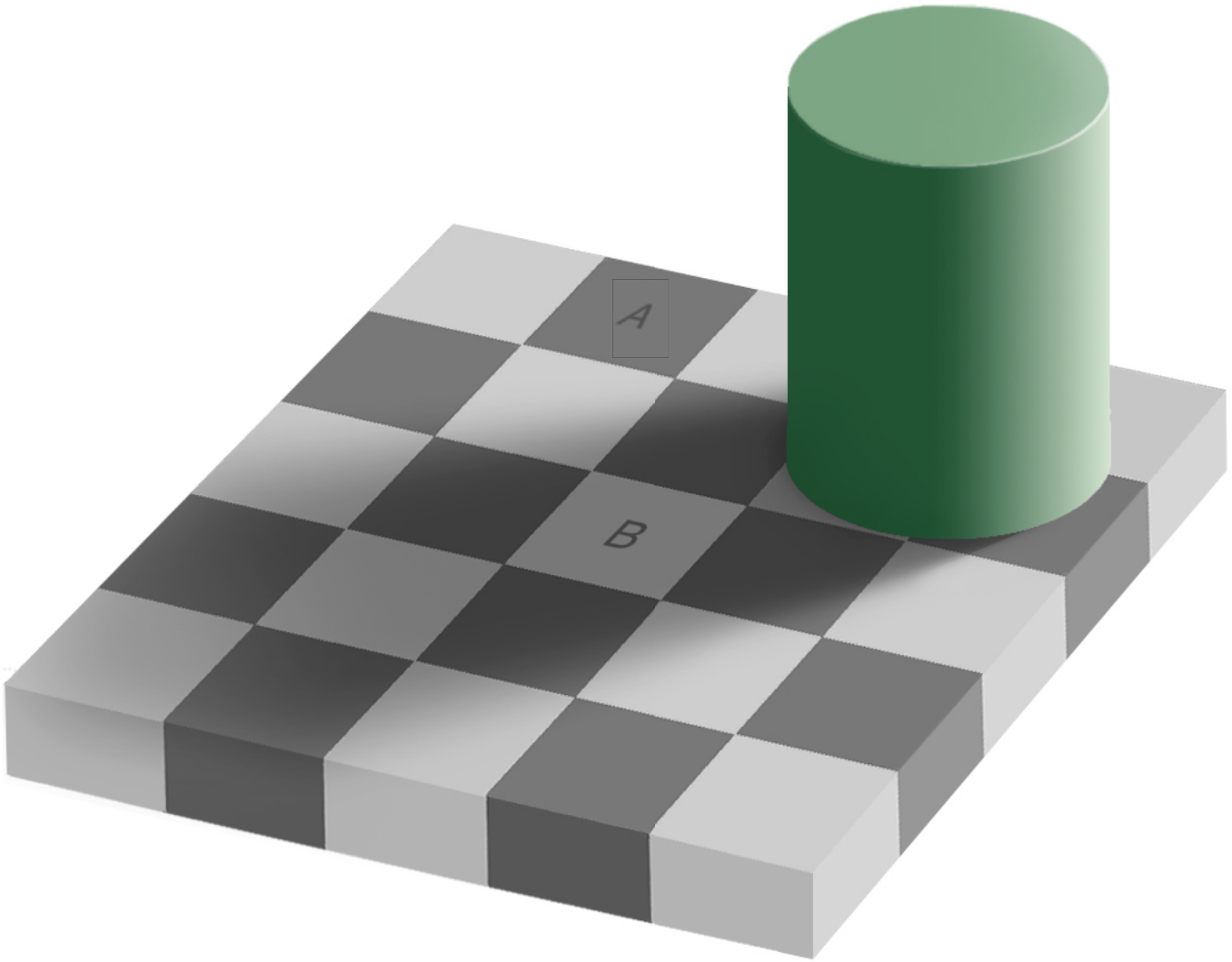


Image by R. Beau Lotto



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

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.

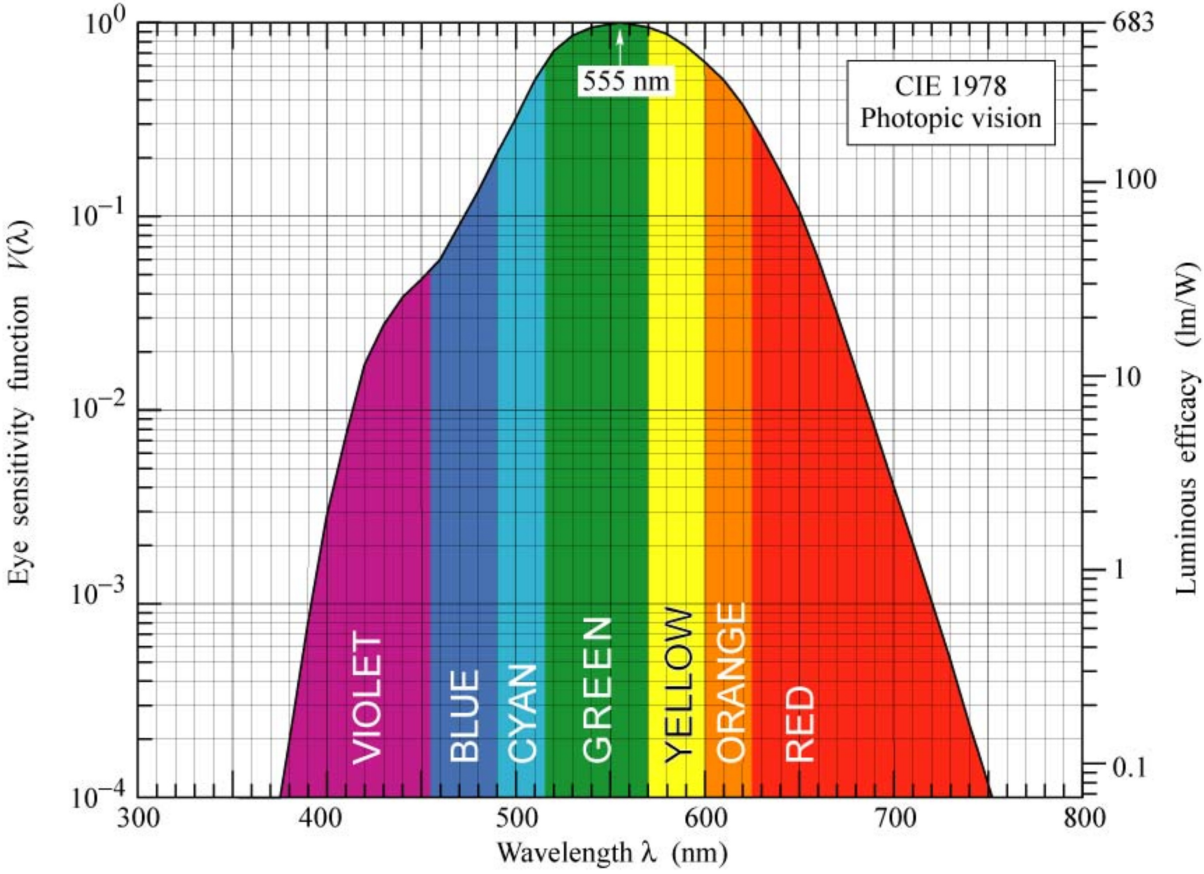


Fig. 16.7. Eye sensitivity function, $V(\lambda)$, (left ordinate) and luminous efficacy, measured in lumens per Watt of optical power (right ordinate). $V(\lambda)$ is greatest at 555 nm. Also given is a polynomial approximation for $V(\lambda)$ (after 1978 CIE data).

Objective or subjective color phenomena?

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

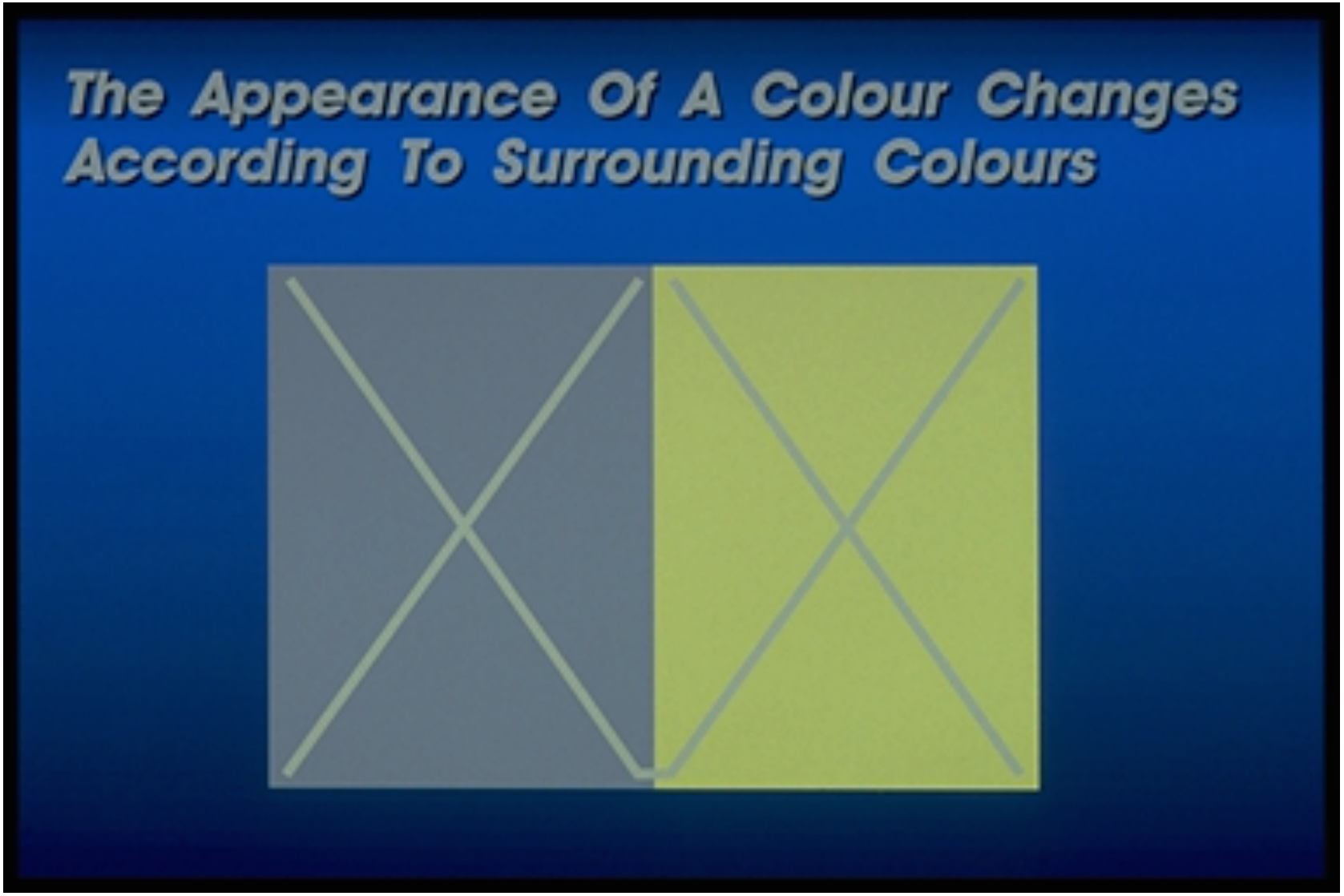
Objects that are seen as highly colored, and easily discriminable in daylight, lose their colors when viewed under sodium vapor light

