Color Appearance, Color Order, & Other Color Systems

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Color Terms
Color Definition

Color is an attribute of visual sensation ...
Hue

Attribute of a visual sensation according to which an area appears to be similar to one of the perceived colors, red, yellow, green, and blue, or to a combination of two of them.
Brightness, Lightness

Brightness: Attribute of a visual sensation according to which an area appears to emit more or less light.

Lightness: The brightness of an area judged relative to the brightness of a similarly illuminated area that appears to be white or highly transmitting.
Colorfulness

Attribute of a visual sensation according to which the perceived color of an area appears to be more or less chromatic.
Saturation, Chroma

Saturation: Colorfulness, chromaticness, of an area judged in proportion to its brightness.

Chroma: Colorfulness of an area judged as a proportion of the brightness of a similarly illuminated area that appears white or highly transmitting.
Hue, Lightness, Chroma

INCREASING LIGHTNESS

INCREASING CHROMA
Hue, Lightness, Saturation

INCREASING LIGHTNESS

INCREASING SATURATION
Hue, Brilliance, Saturation

INCREASING BRILLIANCE

INCREASING SATURATION
Hue, Brilliance, Saturation

E. Hering:  *Zur Lehre vom Lichtsinne*  (1878)
A. Pope:  *Tone Relations in Painting*  (1922)
Scandinavian Colour Institute:  *Natural Color System*  (1978)
Color Perception
Color Science
The Eye
The Retina
Skin Color Variations

One Person — Hemoglobin Level and Oxygenation (Melanin Fixed)
Mean Color Background

Credit — Chris Thorstenson (RIT & UR)
Simultaneous Contrast
Simultaneous Contrast
Simultaneous Contrast
White’s
The Brain
Chromatic Adaptation
A CYAN FILTER
Cognition
Colorimetry
CIE XYZ

Nominal Scaling

Color Matches

No Differences or Appearance
CIELAB

Ratio and Interval Scaling
Color Differences
Approximate Appearance
CIECAM02

Ratio and Interval Scaling

Color Appearance

More Dimensions
Color Systems
Types of Color Systems

**Color Naming Systems:** Color is defined and specified according to some, essentially arbitrary, naming system (e.g., Pantone, Trumatch, Paint Color Cards).

**Color Mixing Systems:** Color is defined according to the properties of a given system (e.g., RGB, CMYK, HSV, DIN, XYZ, etc.)

**Hybrid Systems:** Color is defined by a combination of systems (e.g., appearance and additive mixing in Colorcurve).

**Color Appearance Systems:** Color is defined according to various appearance attributes (e.g., Hue, Value, Chroma in Munsell, Hue, Blackness, Chromaticness in NCS, Color differences in OSA UCS).
Color Order Systems
Color Order Systems

Systems that define *color appearance* according to some orderly arrangement to facilitate the naming and communication of colors (among other applications).

Often the systems define colors using perceptual variables.

Such systems are typically embodied with atlases of color samples rather than through mathematical relationships to colorimetric coordinates.
Color Appearance Systems

The Munsell system (Munsell Book of Color) and Swedish Natural Color System (NCS) provide two important examples of systems defined by color appearance.

Thus their scales, while not defined mathematically can be used to develop and test color appearance models.
Munsell
Munsell Constant-Hue Page
Munsell Notation

Munsell Notation
7.5R 5/10
Hue Value/Chroma
Inspired by Ewald Hering

Realized by Dr Lars Sivik, Prof Gunnar Tonnquist and Dr. Anders Hård, 1997 AIC Judd Award
Swedish NCS

Based on Hering’s Opponency
NCS Hue Circle
NCS Constant-Hue Page
Natural Color System (NCS)

NCS Notation

20, 70, Y90R
Blackness (s), Chromaticness (c), Hue
Other Systems
Pantone

Color Specifications
Proprietary
Visual Reference, Not Appearance Scales
RAL

Color Specifications
Proprietary
Visual Reference, Not Appearance Scales
DIC

Color Specifications
Proprietary
Visual Reference, Not Appearance Scales
sRGB, AdobeRGB

RGB Primaries Specified
Tone Transfer Specified
XYZ-to-RGB Defined
Rec.709, Rec.2020
RGB, HSL, HSV, CMYK

Device Dependent Spaces
RGB/CMYK Not Defined
Categories of Systems

(1) Systems Related to Colorimetry (e.g., XYZ) or Not

(2) Systems Based on Color Appearance or Not

Munsell & NCS: (1) Yes (2) Yes
sRGB & Rec.2020: (1) Yes (2) No
Pantone, RAL, Paints: (1) No** (2) No

**Proprietary
Principal/Unique Hues

Munsell:
5 Principal Hues:
Based on Thresholds/Differences

NCS:
4 Unique Hues:
Based on Appearance
Individual Differences
Individual Differences

Angelica Dass
Causes

Genetics
• Different Pigments (Color Blind in Extreme)
• Different Pigment Density
• Cone Morphology
• Eye “Color”

Diet, Lifestyle, Environment, Age
• Macular Pigment Density
• Lens Density

Psychology, Cognition
• Knowledge of Conditions
• “Set” of Judgments
• Available Vocabulary
CIE 2006 + INDIVIDUALS

- Stiles & Burch 49 Observers

Fig. 3.12 – 49 sets of rgb-CMFs generated by the proposed observer model (gray lines) aiming to predict the Stiles and Burch’s experiment results. The maxima and minima of 49 sets of CMFs for the Stiles and Burch’s experiment participants are superimposed as color-shaded areas. All the CMFs are normalized to equal area.
Color Rendering
Animal Vision
Animal Vision
Birds

Kestrel
Bees
Bee Color Vision

Humans

Honey Bees
Goldfish
Goldfish Color Vision
Mantis Shrimp
Complexity

Mantis Shrimp: Extraordinary Eyes

*Homo sapiens*

*Neogonodactylus oinedii*

Marshall et al., 2007; Marshall and Oberwinkler, 1999
Final Thoughts ...
Dimensions

Lightness - Chroma - Hue

Brightness - Colorfulness - Hue

(Saturation instead of Chroma & Colorfulness??)

Brilliance - Saturation - Hue

(Need at least 5 total, which can be defined by 4.)
Colorimetry

CIE XYZ

CIELAB

CIECAM02

(Remember individual variation.)
Color Specification

Pantone, RAL, etc.

sRGB, Rec.709, Rec.2020, Dolby I CtCp

(All could be replaced by colorimetry, but they are convenient and helpful.)
Color Order

Munsell

NCS

(Perhaps could be replaced by a CAM one day.)
Questions