The Mystery of Color

March 25, 2021
Pedram Amani

Overview

Visible spectrum

Atomic picture

Mixing

Eye anatomy

Color spaces

Role of the brain
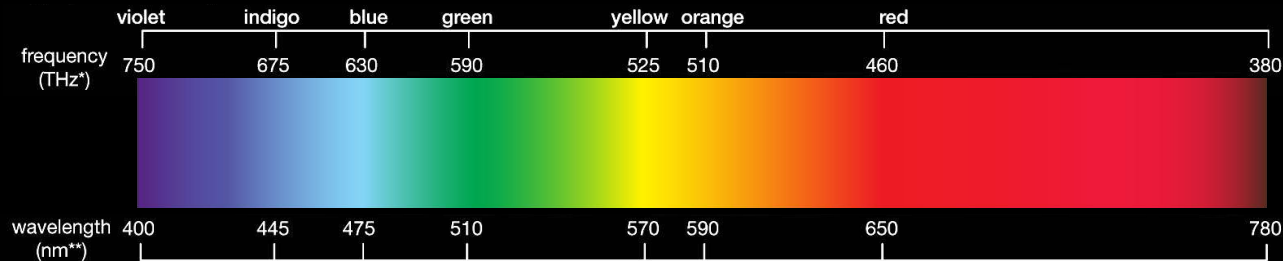
More confusion

What Is Color?

The Visible Spectrum

Newton (1665) − white light decomposed into a color spectrum
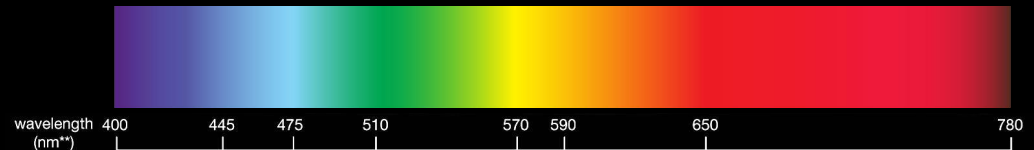
Why can't we see outside of the 400−780 nm range?
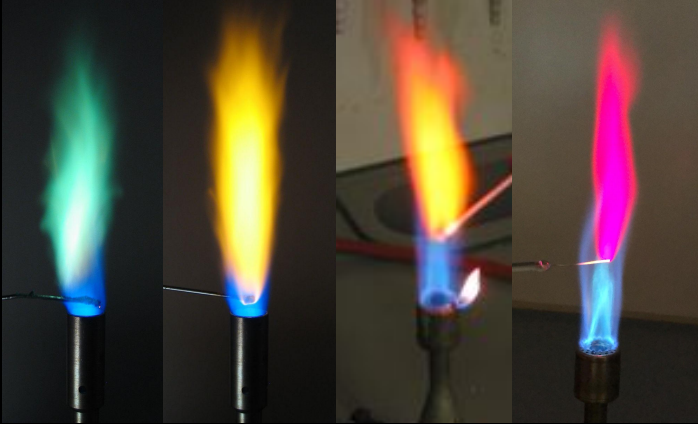

Visible spectrum - Britannica

Emission Spectrum

Configuration	Term	J	Level(cm^{-1})
3s	^{2}S	1/2	0.000
3p	^{2}P°	1/2	16956.172
		3/2	16973.368
4s	^{2}S	1/2	25739.991
3d	^{2}D	5/2	29172.839
		3/2	29172.889
4p	^{2}P°	1/2	30266.99
		3/2	30272.58
4f	^{2}F°	5/2,7/2	34586.92
5p	^{2}P°	1/2	35040.38
		3/2	35042.85
Na II 2s^2 2p^6 (^{1}S$_0$)	Limit		41449.451

Energy levels of sodium – NIST

Let's heat some table salt. What color would we observe?

wavelength (nm**) 400   445   475   510   570 590   650   780
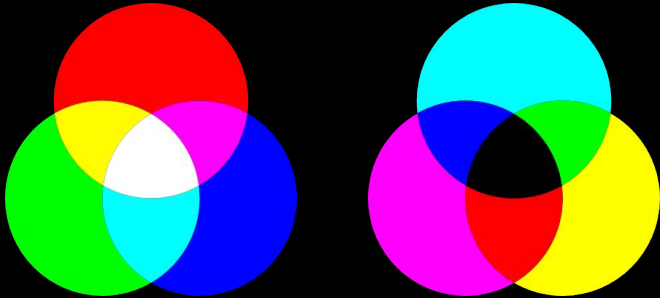
Salt Flame Demo