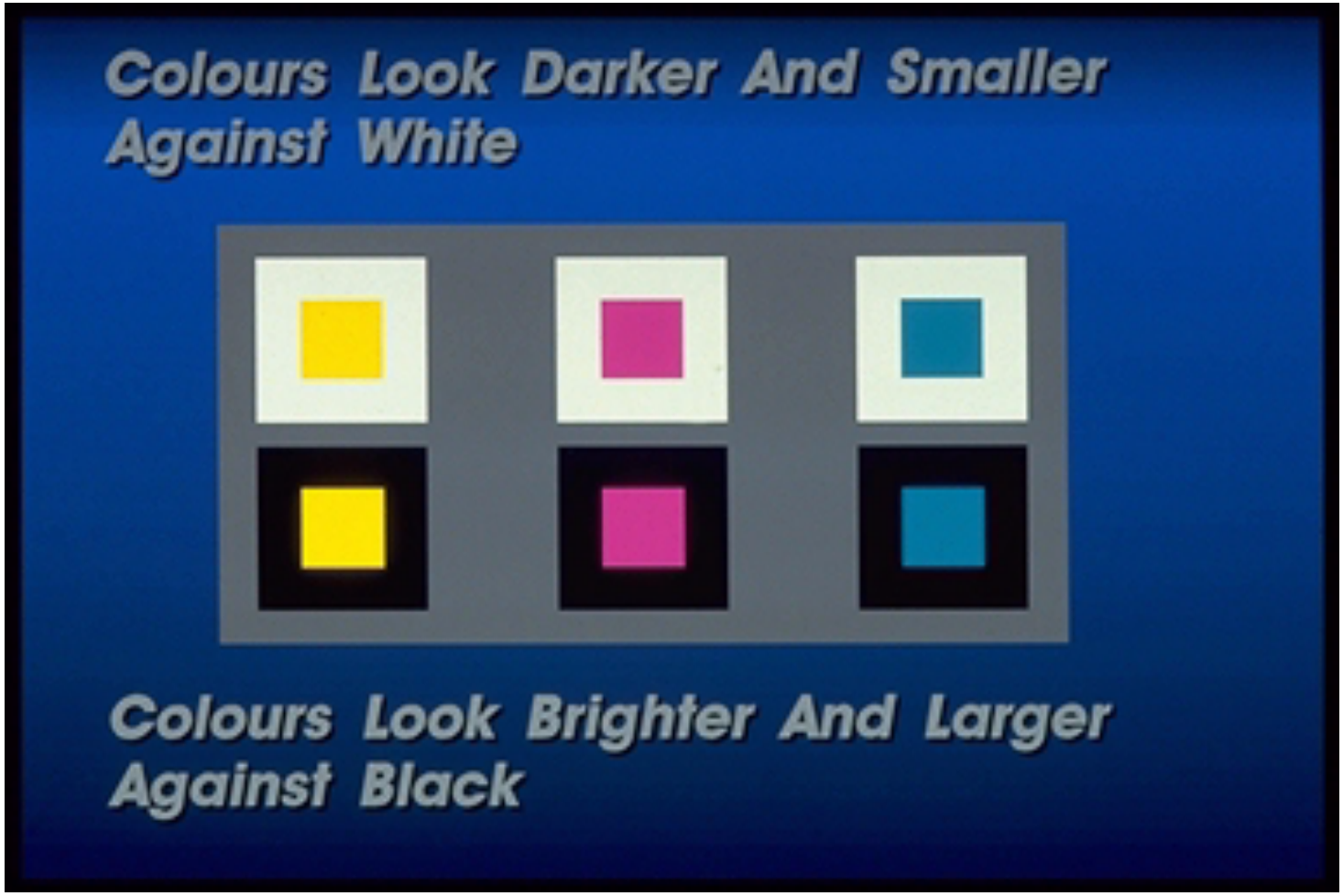
Color and appearance

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

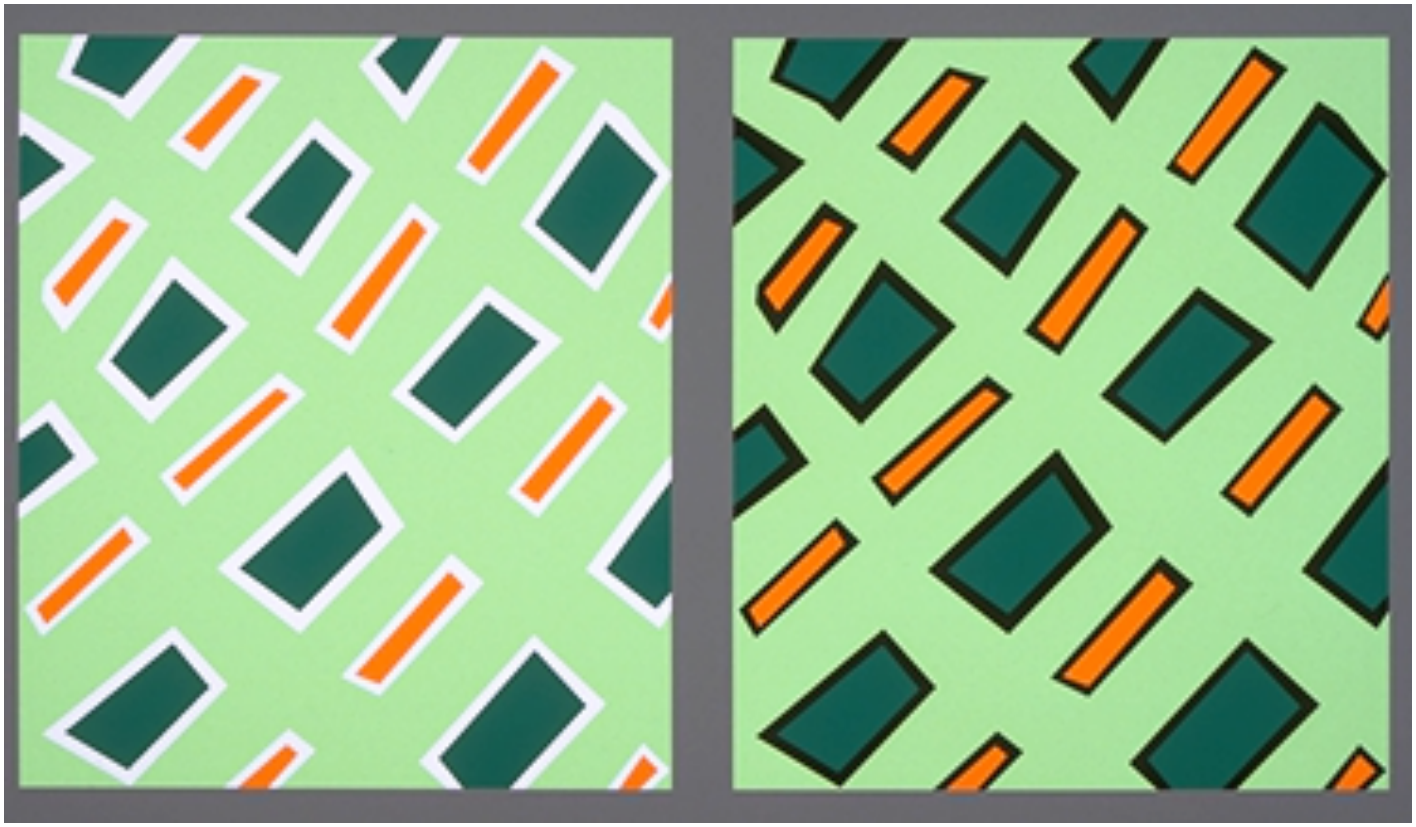
The importance of the surround



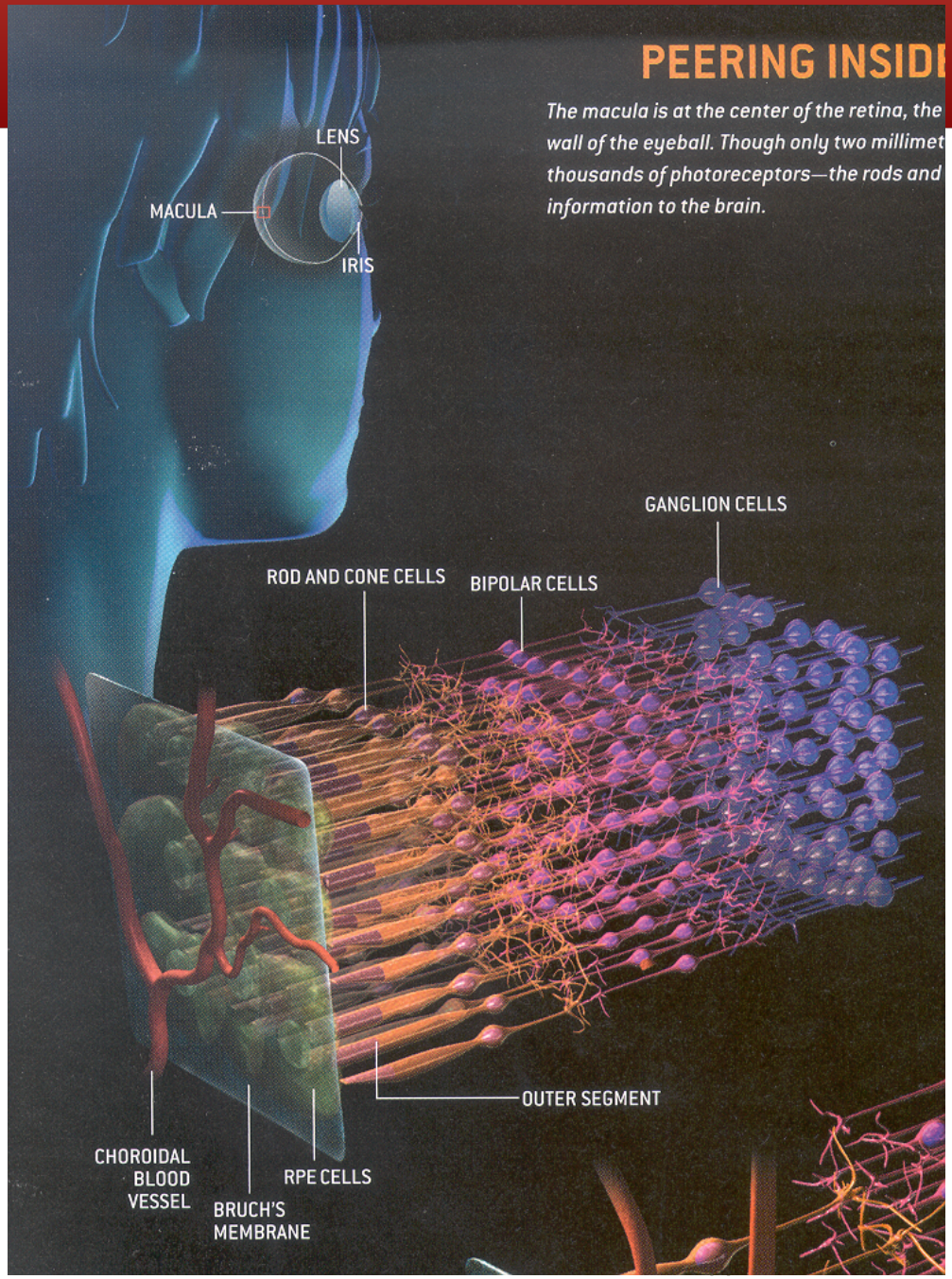


This is caused by the local adaptation of the retinal response. The neural systems "fills in" the area to be consistent with its perception of the edge contrast

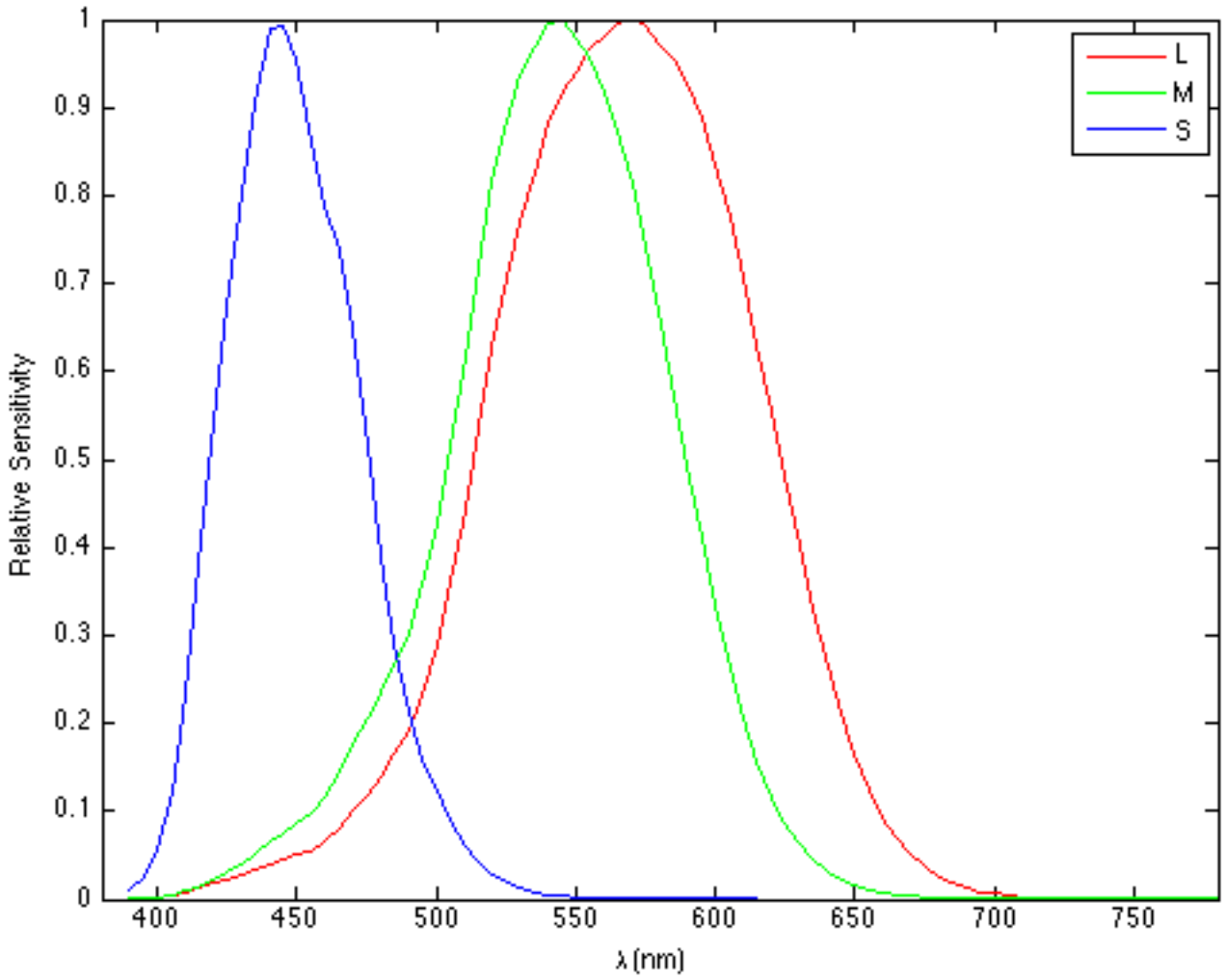
Bezold effect



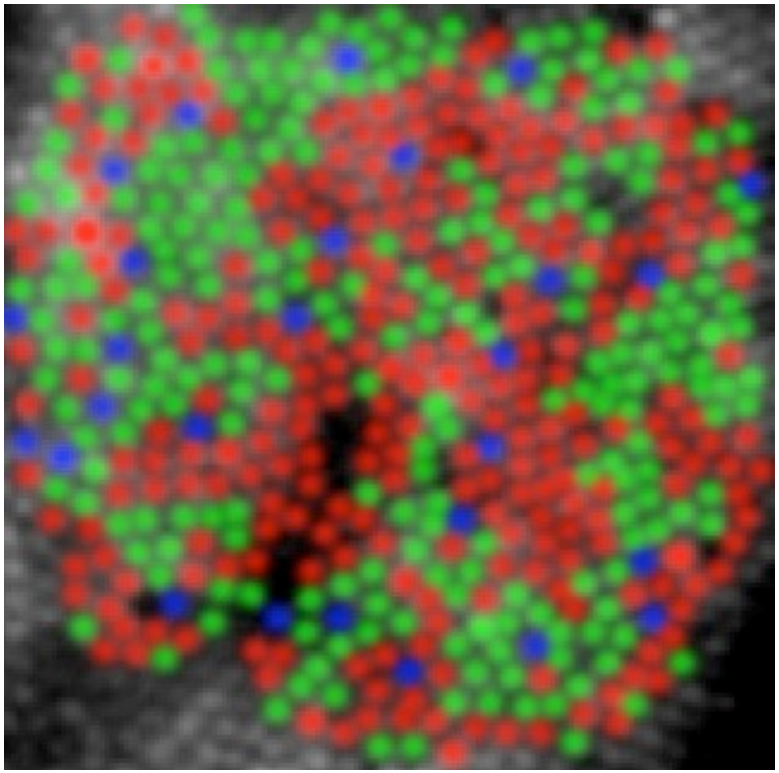
Because the appearance of any color depends on the color of its surround, the change of just one color in a geometric design changes the appearance of the overall design

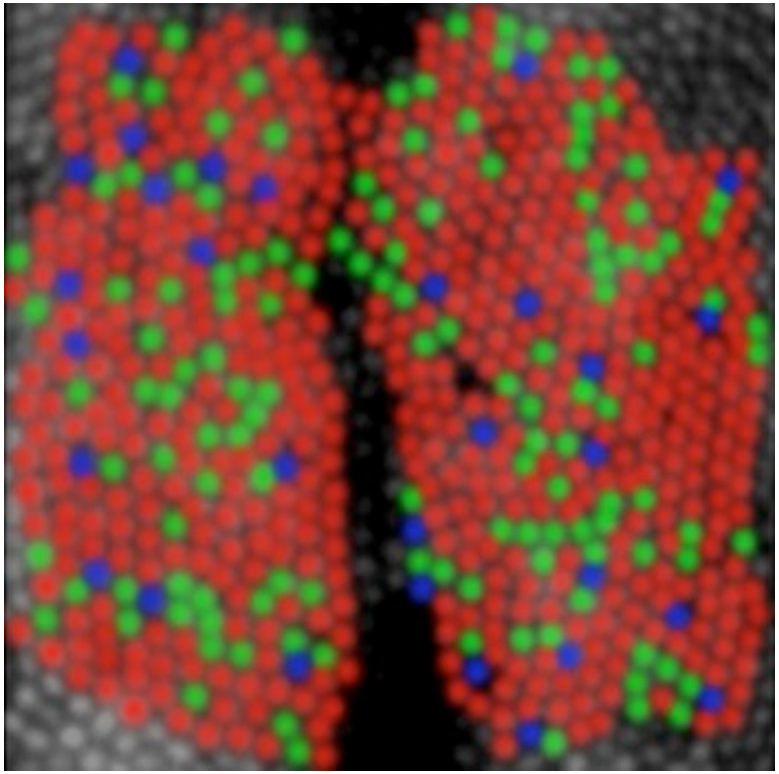

PEERING INSIDE
The macula is at the center of the retina, the
wall of the eyeball. Though only two millimet
thousands of photoreceptors—the rods and
information to the brain.
LENS
MACULA
IRIS
GANGLION CELLS
ROD AND CONE CELLS
BIPOLAR CELLS
OUTER SEGMENT
CHOROIDAL BLOOD VESSEL
BRUCH'S MEMBRANE
RPE CELLS

Relative sensitivity of the eye: three cones



Cones Distribution





L 50.6% M 44.2% S 5.2%

L:M=1.15

L 75.8% M 20.0% S 4.2%

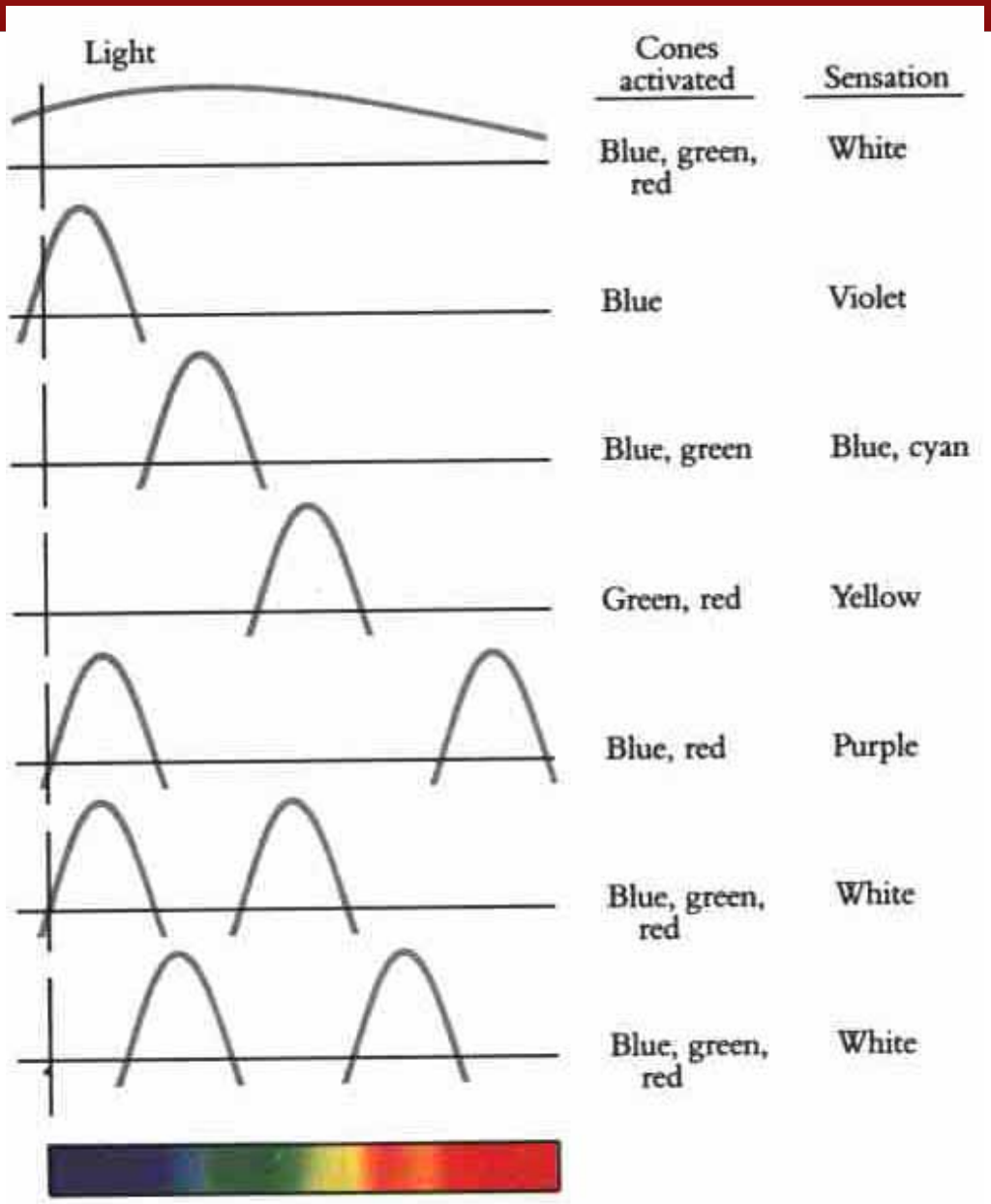
L:M=3.79

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.

