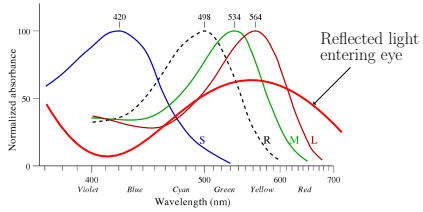
Biological Vision and Applications
Module 02-04: Color Perception

Hiranmay Ghosh

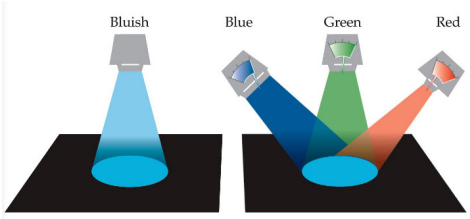
Cones and Color perception



- Incident light is characterized by $I(\lambda)$
- Let the response curve for the cones be $S(\lambda), M(\lambda)$ and $L(\lambda)$
- Exitation level of the S-cones is given by $E_S = \int_\lambda S(\lambda).I(\lambda).d\lambda$
  - ... and similarly for M- and L- cones
- Perceived color $C = f(E_S, E_M, E_L)$
  - Incident light of different spectra may result in the same color perception

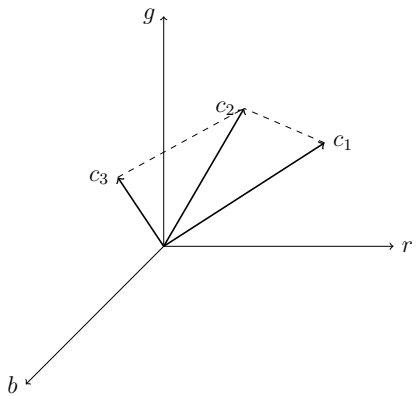
Trichromatic Color Theory

- Perceived color is a linear function of three independent variables
  - Response levels of the cones
- A perceived color can be matched by a linear combination of three primary colors
  - Proved by psychological experiments



Device dependent color models

RGB Model

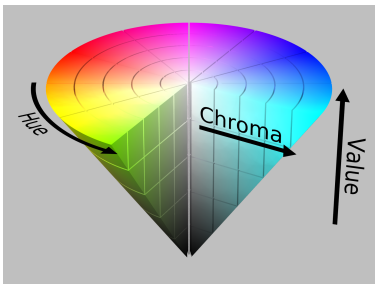


- Electronic devices typically use combination of red, green and blue to produce color
  - Combinations to be used depend on hardware characteristics
  - Device-dependent color model
- Each color is represented by a point in 3D space
  - Let $\vec{c_1}$, $\vec{c_2}$ and $\vec{c_3}$ represent three colors in *rgb* space
  - $| \vec{c_1} - \vec{c_2} | < | \vec{c_2} - \vec{c_3} |$ does not necessarily mean that
    - $\vec{c_2}$ is perceptually closer to $\vec{c_1}$ than $\vec{c_3}$

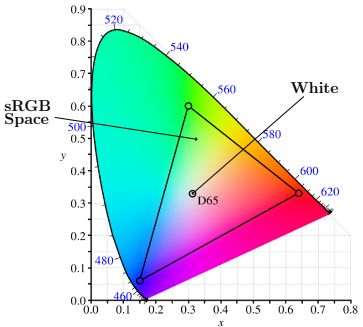
Device independent color models

HSV Model, CIE Model

- Munsell described color in terms of its three perceptual properties, namely
  - Hue (shade), Value (lightness), and Chroma (color purity)
- This is referred to as device-independent color model
- It has been later refined to many other models
  - HSV (Hue-Saturation-Value), CIE-XYZ and CIE-LAB
- In these models too, a color is represented by a point in a 3D space
  - The color distances in these spaces closely conform to perceptual distances



sRGB Color space



- Perceived color can be matched by a "linear combination" of three primary colors
  - The combination can involve addition and subtraction
- Unfortunately, we can only add (not subtract) color in electronic devices
  - We can produce only a subset of perceivable colors with the devices
- The color space that can be produced by a device is called sRGB space
  - Depends of the device characteristics

Are 24-bits sufficient to represent all perceivable colors?

- Human eye can distinguish between
  - Approximately 128 different hues
  - Around 20 to 30 different saturation values (for each hue)
  - Between 60 and 100 different brightness levels
- Combinatorially, human eye can distinguish between roughly 300,000 – 350,000 different colour shades
- 24 bits has a provision to represent 16 million colour shades!
  - The issue is how we intelligently utilize the 24 bits

Opponent process theory

Experiment

- Concentrate on the blue cicle below for about 10 seconds and then shift your gaze to the white area of the screen

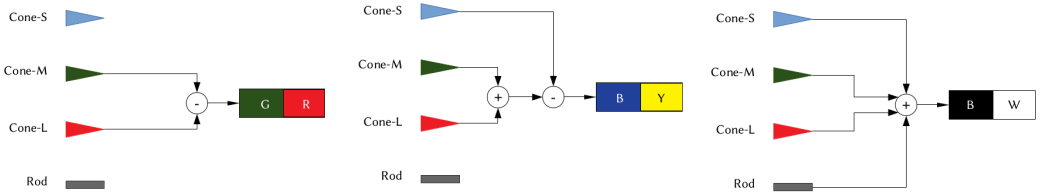
Opponent process theory

(Continued)

- You must have seen an yellow “after image” in the last slide
- The neural network connects the photo-receptors in a certain way to distinguish between three opponent color pairs
  - red *vs.* green
  - blue *vs.* yellow
  - dark (black) *vs.* bright (white)

Opponent process theory

(Continued)



Further reading

- An excellent blog on color science
  - https://medium.com/hipster-color-science/a-beginners-guide-to-colorimetry-401f1830b65a

Quiz

Quiz 02-04

End of Module 02-04