Colored flames from left to right: CuSO4, NaCl, CuCl, LiCl
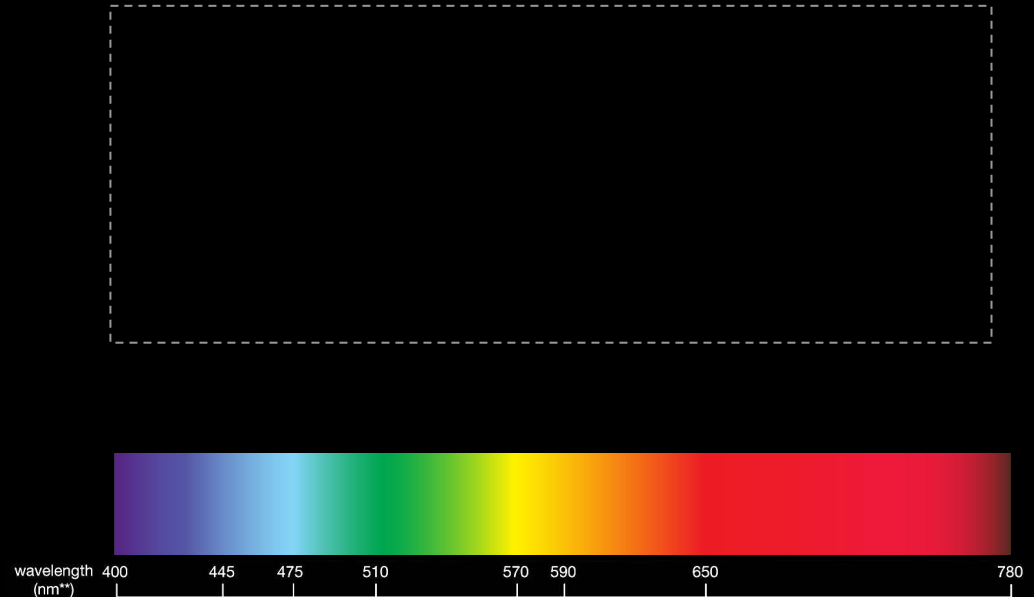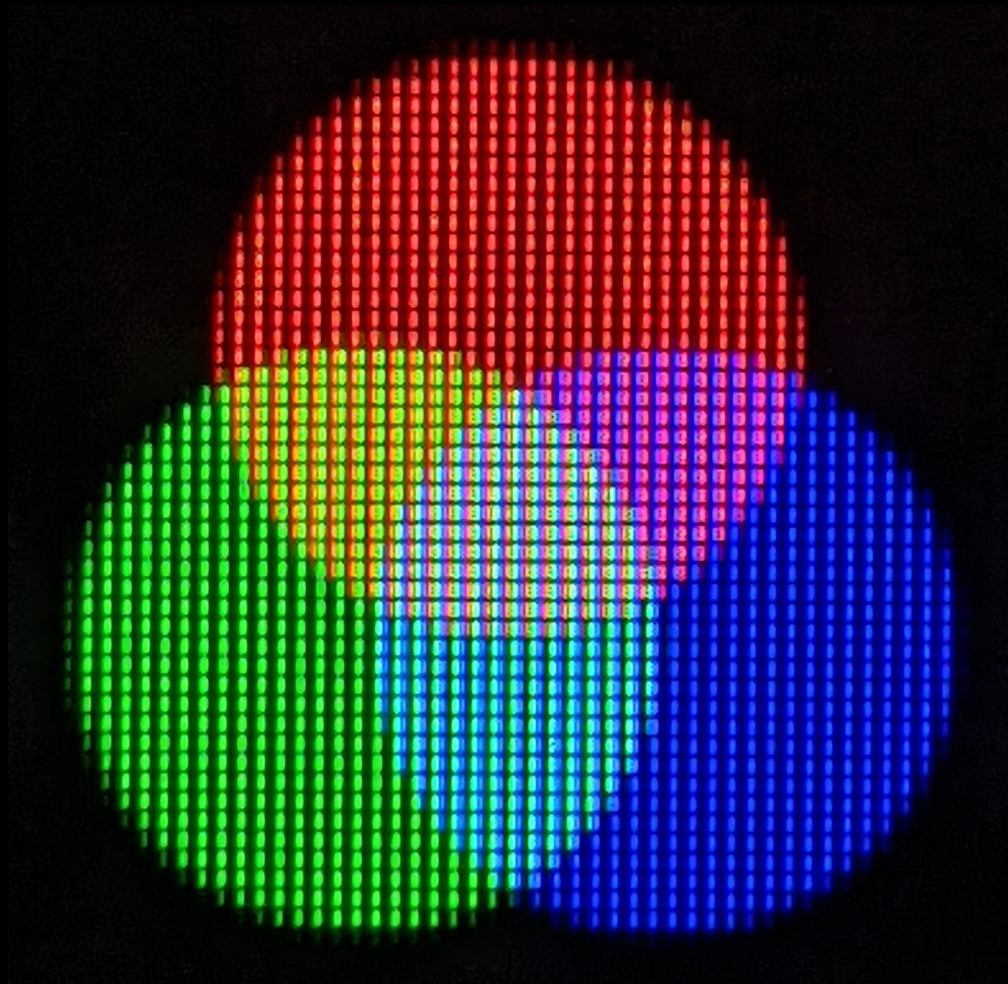
Do you see the yellow?