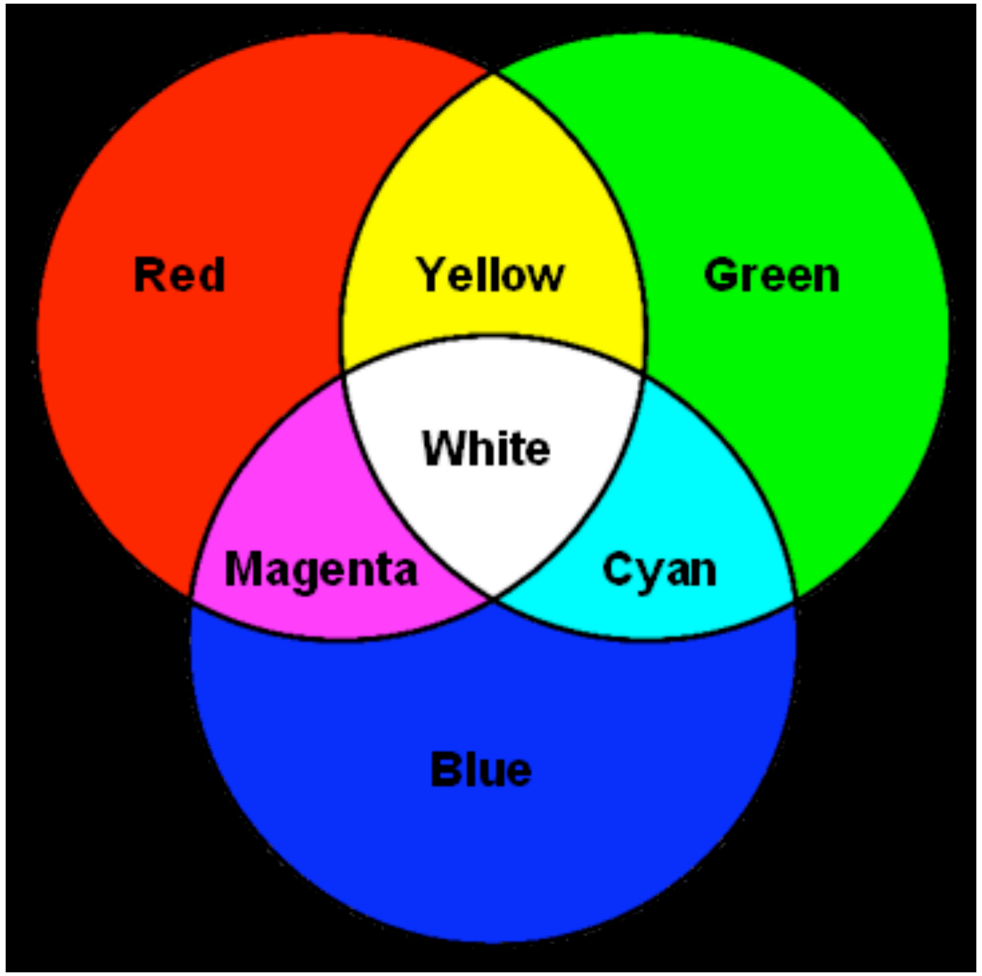
True!

Three colors!

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

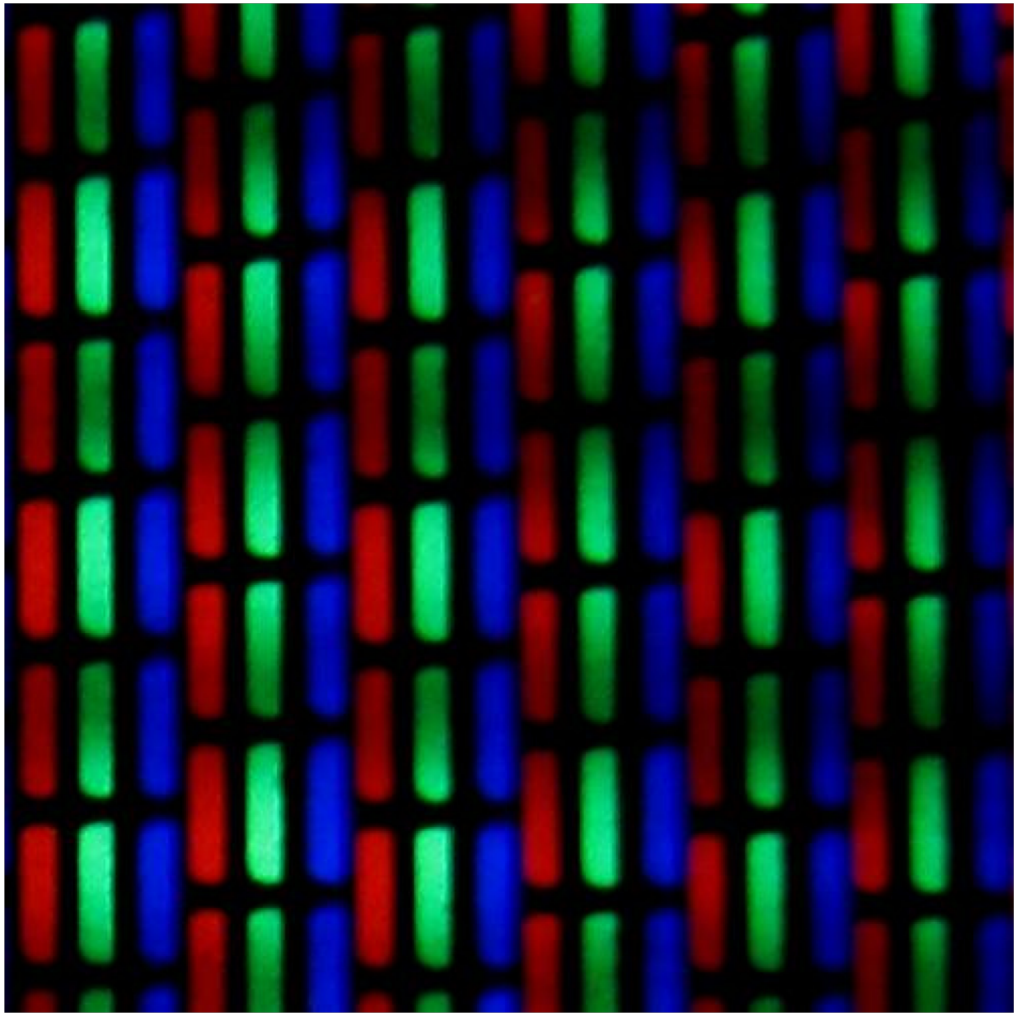
Additive synthesis



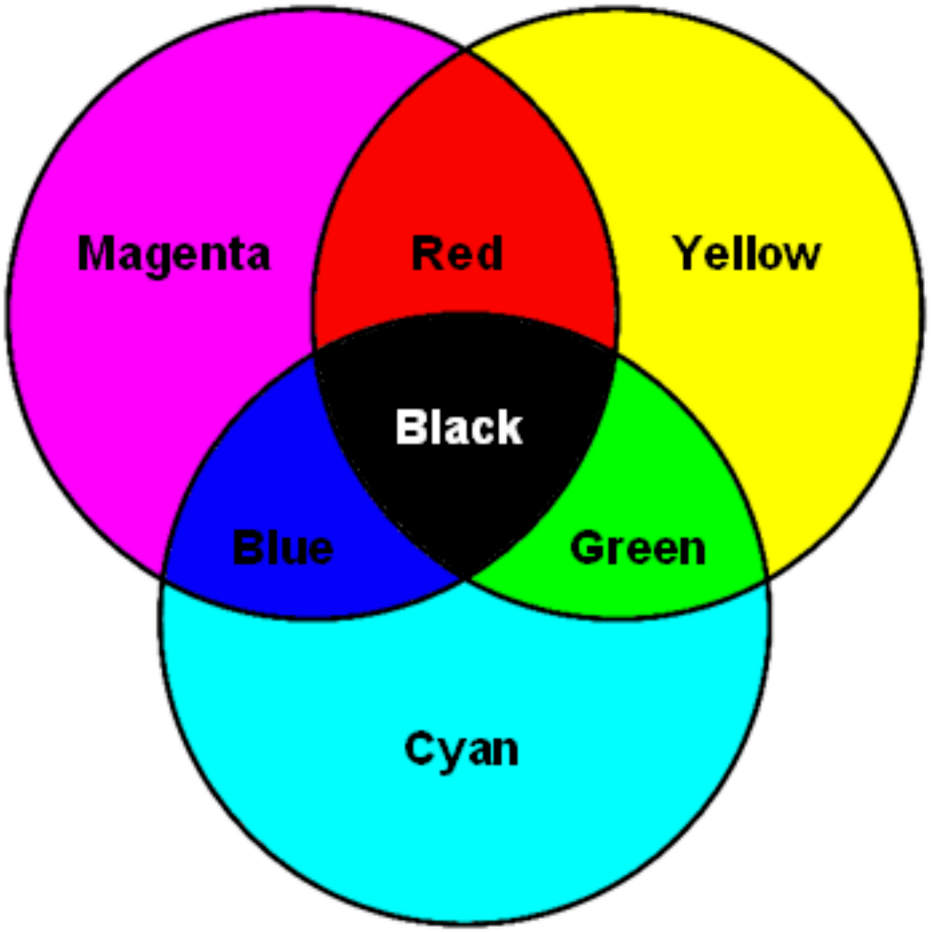
With red, green and blue a wider range of colors is available (in the real world, not in the physics world) for some of the combinations

