Comp/Phys/Apsc 715

Lecture 5: Trichromacy, Color Spaces, Properties of Color

Example Videos

- Segmentation and visualization of neurons
- Astro Visualization (the Millennium Run)
- Dragonfly Flight Analysis

Administrative

Homework to post by next Thursday

→ At least a week ahead of when it is due

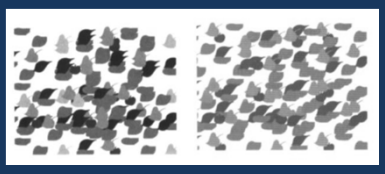
How Important is Color (Hue)?

- Color is Irrelevant
- Color is Critical

Color is Irrelevant…

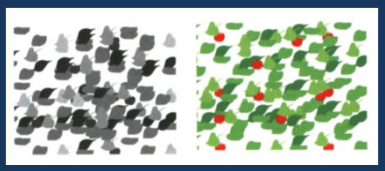
- To determine object shapes
- To determine layout of objects in space
- To determine how objects are moving
- Therefore, to much of modern life
  - Laboratory assistant went 21 years without realizing he was color-blind

Color is Critical…



Color is Critical…

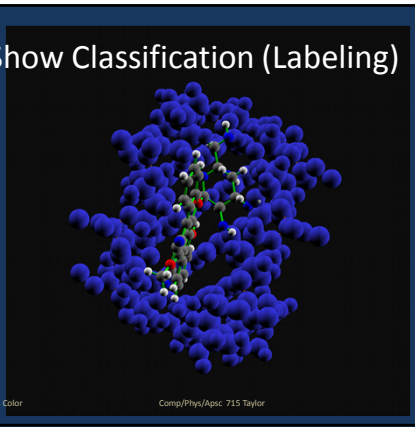
- To help us break camouflage
- To judge the condition of objects (food)
  - Ripe or rotten?
  - Poisonous?
- To determine material types



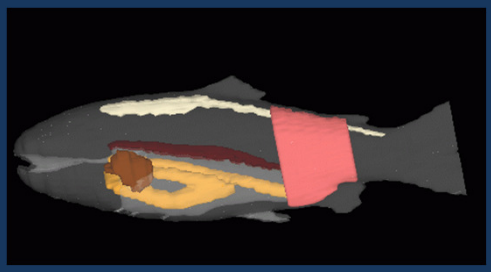
Uses of Color

- Good for labeling and categorizing
  - Show classification (labeling)
  - Mimic reality
  - Draw attention
  - Show grouping
- Poor for displaying shape, detail, or space
  - Use luminance

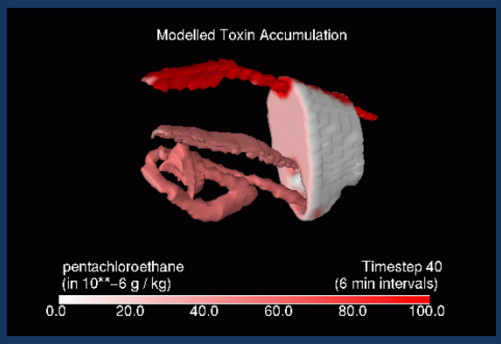
Show Classification (Labeling)



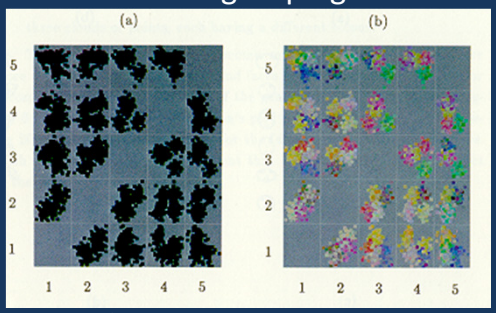
Mimic reality



Draw attention

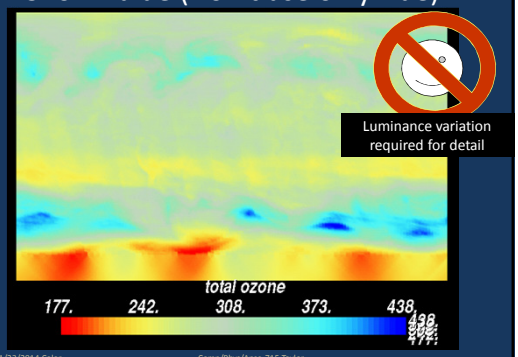


Show grouping



- Ware, p. 142

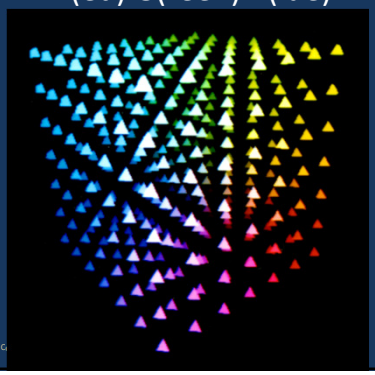
Show Value (Don't use only Hue)