Mixing of Light

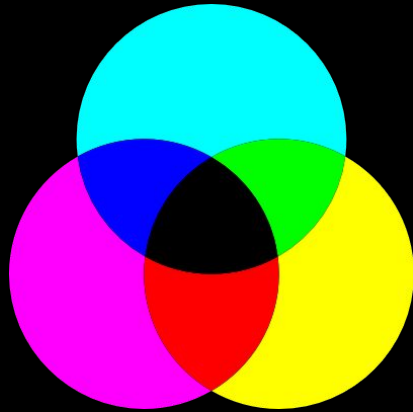Where on the visible spectrum do we find magenta?

Additive and subtractive mixing of light

wavelength (nm**)   400   445   475   510   570   590   650   780

RGB Pixels

Color Mixing Demo

What should we try?

wavelength 400   445   475   510   570 590   650   780
(nm**)

Human Eye Anatomy

Invaginations of cell membranes that form a stack of membranous disks where photopigments exist as transmembrane proteins

Outer segment

Connecting cilium

Inner segment

Mitochondria

Nucleus

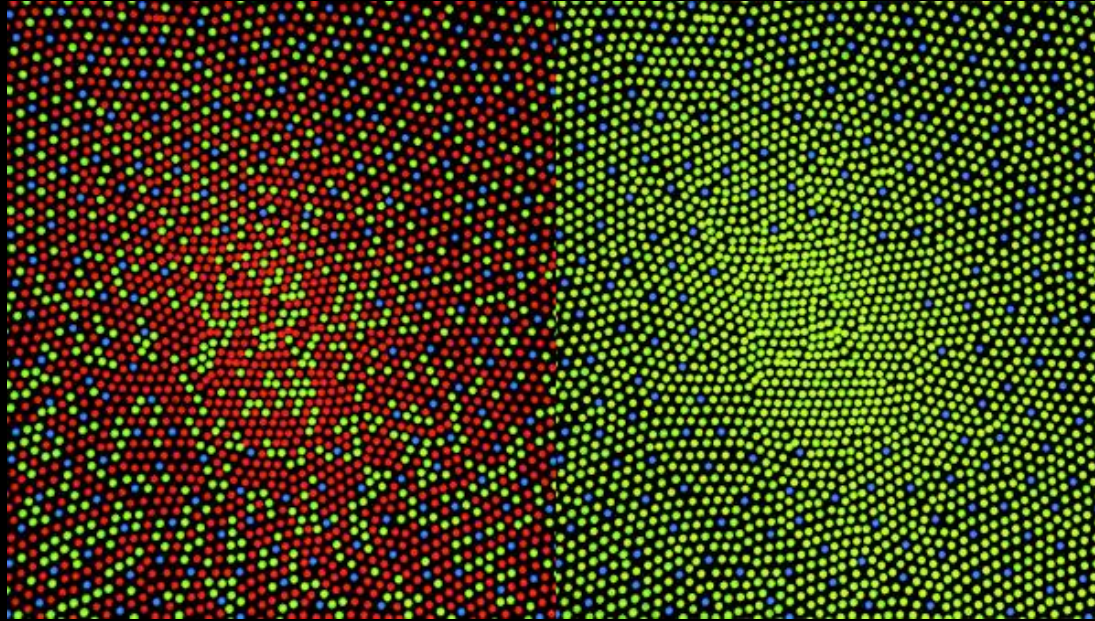Synaptic terminal that forms a synapse with a neuron