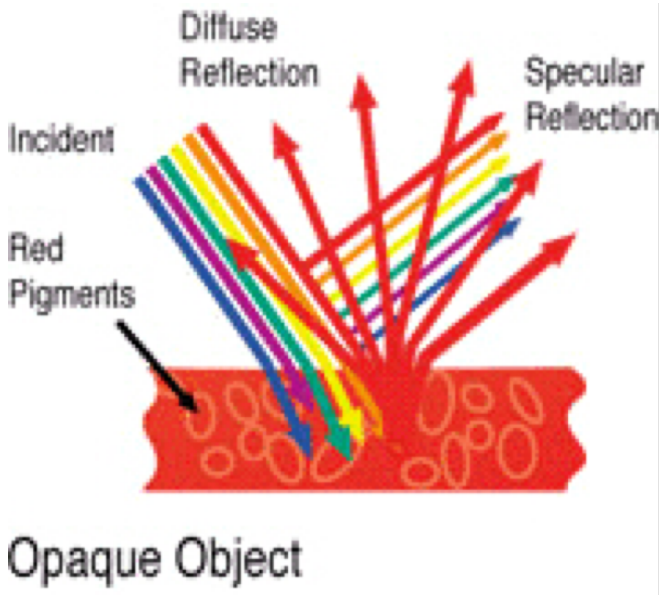
Examples of additive color effects

Lamp in stage productions, TV screen, computer monitor

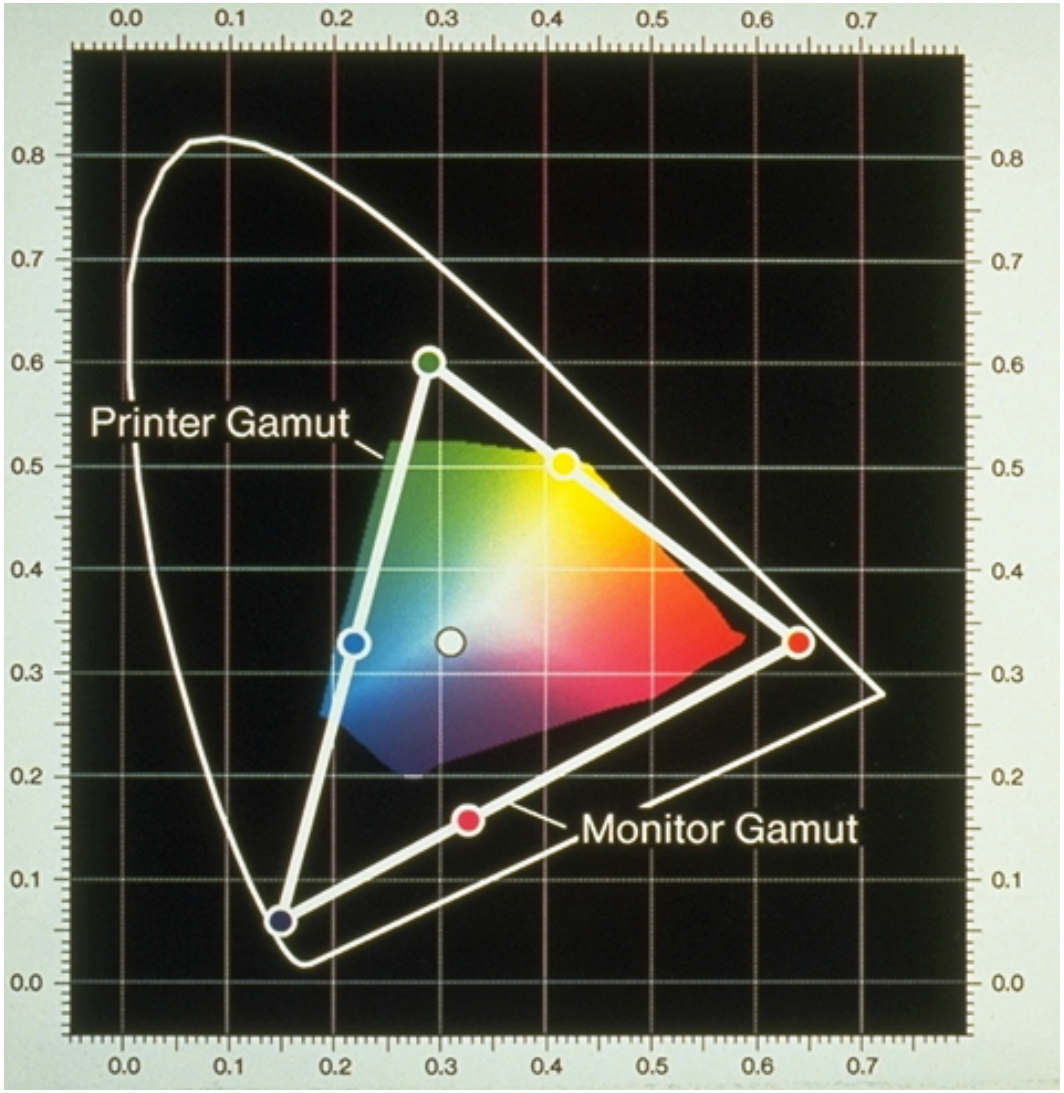


Subtractive synthesis





Unsolvable problem

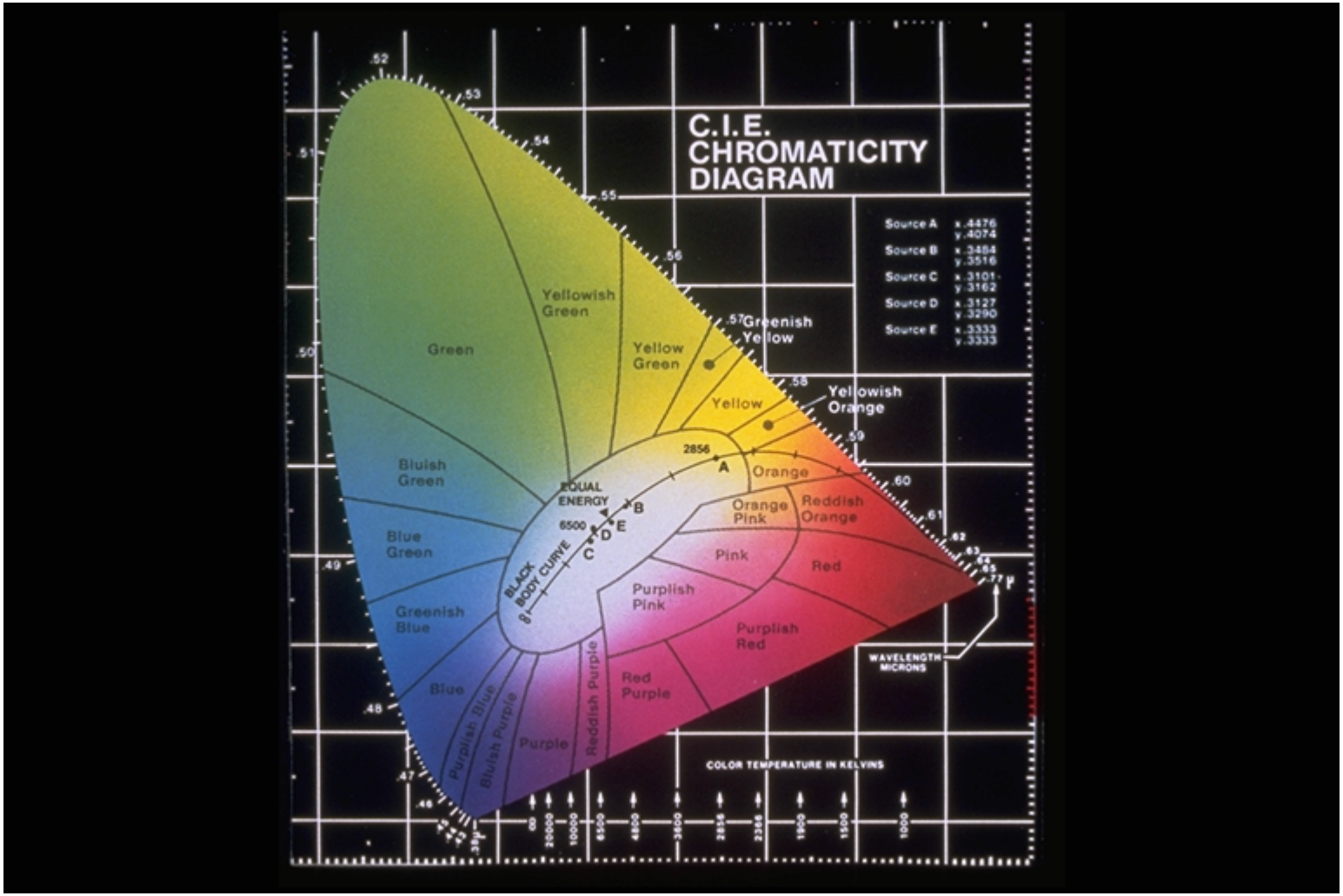


The standard observer CIE 1931

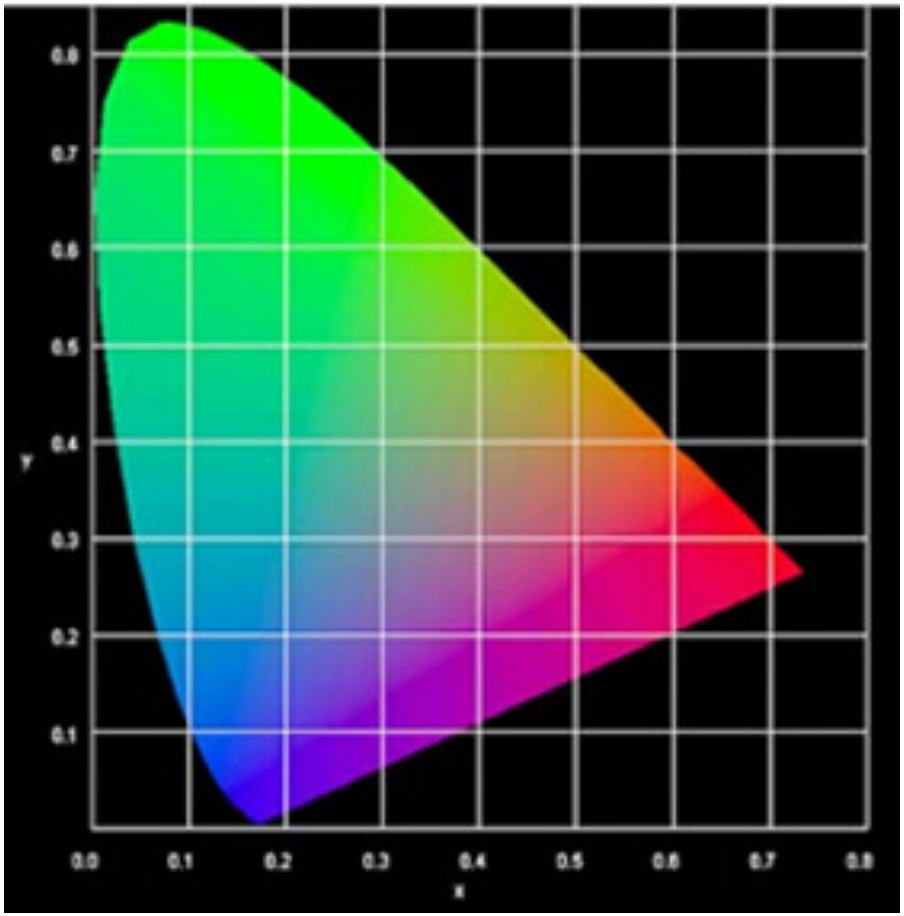
To obtain all the colors using only the plus sign the CIE in 1931 defined three imaginary colors X,Y,Z.

A color can be specified using three numbers

CIE chromaticity diagram



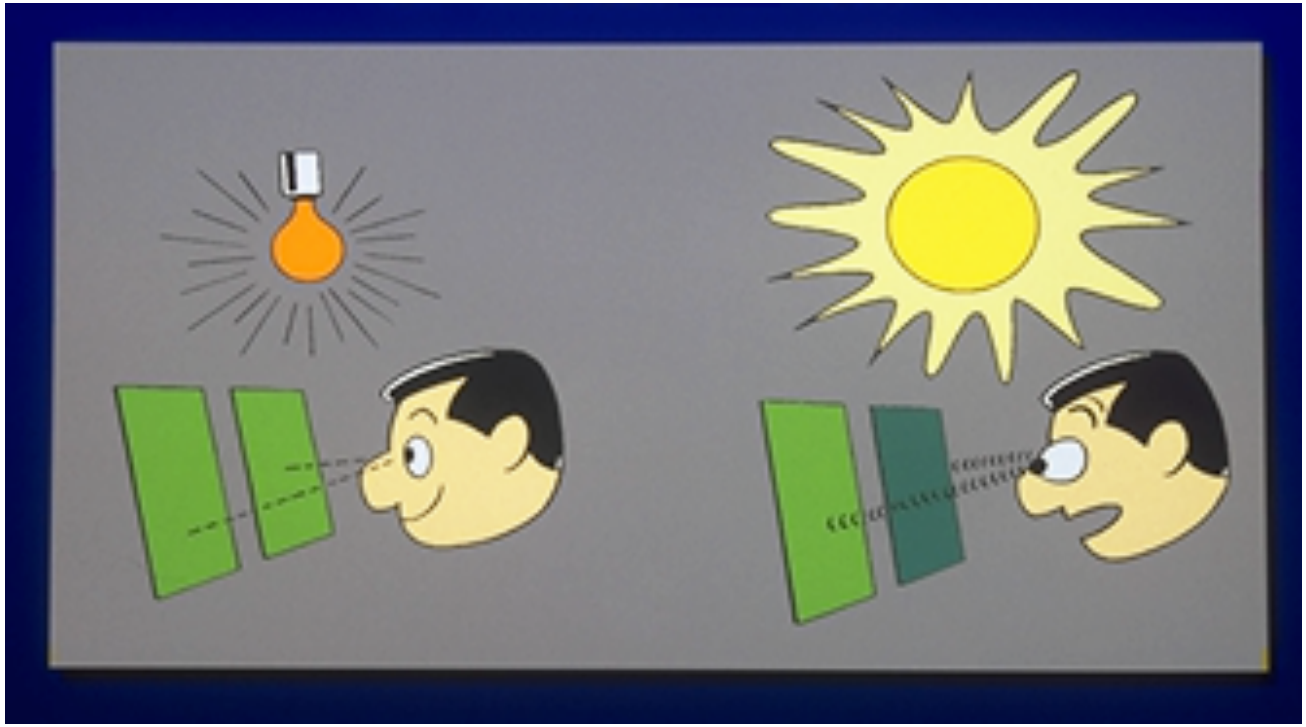
CIE chromaticity diagram



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)

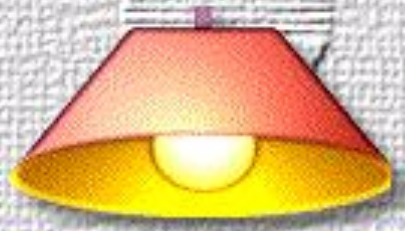
Metamerism

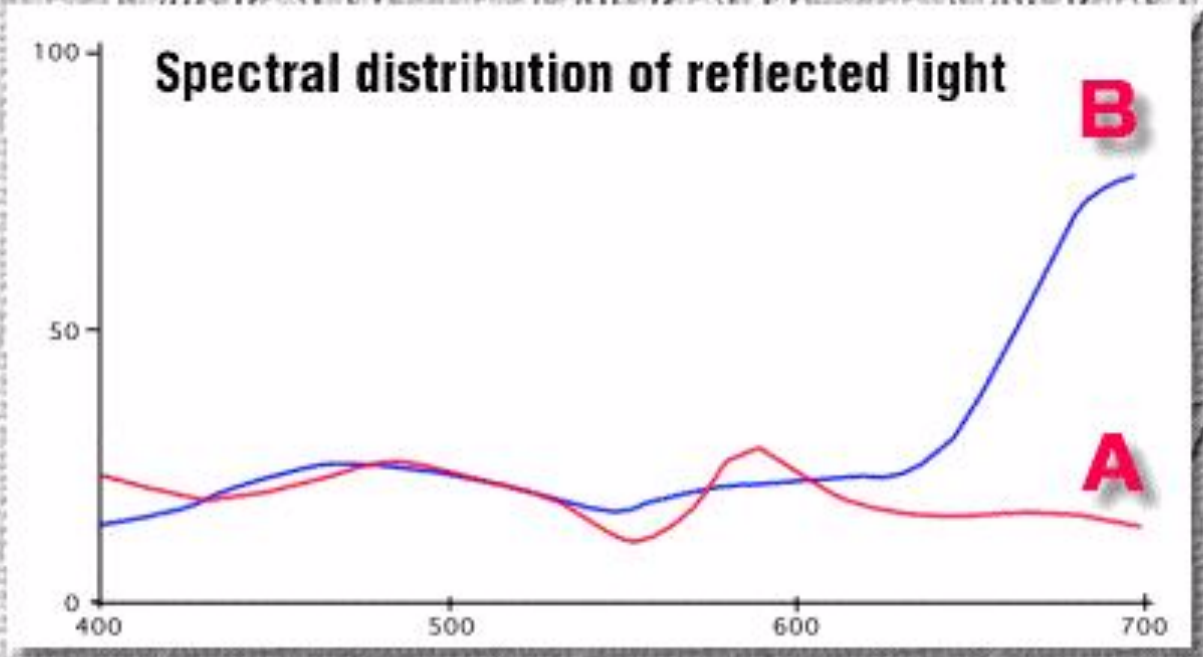
Colors may appear to match under one light source, but not under another: is the metamerism. Two colors that have the same appearance but different spectral reflectance distributions are defined a a metameric pair



