The Art and Science of Depiction

Color

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Talks
• Abstract
• Issues

Plan
• Color blindness
• Color Opponents, Hue-Saturation Value
• Perceptual color effects
• Color categories and culture

Physical spectrum

Summary
**Metamerism**
- Different spectrum
- Same response

**Puzzles**
- Why is violet “close” to red
- Primaries
  - Cyan and magenta are not “spontaneous” primaries
- Color mixing

**Why color is complex**
- 3 dimensional
- Difference spectrum-color
- Additive-subtractive
- LMS-opponents-Hue Saturation Value
- Color constancy
- Color appearance effects
- Cultural
- Preferred colors, memory

**Color synthesis**
- Additive: red, green, blue
- Subtractive: cyan, magenta, yellow

**Color synthesis: a wrong example**

**Plan**
- Color blindness
- Color Opponents, Hue-Saturation Value
- Perceptual color effects
- Color categories and culture
Color blindness

- Dalton
- 8% male, 0.6% female
- Genetic
- Dichromate (2% male)
  - One type of cone missing
  - L (protanope), M (deuteranope), S (tritanope)
- Anomalous trichromat
  - Shifted sensitivity

We are all color blind

- Center of retina
- No S (blue)
- We compensate via gaze movement
- Not well understood

Color blindness test

- Maze in subtle intensity contrast
- Visible only to color blinds
- Color contrast overrides intensity otherwise

Color blindness correction

- Filter
  - On one eye
  - Set of filters (case of electronics)

Color blind impressions

- A normal scene
- B protanope L
- C deuteranope M
- D tritanope S
**Color blindness & Painting**

- Restricted to blue-yellow

![Goethe after a color-blind](image1)

**Color blindness & Painting**

- Restricted to blue-yellow

![Meryon, Le Vaisseau Fantôme](image2)

**Color blindness & Painting**

- Restricted to blue-yellow

![J. J.](image3)

**Color vision variability**

- Color blindness
- Mutations
- Gender, racial
- Cultural differences

**Preferred colors**

- Caucasian skin
  - More tanned
- Grass
  - Greener
- Sky
  - Bluer
Plan

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Color Opponents

- Hering
- A color can be “blue-green”, “yellow-red”, “yellow-green”, etc.
- But never “yellow-blue” or “red-green”
- Suspected two opponents:
  - Blue-yellow axis
  - Red-Green axis

Color reparameterization

- The input is LMS
- The output has a different parameterization:
  - Light-dark
  - Blue-yellow
  - Red-green

Color opponents wiring

- Sums for brightness
- Differences for color opponents

Double center surround opponents

- Center-surround
- Color opponents

Opponents and image compression

- JPG, MPG
- Color opponents instead of RGB
- Compress color more than luminance
Blue-yellow opponent and painting

- Often used to depict night
- (S cones share properties with rods...)
- Van Gogh
  *Café at Night*

Red-green opponent and painting

- Jawlensky

Opponent and painting

- Degas

Color reparameterization

- The input is LMS
- The output has a different parameterization:
  - Light-dark
  - Blue-yellow
  - Red-green
- A later stage may reparameterize:
  - Brightness or Luminance or Value
  - Hue
  - Saturation

Hue Saturation Value

- One interpretation in spectrum space
- Not the only one because of metamerism
*Munsell book of colors*
- Perceptually uniform

*History of color theories*
- Aristotle & followers
- Scale from black to white
  - Blue, red, yellow
  - Position of green varies
- Nicolas Poussin
  *Ecstasy of Saint Paul*
  1650

*Plan*
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*Color appearance effects*
- …
- Goethe, 19th century
  - Importance of subjective experience
- Chevreul, 19th century
  - Law of simultaneous contrast, optical mix
- Modern theories
  - Measured effects

*Simultaneous contrast*
- Chevreul
- In color opponent direction

*Crispening*
- Increased sensitivity
**Simultaneous contrast**

- In color opponent direction
- Center-surround

**Eugène Delacroix**

**Impressionism**

- Claude Monet

**Post-Impressionism**

- Van Gogh
**Land Retinex**

- Reflectance vs. Luminance
- Illumination Level (in photosolar model)

**Haloing, local contrast**

- Seurat, *Bathers at Asnières*, 1884

**Edge burning**

- Ansel Adams

**Spreading**

- Optical mix when spatial frequency increases
- But before fusion frequency
- Additive mix! (opposed to pigment mix)