Cone cell anatomy

Ganglion, rod, and cone cells
Retinal + photopsins

Three photopsins: photoreceptor proteins
L, M, S opsins

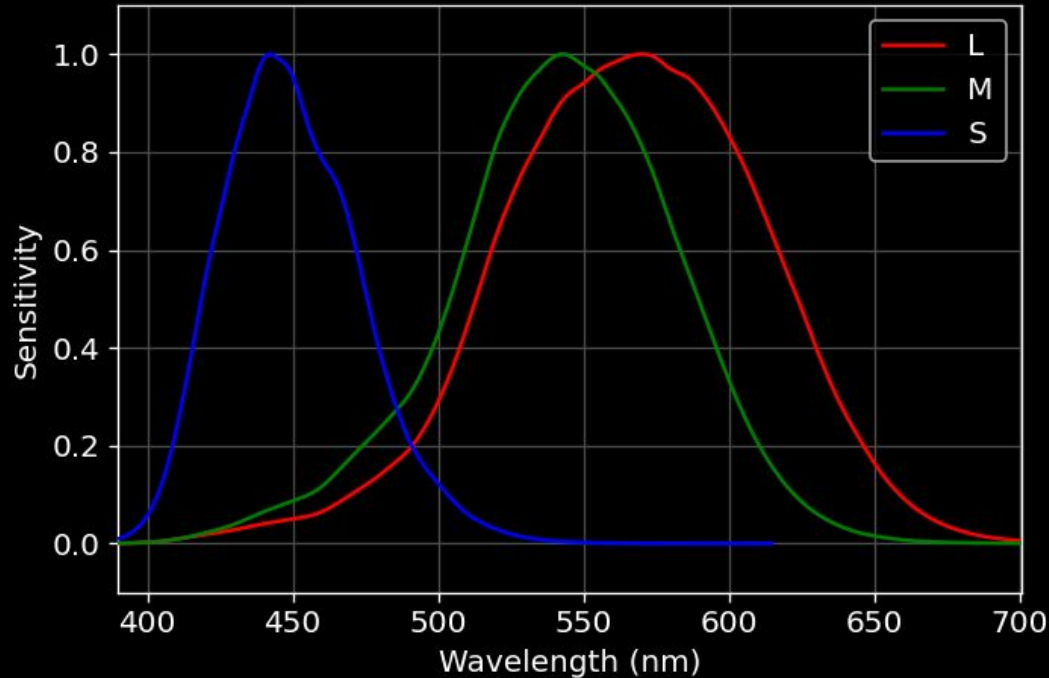Retinal molecule structure

Cone Cell Distribution

Cone cell distribution in the fovea: normal color