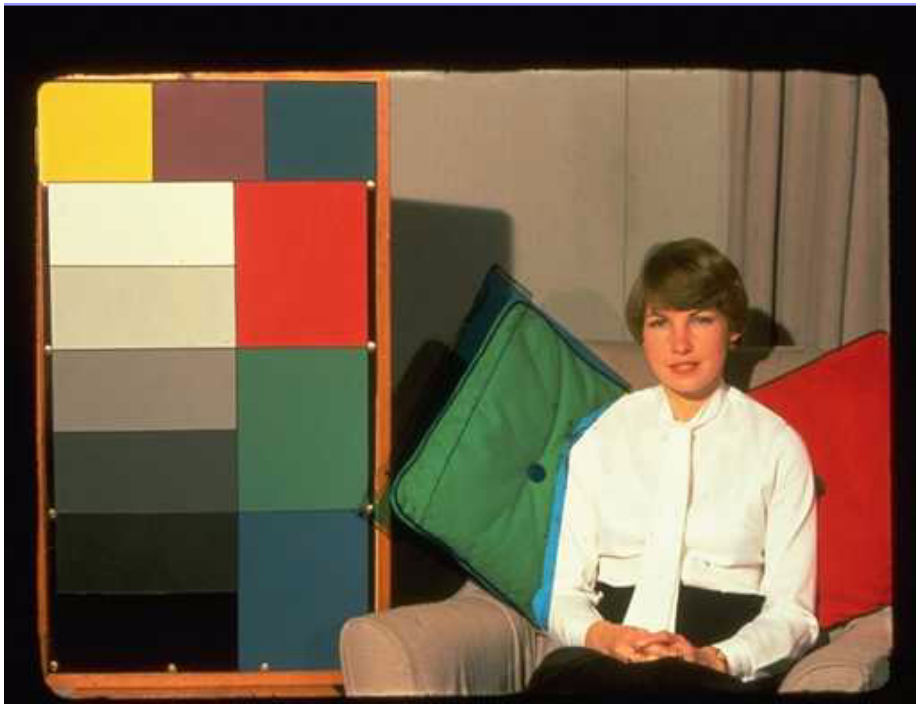
Standard
D_{65} Illumination

Standard
A Illumination

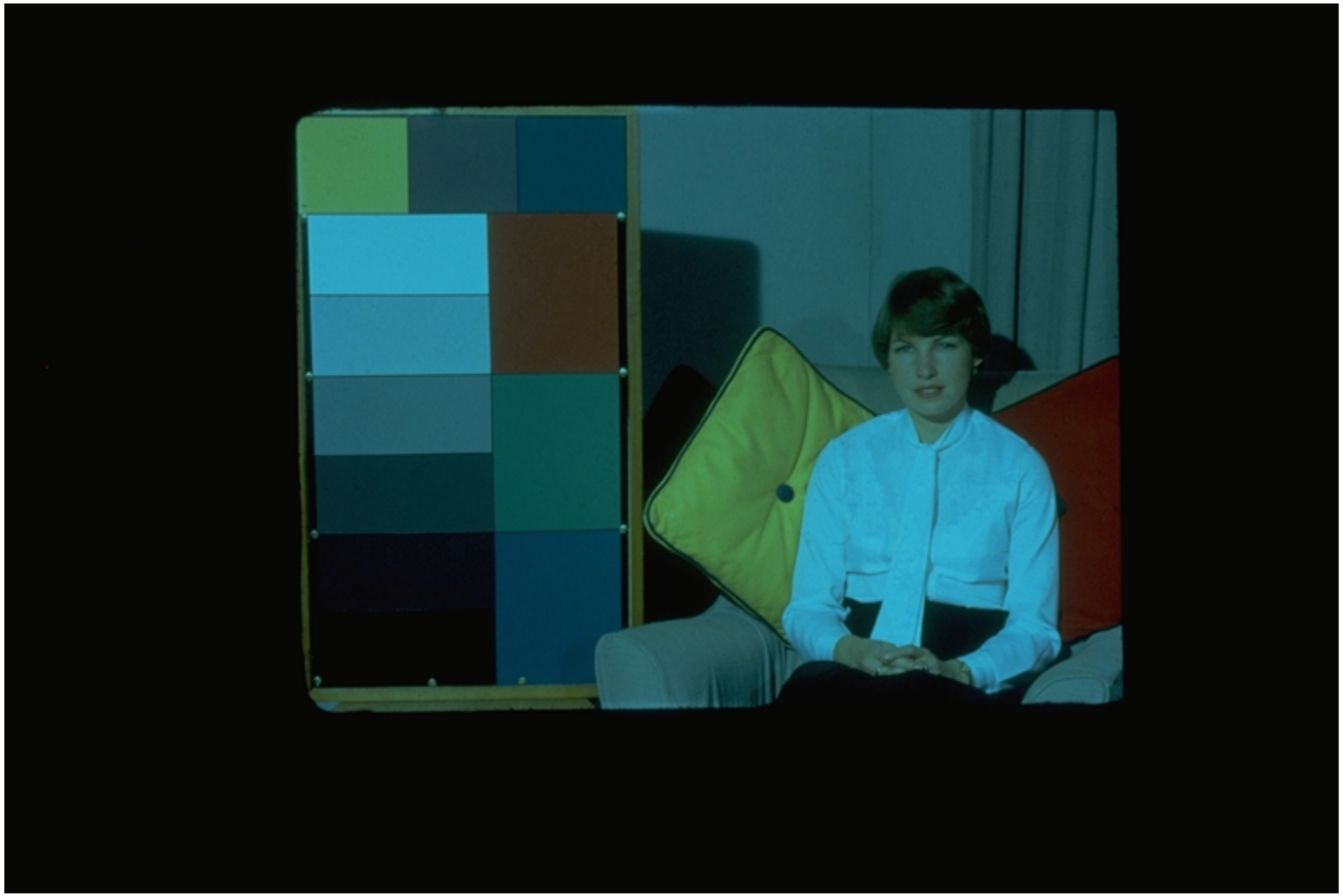




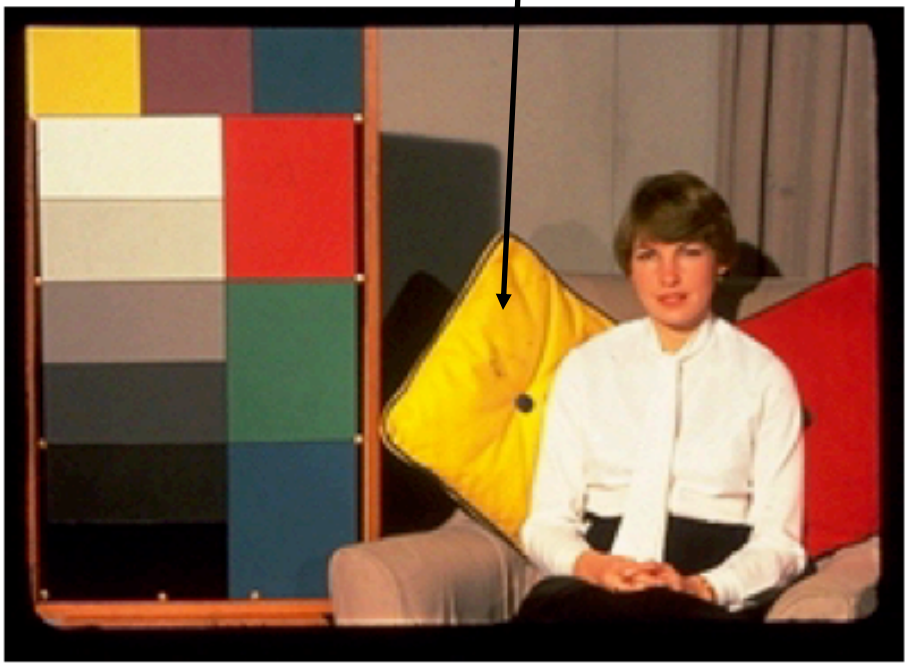
Color constancy

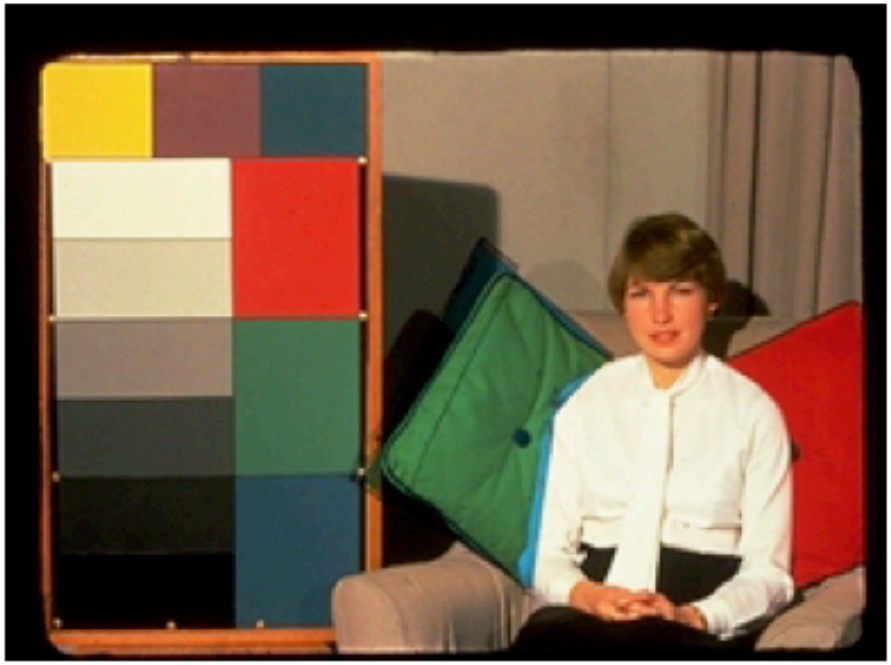


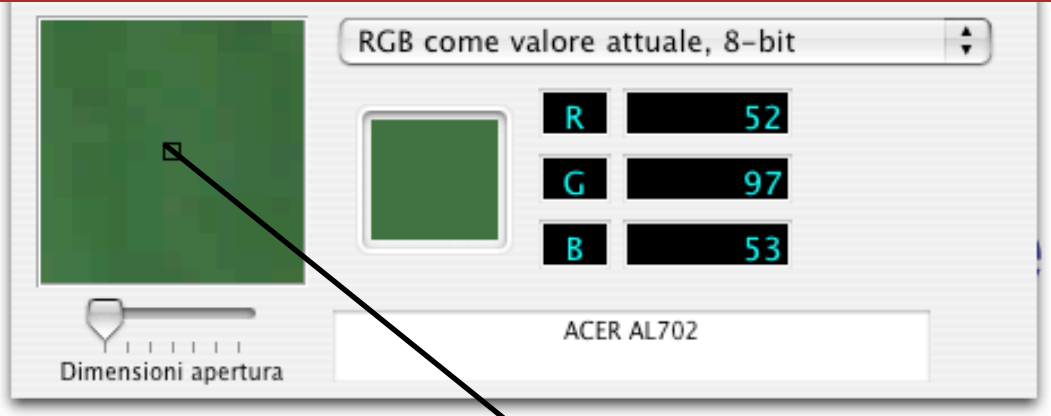
Color constancy

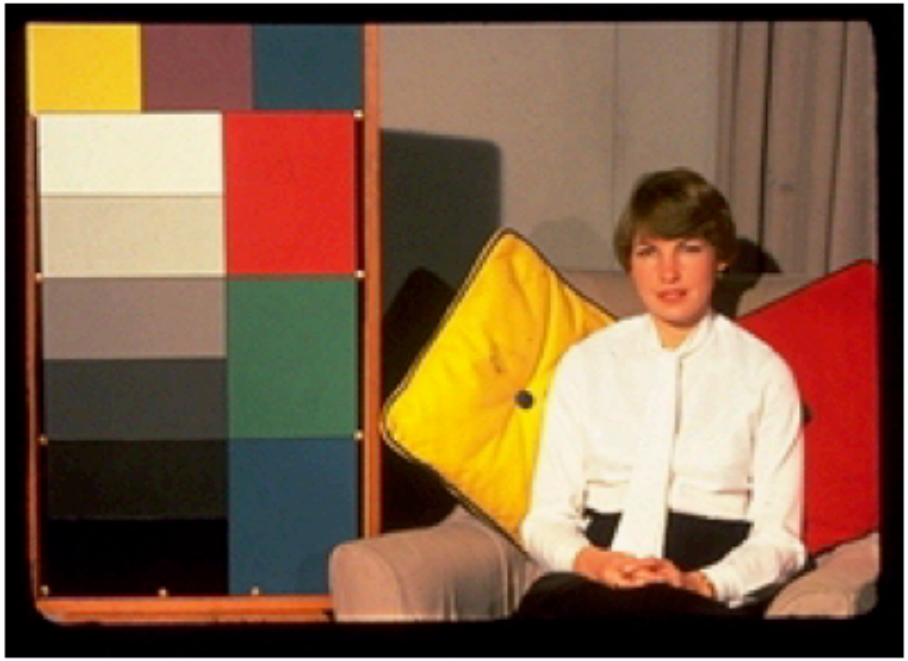


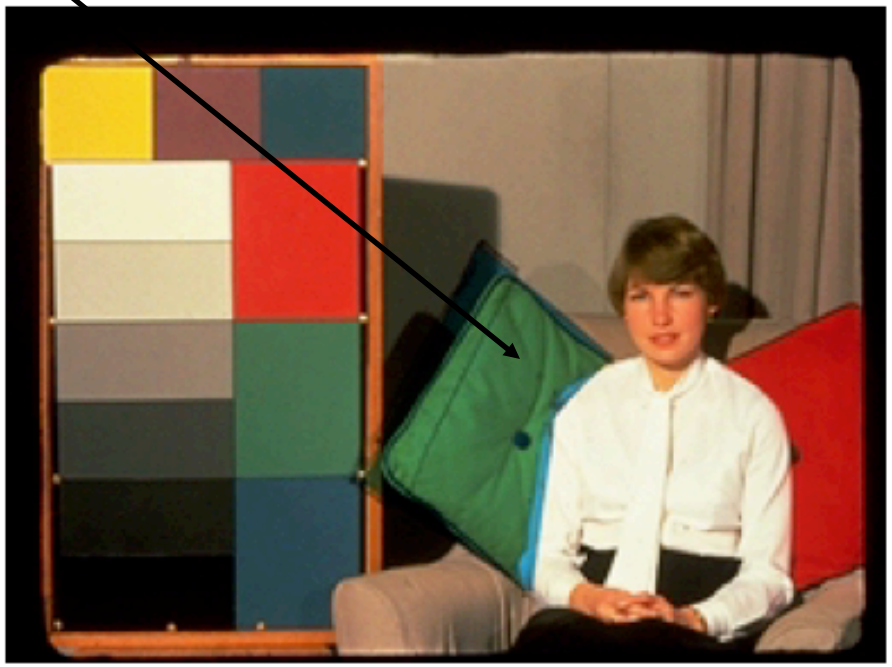

RGB come valore attuale, 8-bit
R
246
G
167
B
9
Dimensioni apertura
ACER AL702



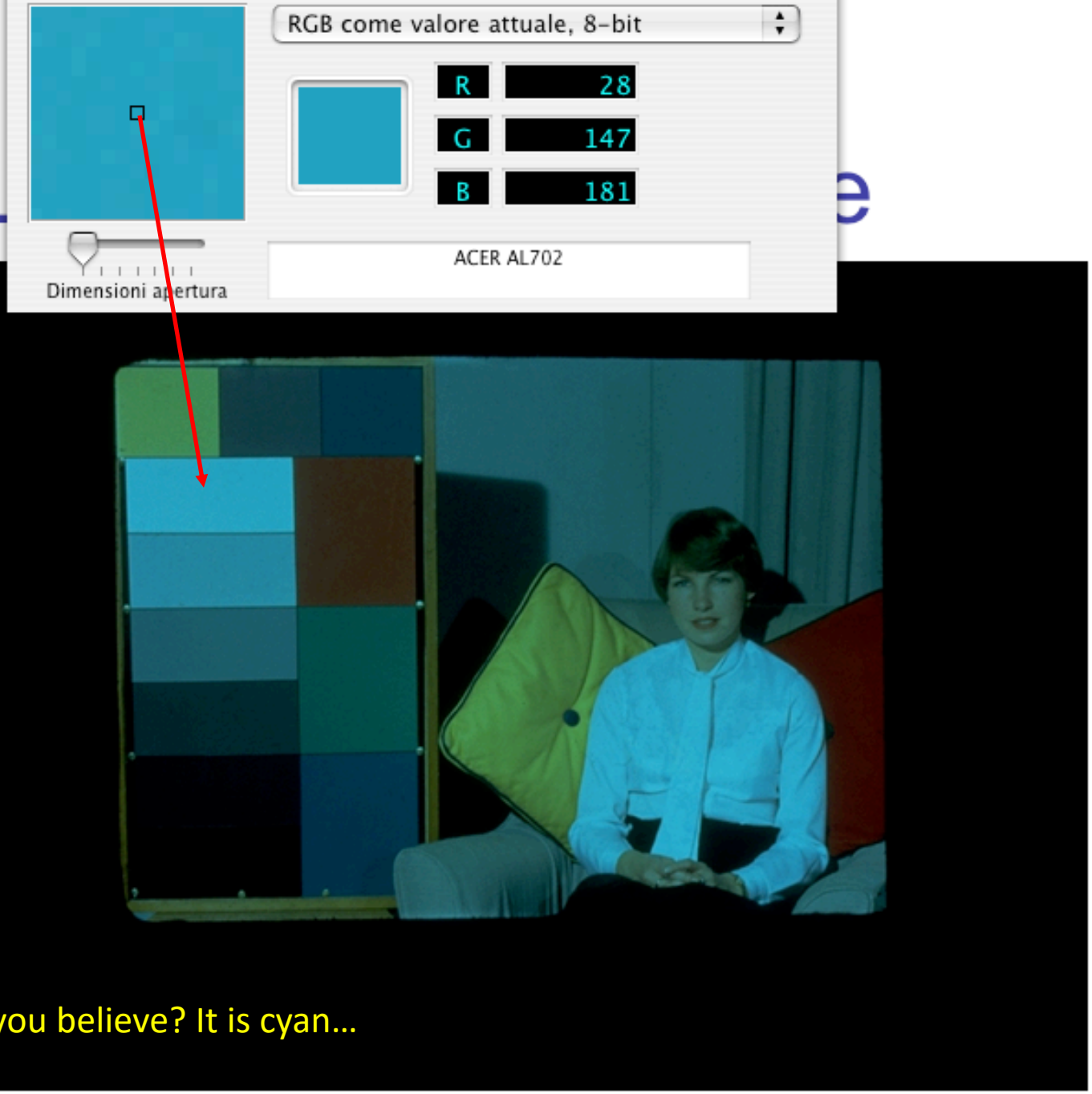



RGB come valore attuale, 8-bit
R
52
G
97
B
53
Dimensioni apertura
ACER AL702



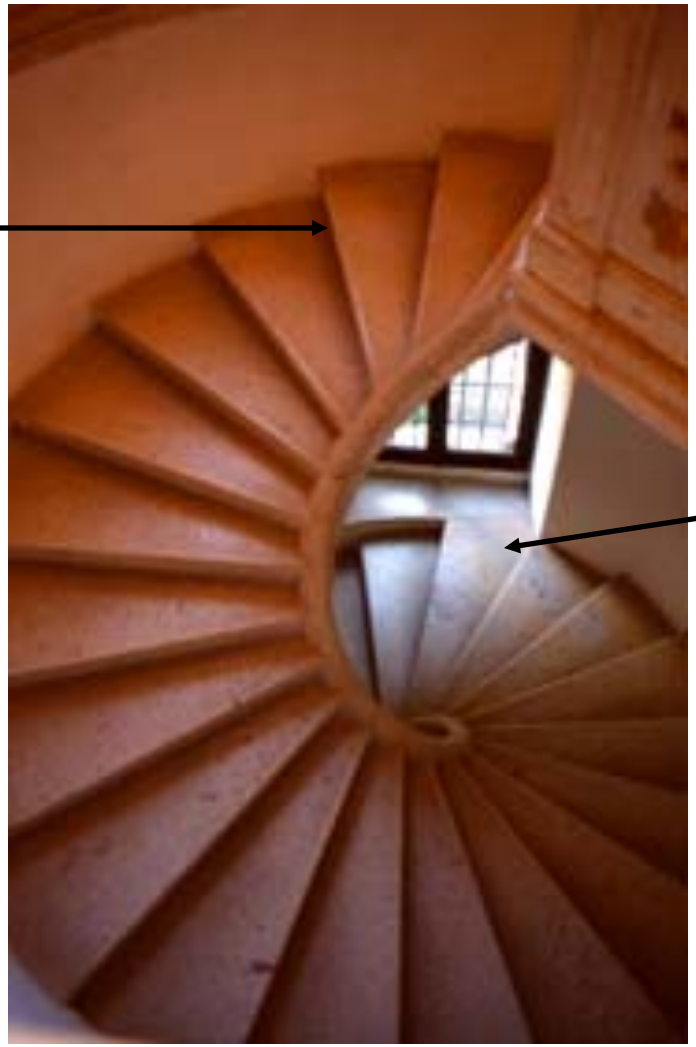


It is green, no doubt


RGB come valore attuale, 8-bit
R 28
G 147
B 181
ACER AL702
Dimensioni apertura
Do you believe? It is cyan…