**Pointillism**

- George Seurat, *The Channel of Gravelines, Grand Fort-Philippe*, 1890

**Pointillism**

- George Seurat, *La Grande Jatte*, 1886
**Pointillism**
- George Seurat, *La Grande Jatte*, 1886

**Divisionism**
- Paul Signac, *The Mills at Overschie*, 1905

**“Layered” pointillism**

**Photo-Mosaics**

**Artistic Halftoning**
- Ostrovoukhov 1999

**Other effects**
- Problems for color reproduction
- Problems in design and production
**Hunt and Stevens effect**
- Stevens effect
  - Contrast increases with luminance
- Bartleson-Breneman effect
  - Image contrast changes with surround
  - A dark surround decreases contrast
    (make the black of the image look less deep)
- Hunt effect
  - Colorfulness increases with luminance
- Hence the need for gamma correction

**Bezold-Brücke Hue Shift**
- Monochromatic stimulus
- Perceived hue changes when luminance varies

Wavelength shift necessary to keep the same hue when luminance is decreased by a factor of 10

**Abney Effect**
- Hue changes with the addition of pure white

**Color appearance models**
- Predict the appearance of a color depending on
  - Objective stimulus
  - Surrounding, context

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**Color categories**
- Prototypes
- Harder to classify colors at boundaries
**Color and culture**
- Ancient Greeks
  - Same term for blue-green-dark
- Berinmo

**Lexical study of basic color terms**
- Berlin and Kay 1969-78
- 20+78 languages
- Monolexemic
  - Not compound, e.g. not “blue-green”
- Primary chromatic reference
  - Not material, e.g. not “gold”
  - But allow “orange”
- General purpose
  - No specific field, e.g. not “blond”, “roan”
- High frequency
  - E.g. not “mauve”, “taupe”, “puce”

**Lexical study of basic color terms**
- 20+78 languages
- 16 basic color terms
  - 11 in English
    - Red, green, blue, yellow, black, white, gray, orange, purple, brown, pink
  - light-blue
  - 4 that encompass more than one color
    - Warm, cool, light-warm, dark-cool

**Visual Perception**
- Very complex
- Different stages
- Different pathways for different elements
- Can explain some pictorial techniques/styles
- Can be helped of challenged

**Discussion**
- Piranesi
<table>
<thead>
<tr>
<th><strong>Discussion</strong></th>
<th><strong>Color terms (Fairchild 1998)</strong></th>
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<tbody>
<tr>
<td>- Perception and images</td>
<td>• Color</td>
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<td>- Does it help the analysis</td>
<td>• Hue</td>
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<td>- Does it dazzle?</td>
<td>• Brightness vs. lightness</td>
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<td>- Does it refrain creativity?</td>
<td>• Colorfulness and Chroma</td>
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<td>• Saturation</td>
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<td>• Unrelated and related colors</td>
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<th><strong>Color</strong></th>
<th><strong>Related and Unrelated Colors</strong></th>
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| – chromatic and achromatic content. This attribute can be described by chromatic color names such as yellow, orange, brown, red, pink, green, blue, purple, etc., or by achromatic color names such as white, gray, black, etc., and qualified by bright, dim, light, dark, etc., or by combinations of such names. – Note: Perceived color depends on the spectral distribution of the color stimulus, on the size, shape, structure, and surround of the stimulus area, on the state of adaptation of the observer's visual system, and on the observer's experience of the prevailing and similar situations of observations. | • Unrelated Color
– Color perceived to belong to an area or object seen in isolation from other colors. • Related Color
– Color perceived to belong to an area or object seen in relation to other colors. |

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<th><strong>Hue</strong></th>
<th><strong>Brightness vs. Lightness</strong></th>
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| – Hue
- Attribute of a visual sensation according to which an area appears be similar to one of the perceived colors: red, yellow, green, and blue, or to a combination of two of them. • Achromatic Color
- Perceived color devoid of hue. • Chromatic Color
- Perceived color possessing a hue. | • 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. |
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<td>• Colorfulness</td>
<td>– Colorfulness of an area judged in proportion to its brightness.</td>
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<td>– Attribute of a visual sensation according to which the perceived color of an area appears to be more or less chromatic.</td>
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<td>• Chroma</td>
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