vision (left), color blind protanopic (right)
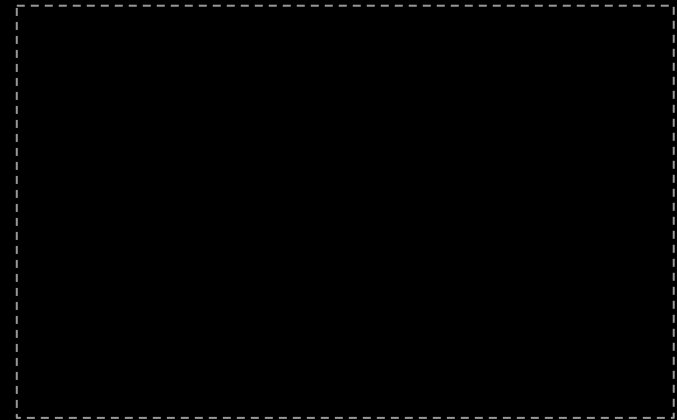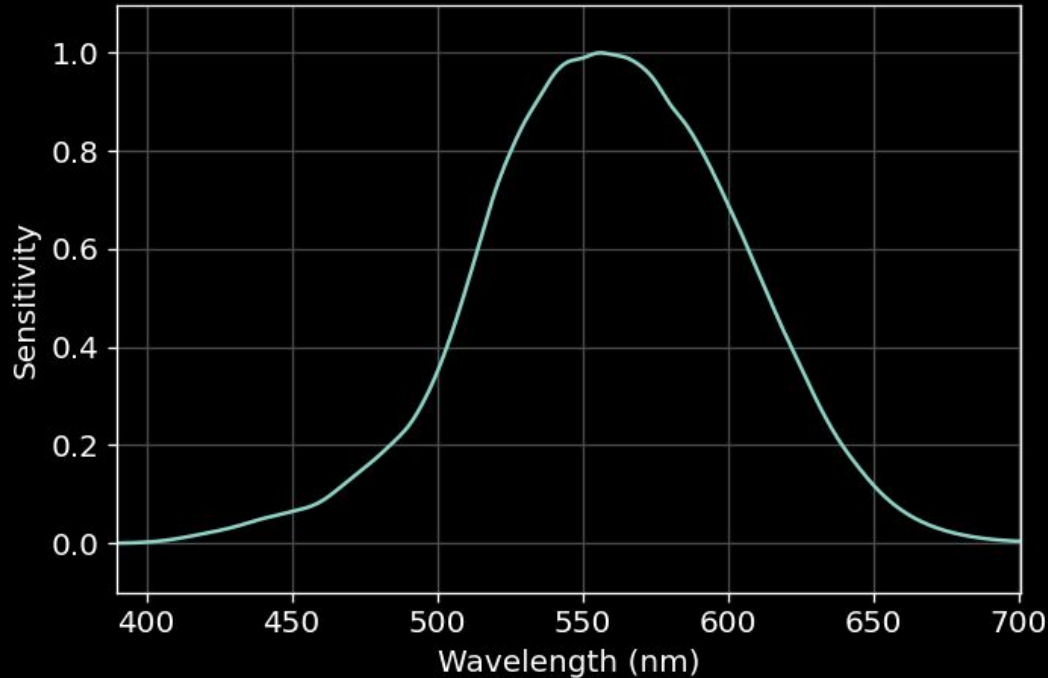
LMS Cone Fundamentals

CIE 2006 cone fundamentals

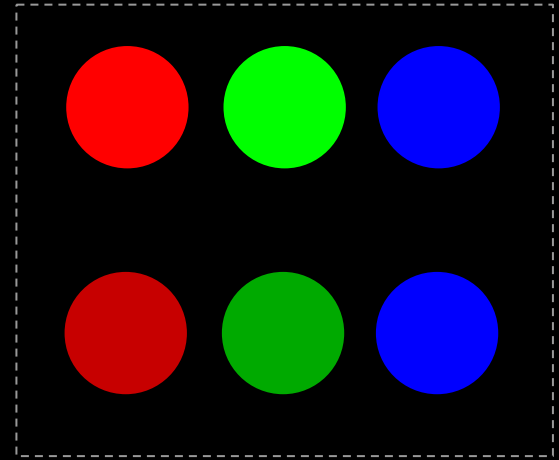International Commission on Illumination − Vienna