Color constancy

Appears red

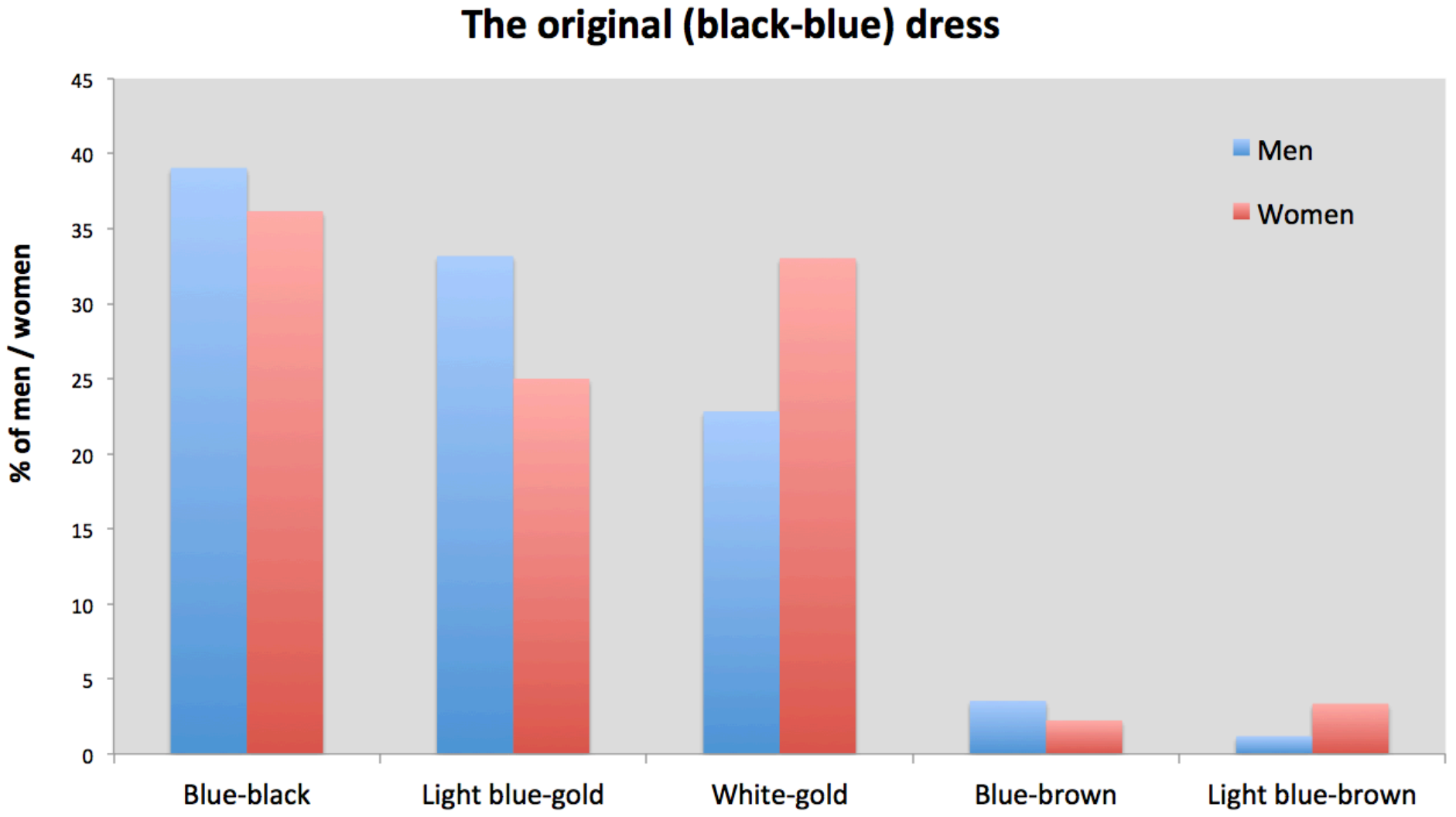


Appears white-bluish

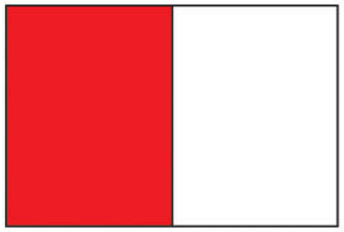
Same color, different perception?

#thedress
March 2015

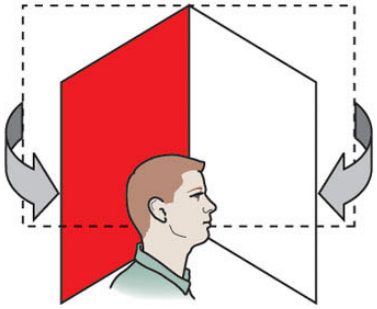
Kuvankappaus data



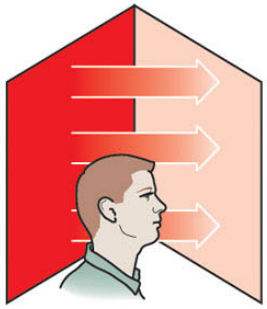
Esperimento di Bloj, Kersten, and Hurlbert



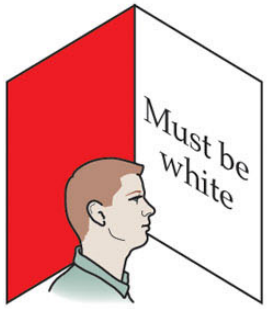
1. Start with a card half red, half white.



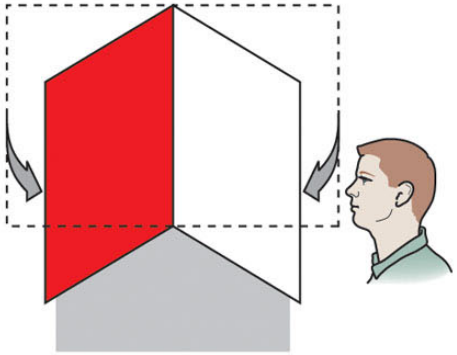
2. Fold it so that red faces white.



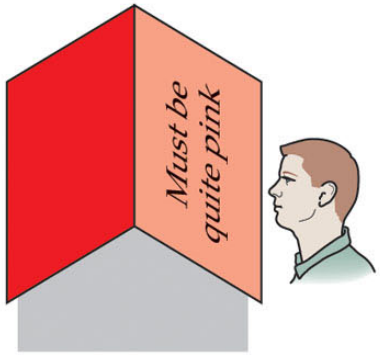
3. Light reflects from red onto white.



4. The visual system "knows" about the reflection and knows to discount it.

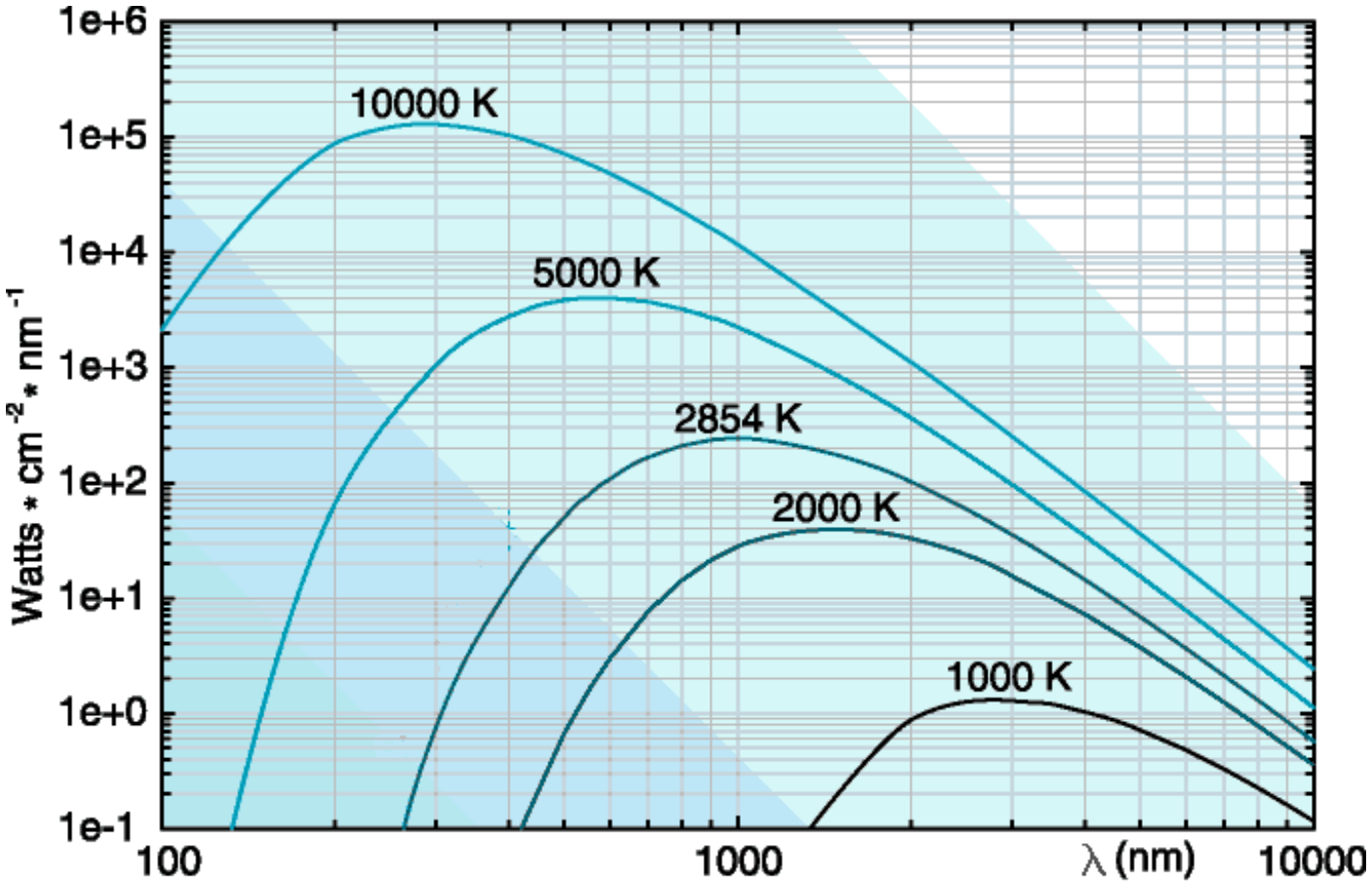


5. Now, fool the visual system into thinking the card is folded like a roof.



6. Without the reflection explanation, the white side now looks quite pink.

Black body


1e+6
1e+5
1e+4
1e+3
1e+2
1e+1
1e+0
1e-1
Watts * cm -2 * nm -1
10000 K
5000 K
2854 K
2000 K
1000 K
100
1000
λ (nm)
10000

Color temperature

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

Question

Is a candle a cold or a hot light source? Has It a low or high color temperature?

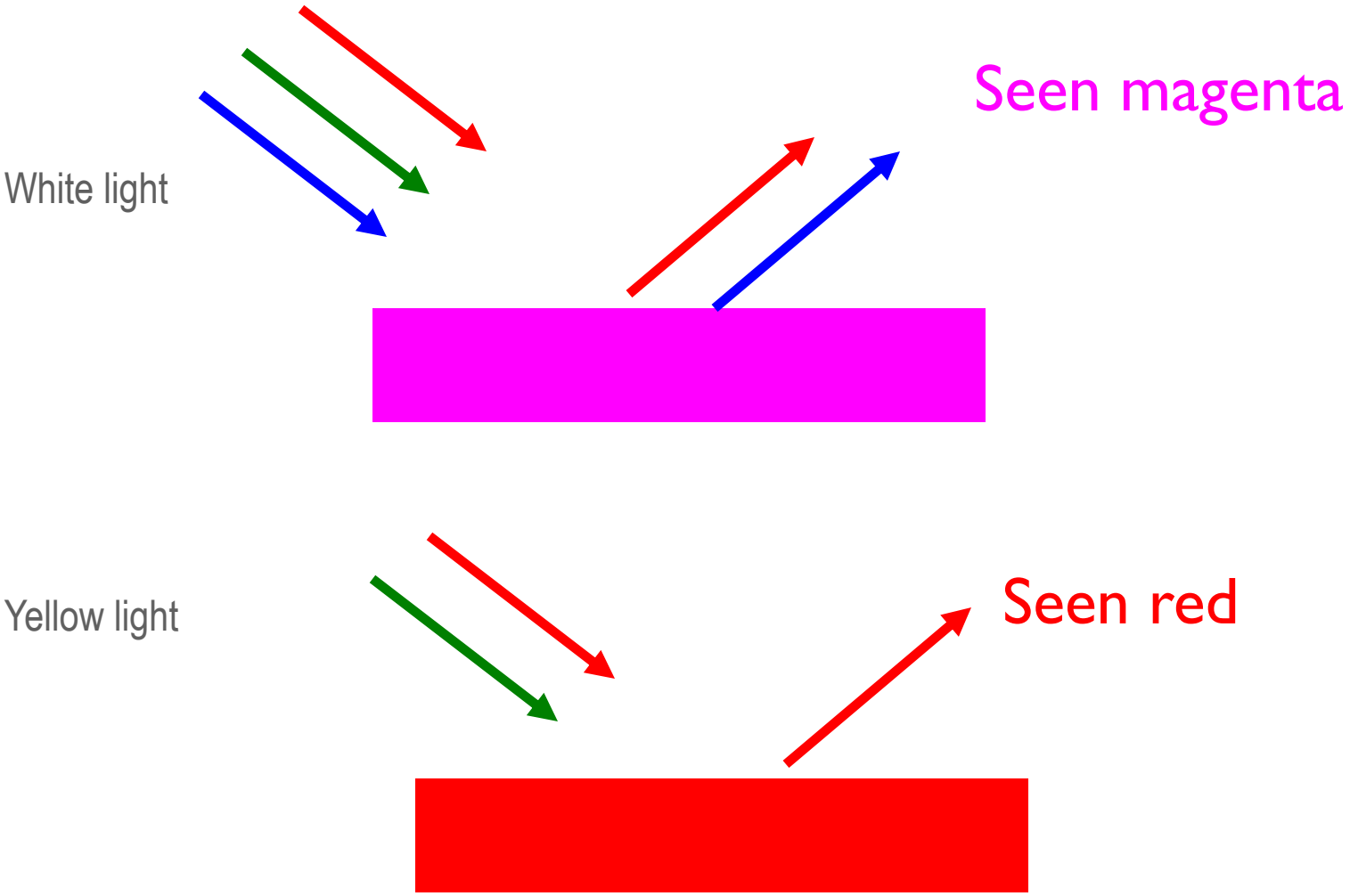
A candle is a hot source (psychologically speaking) and it has a low color temperature (physically speaking)

Color rendering index

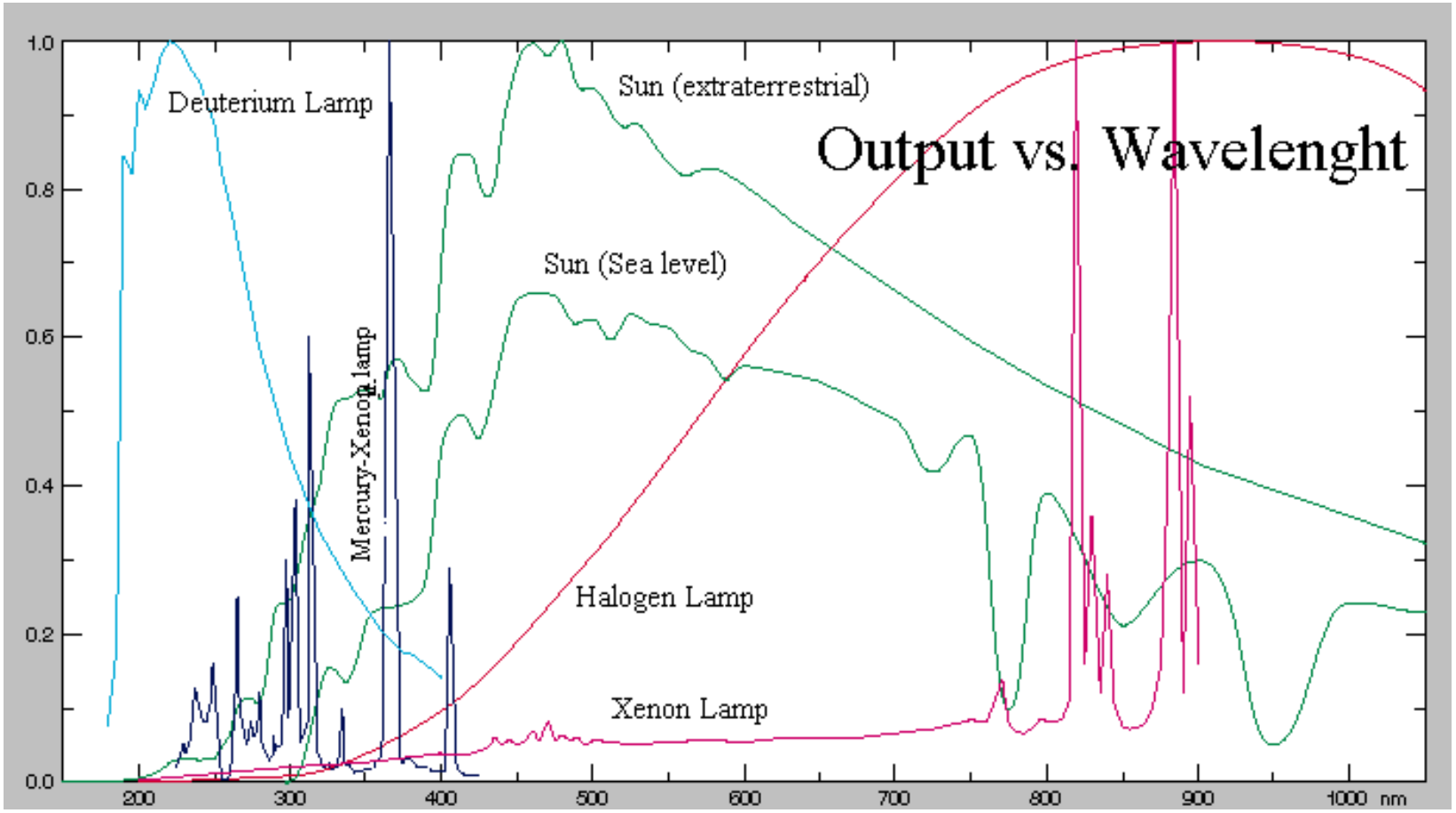
Color rendering of a light source is the effect the source has on the color appearance of objects in comparison with their appearance under a reference source.

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

Light and color



Nothing like the sun?

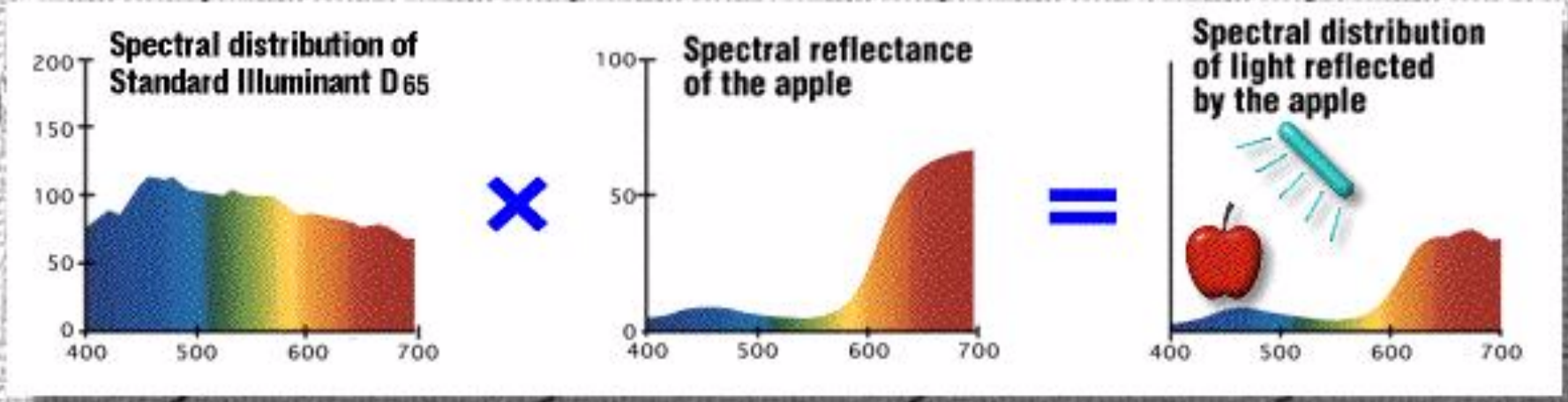


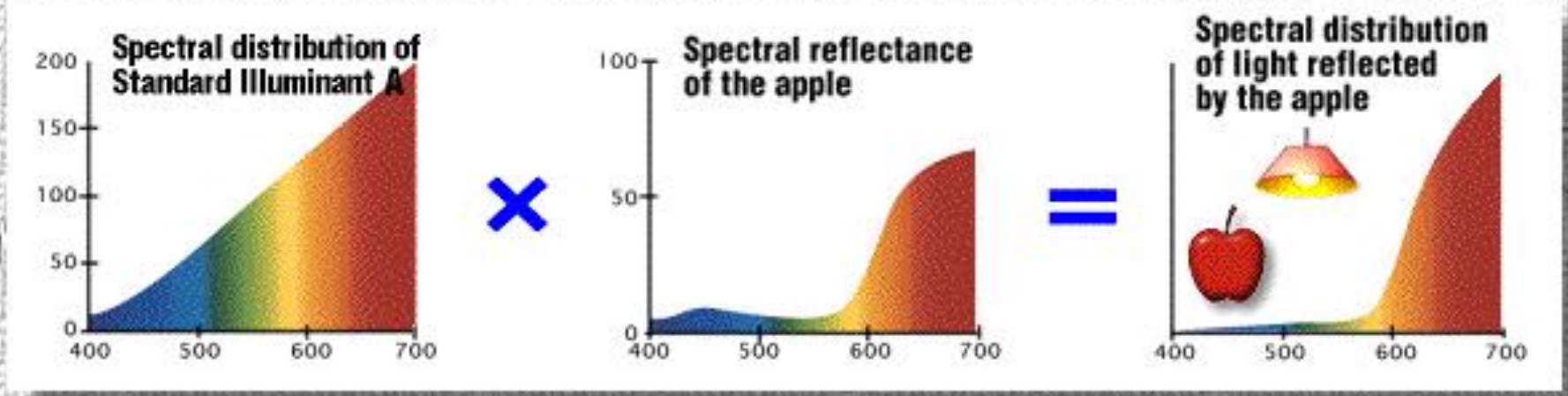
It's strange but...

in a sense

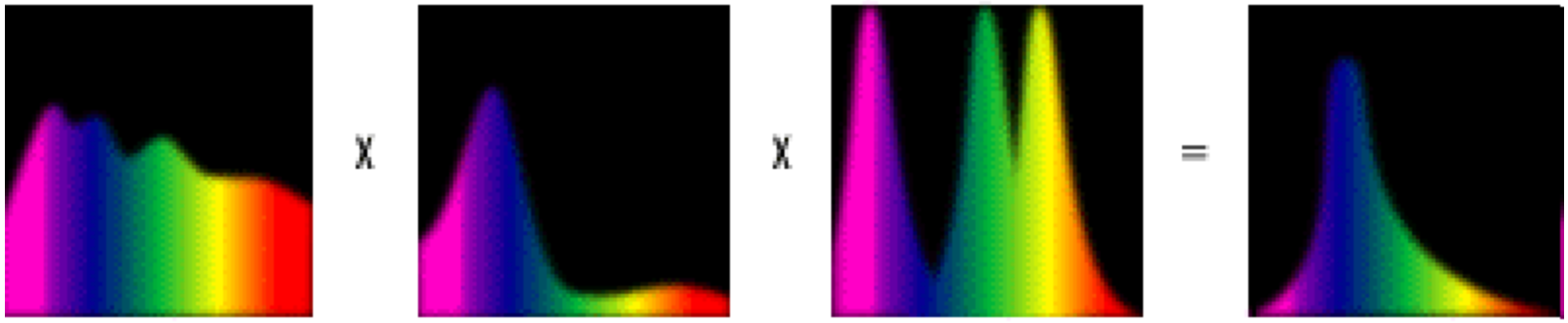
Color doesn't exist

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

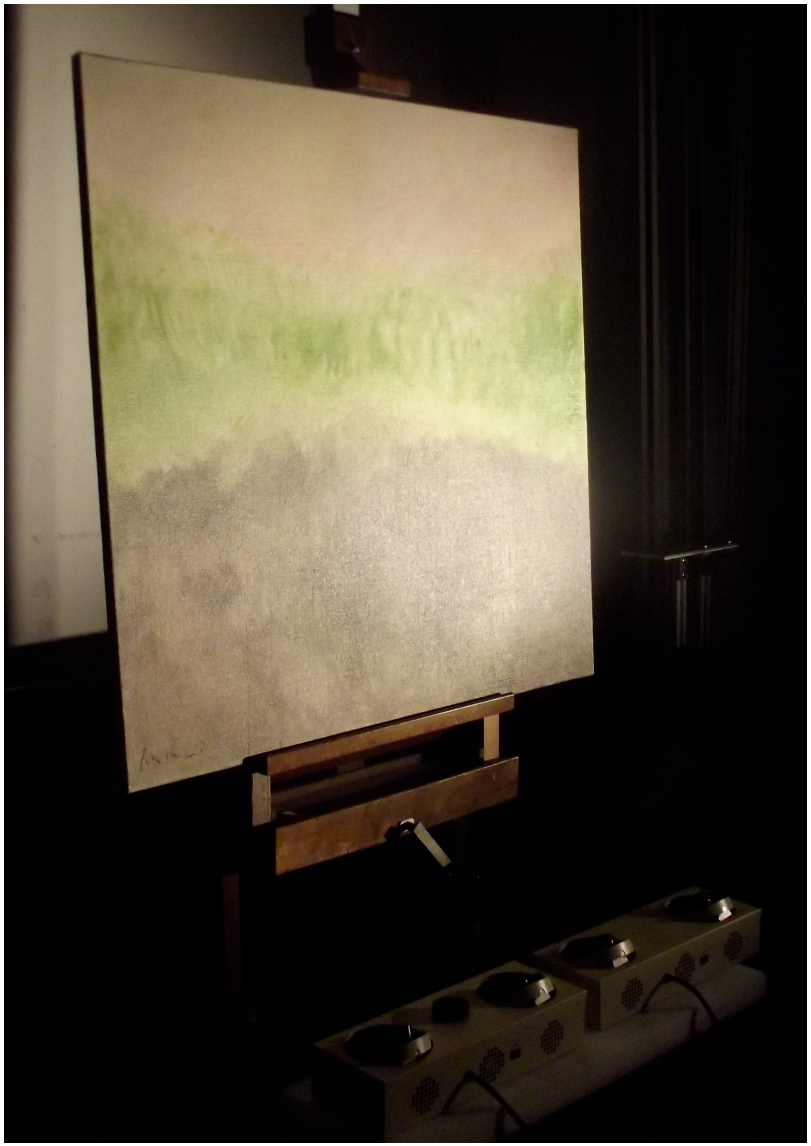
Aim of the experiment

Evaluating subjective preferences regarding lighting in front of a painting

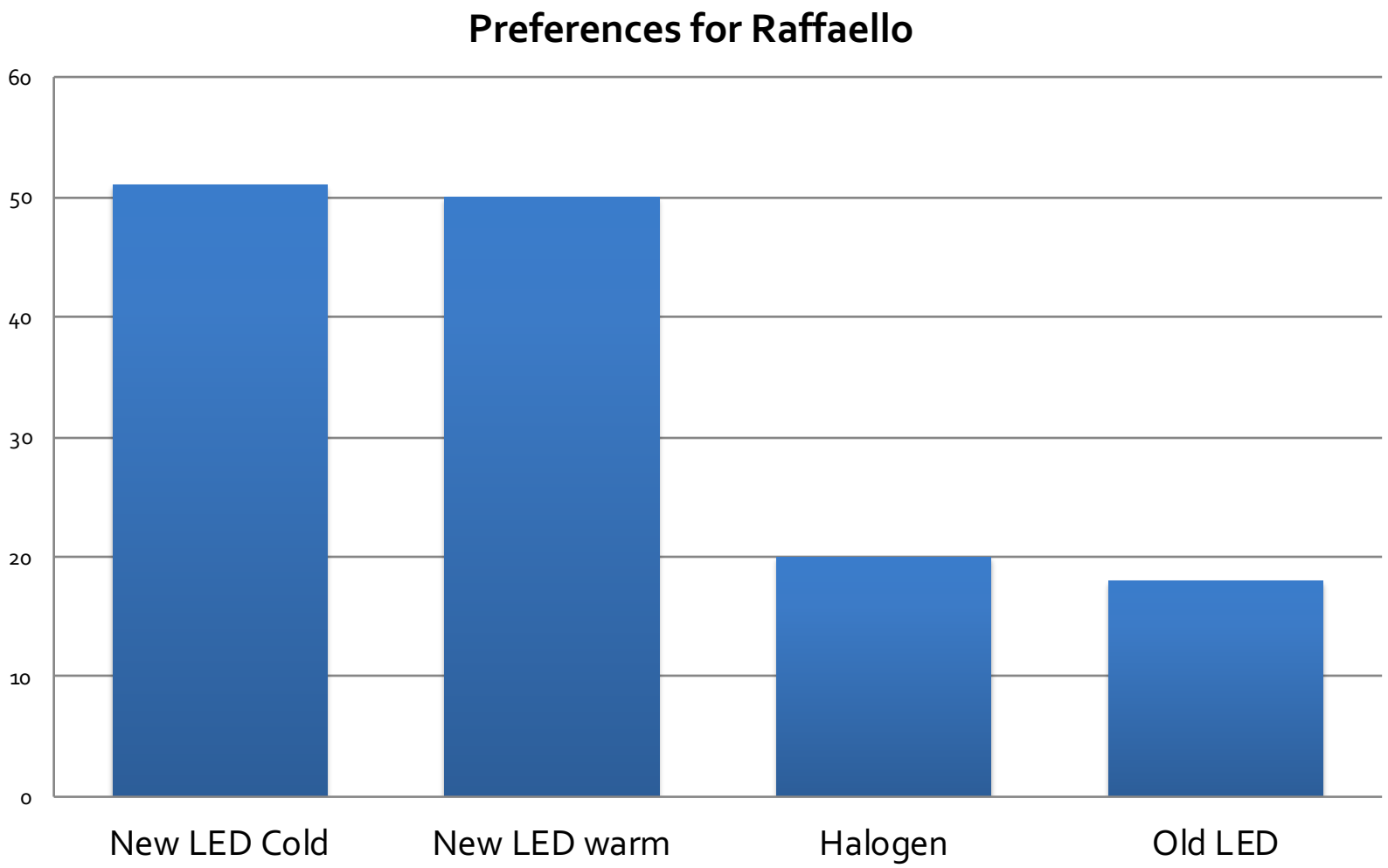
Paintings selected for the experiment

"Madonna del Granduca"
Raffaello (1504)
Olio su tavola 84,4 X 55,9 cm

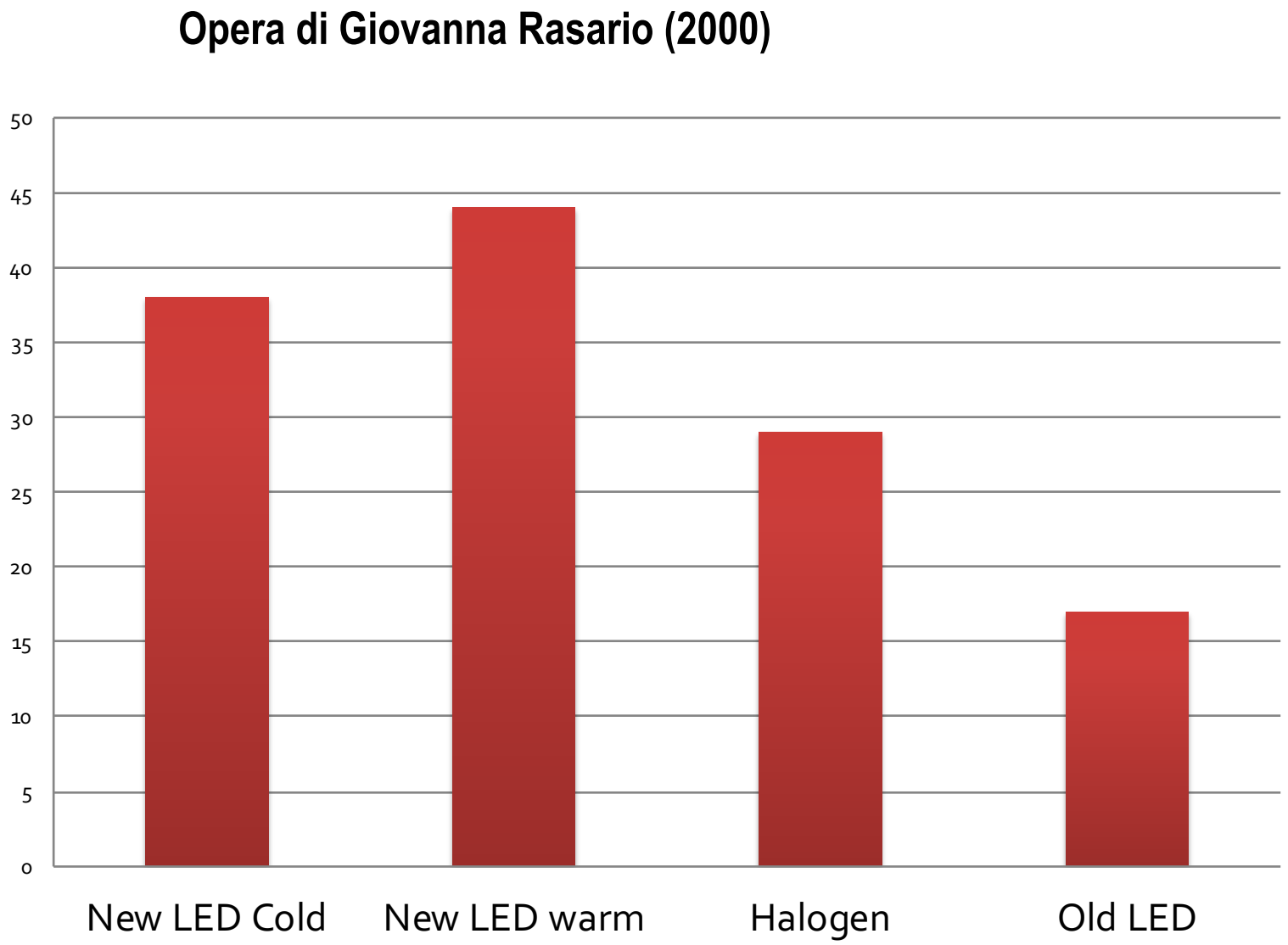
Paintings selected for the experiment



"*L'Assoluto della luce*"
di Giovanna Rasario (2010)