What wavelength are our eyes most sensitive to?
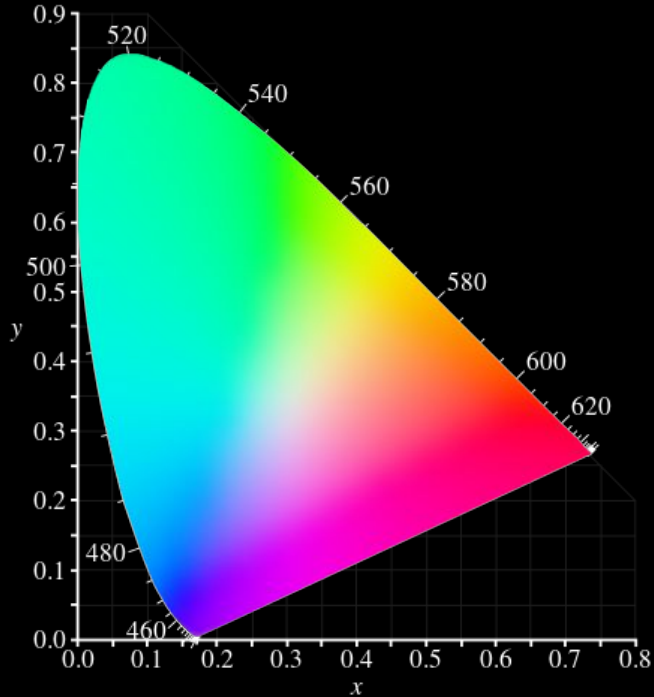
Photopic Luminous Efficiency Function

Select the brightest circle in each row.

CIE xyY Color Space

Chromaticity and brightness

$$X = 1.9474\ L - 1.4144\ M + 0.3648\ S$$
$$Y = 0.6899\ L + 0.3483\ M$$
$$Z = 1.9349\ S$$
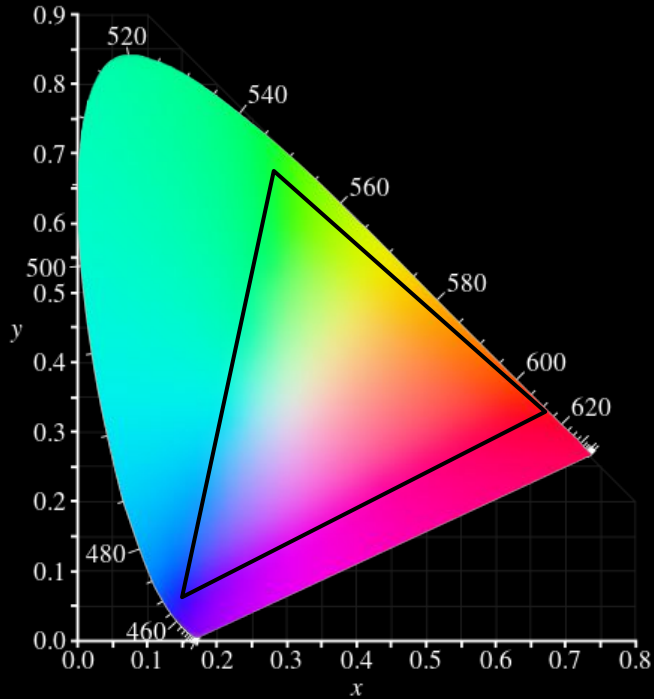
$$x = X / (X + Y + Z)$$
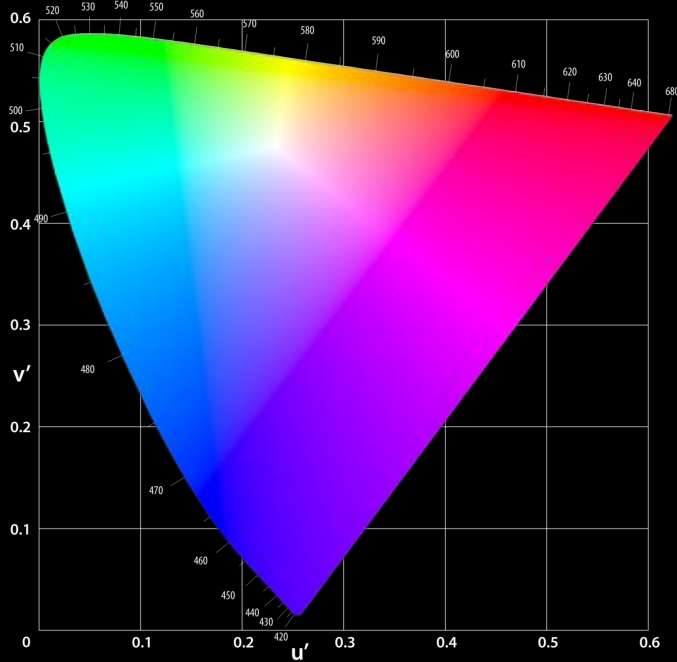$$y = Y / (X + Y + Z)$$

Another Color Space

DCI-P3 color space

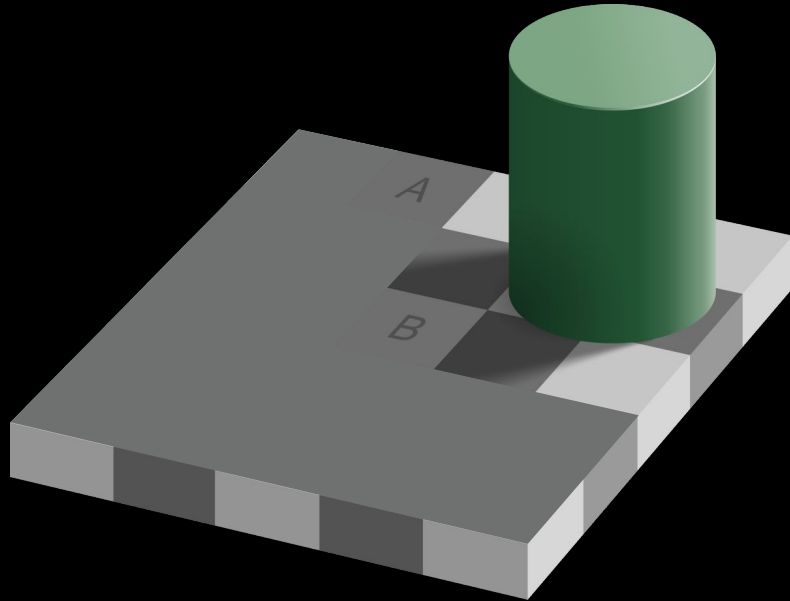DCI-P3 only covers about 45% of chromaticities

Yet Another Color Space

CIELUV color space
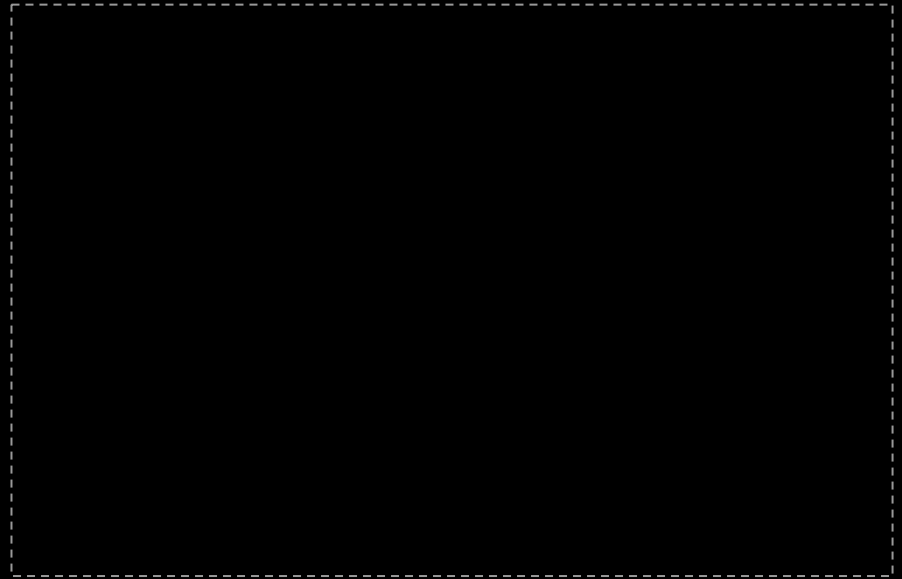
Perceptually uniform presentation of chromaticity

Role of The Brain

Which one is darker? A or B?

Checker shadow illusion – Edward H. Adelson

A Fun Illusion

Measuring color – Andrew Hanson

Fechner Demo – Flicker Warning!

Fechner Color Effect

Fechner color effect − Charles Benham

Thank You!

What is color?

The dress – Cecilia Bleasdale