Preferences for Raffaello
60
50
40
30
20
10
0
New LED Cold
New LED warm
Halogen
Old LED

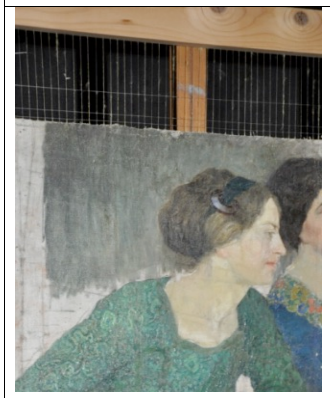
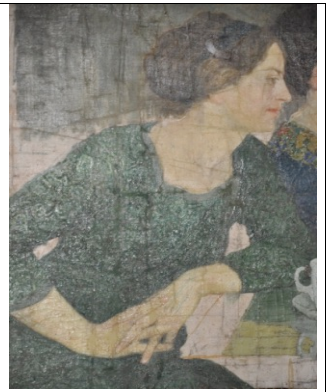
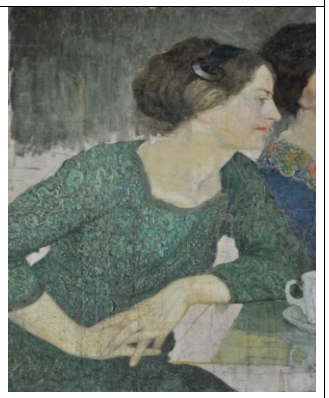
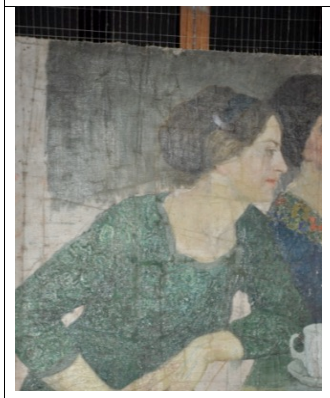
Lighting preferences

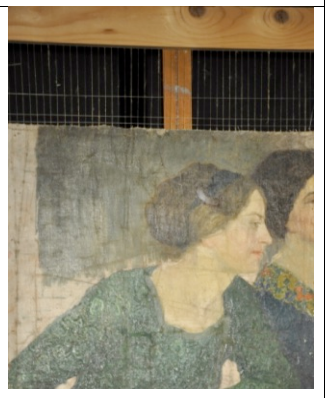


Measuring the inmeasureable

The experiment

Elizabeth Chaplin

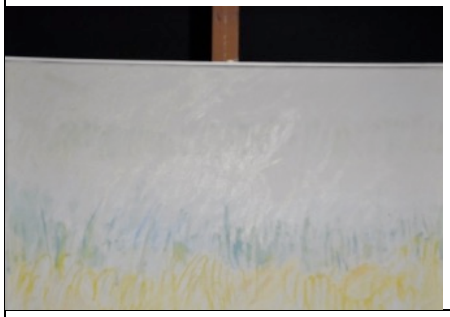
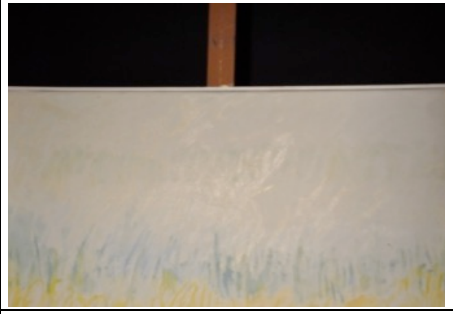





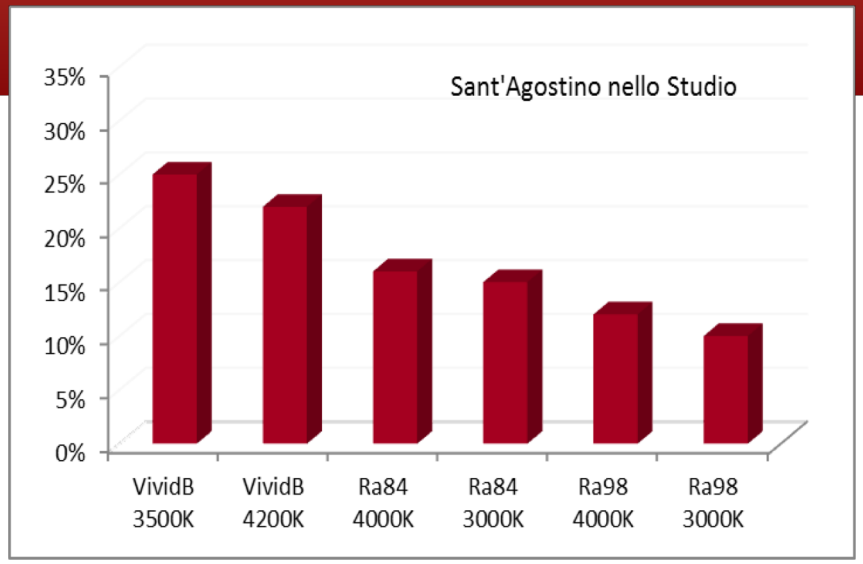


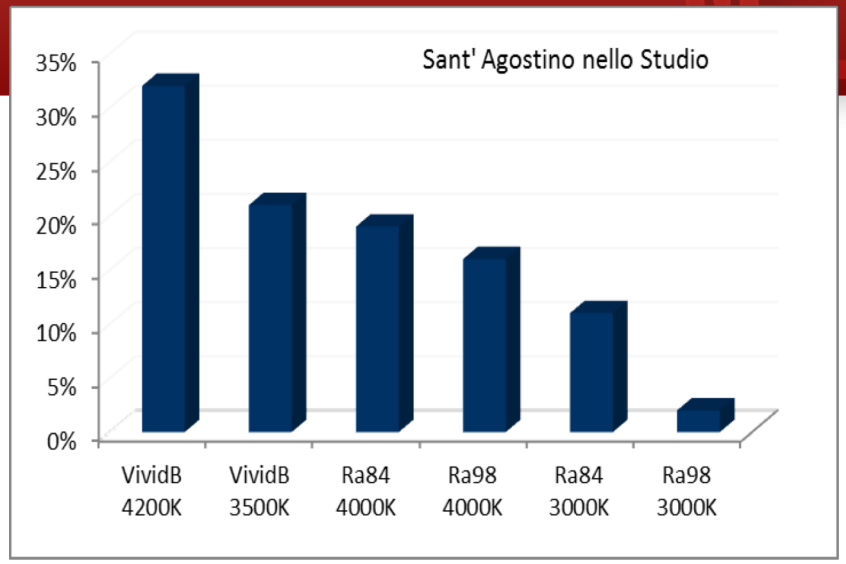
Botticelli

Giovanna Rasario

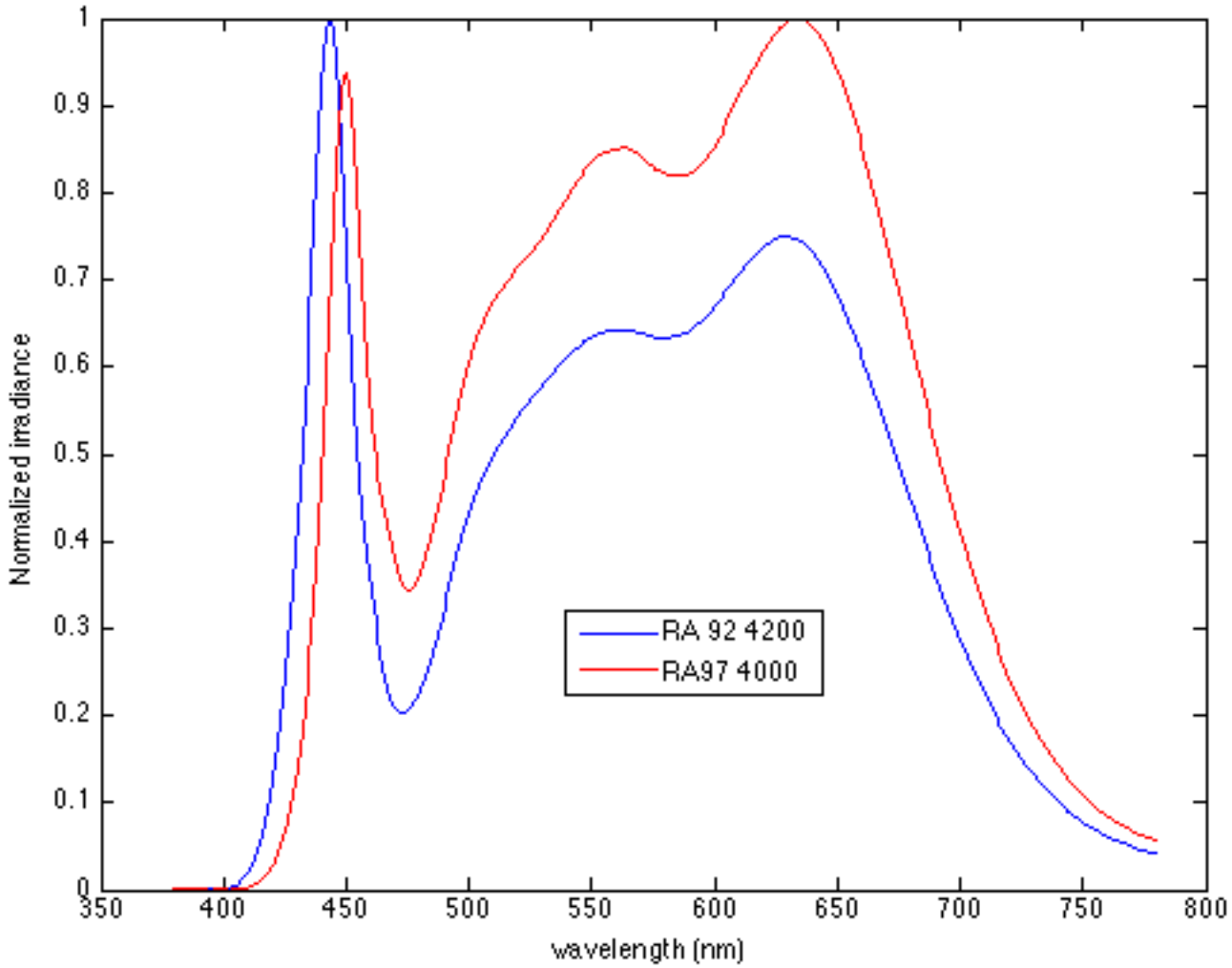


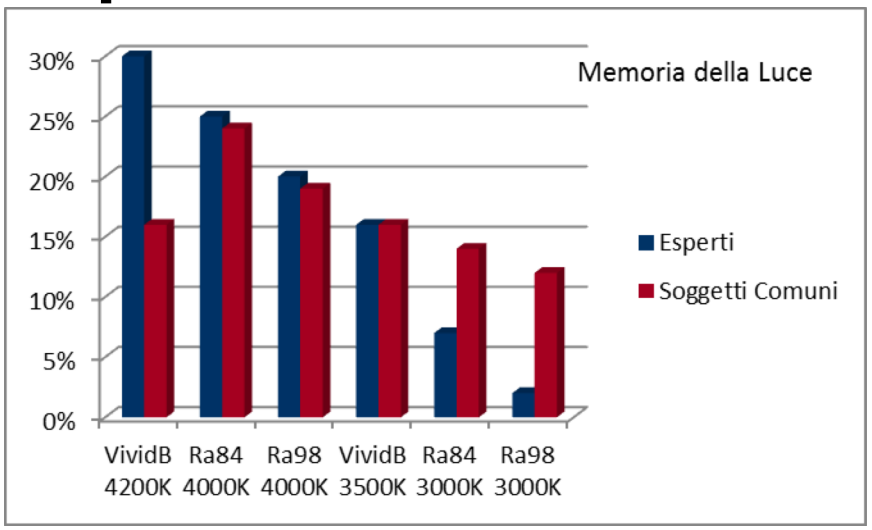


Sant'Agostino nello Studio
35%
30%
25%
20%
15%
10%
5%
0%
VividB 3500K
VividB 4200K
Ra84 4000K
Ra84 3000K
Ra98 4000K
Ra98 3000K

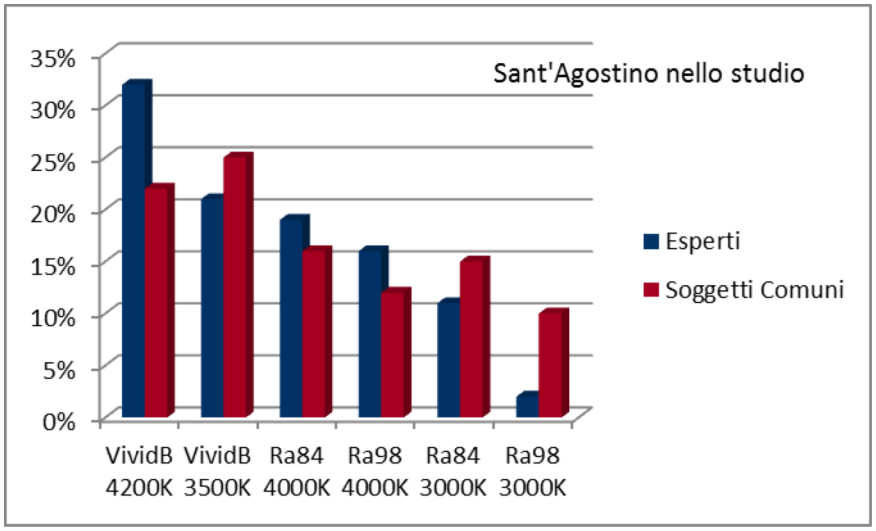

Sant' Agostino nello Studio
35%
30%
25%
20%
15%
10%
5%
0%
VividB 4200K
VividB 3500K
Ra84 4000K
Ra98 4000K
Ra84 3000K
Ra98 3000K

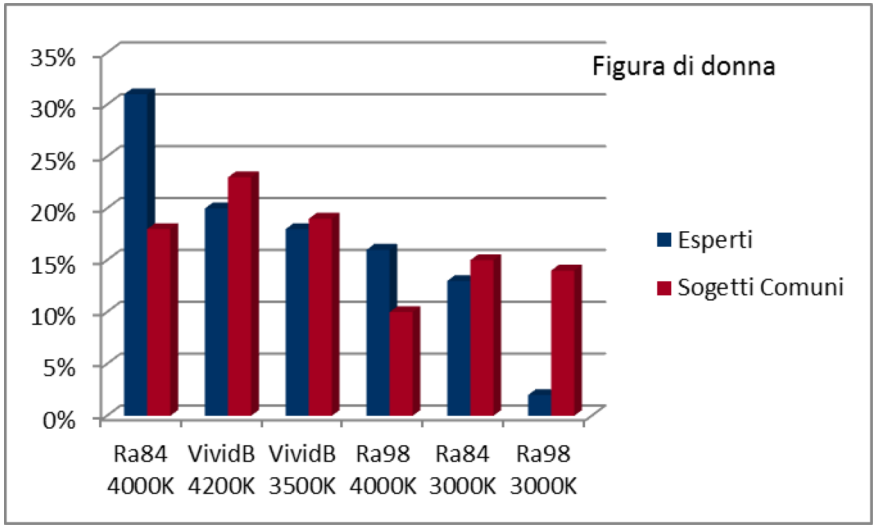
The champion and the worst



Expert or not







Riferimenti

Alessandro Farini

Istituto Nazionale di Ottica-CNR

www.ino.it/home/farini

Blog: www.riflessioniottiche.it

alessandro.farini@ino.it

twitter.com/alefarini

www.facebook.com/alessandro.farini

instagram.com/opticalreader