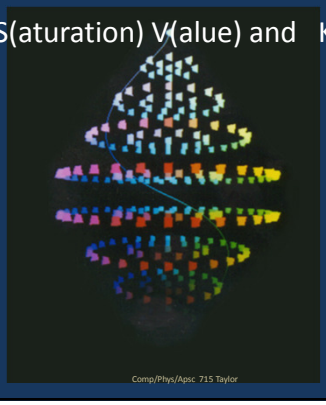
Color Models

- Device-derived
  - convenient for describing display device levels
  - RGB, CMY(K)
- Intuitive
  - based in familiar color description terms
  - HSV, HSB, HLS
- Perceptually uniform
  - device independent, perceptually "uniform"
  - CIELUV, CIELAB, Munsell

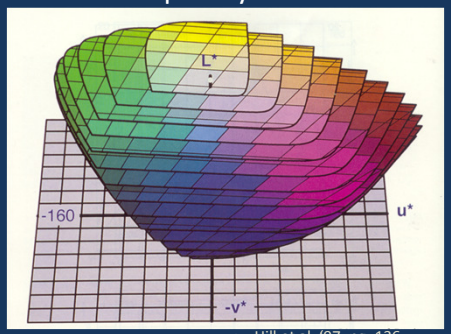
R(ed) G(reen) B(lue)



H(ue) S(aturation) V(alue) and Kindred



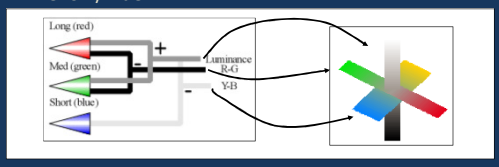
Perceptually Uniform



- Hill et al. '97, pg. 136

Opponent Process Theory

- Cone signals transformed into new channels
  - Black/White (Luminance; ignores blue!)
  - Red/Green
  - Yellow/Blue



Color Naming

- Never “Reddish green” or “Yellowish blue”
- Across cultures, looking at the appearance of color names
  - If only two, they are black and white
  - If three, red is next
  - Fourth and fifth are {yellow, green} (in either order)
  - Sixth comes blue
- This supports the opponent-color theory
- Next comes brown
- Then {pink, purple, orange, gray}

Color Categories

- Task: Name the colors
- Regions same > 75%
- Nonuniform sizes
- Only 8 hues named
  → small number of labels

- Why "rainbow scale" is so nonuniform

Hue vs. Luminance

- Spatial Sensitivity
  - Red/Green and Yellow/Blue each about 1/3 detail of Black/White
- Stereoscopic Depth
  - Pretty much can't do it with hue alone
- Temporal Sensitivity
  - Moving hue-change patterns seem to move slowly
- Form
  - Shape-from-shading works well
  - Shape-from-hue doesn't
- Category: Hue works well!

Color Spatial Sensitivity

It is very difficult to read text that is isoluminant with its background color. If clear text material is to be presented it is essential that there be substantial luminance contrast with the background color. Color contrast is not enough. This particular example is especially difficult because the chromatic difference is in the yellow blue direction. The only exception to the requirement for luminance contrast is when the purpose is artistic effect and not clarity

Color Temporal Sensitivity

- http://visionlab.harvard.edu/Members/Patrick/Demos/index.html

Color Temporal Sensitivity

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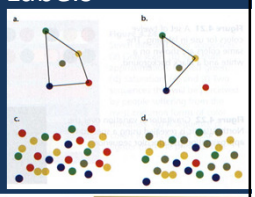
Application: Color for Labeling

- Color is comparatively effective for Nominal Information Coding
  - Only about four gray values can code
  - Can leave luminance channel free for shape perception
- Issues to consider
  - Distinctness, unique hues, number of labels
  - Contrast with background
  - Color blindness
  - Field size
  - Conventions

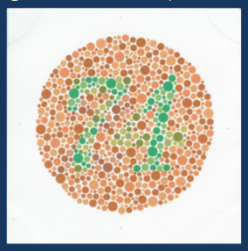
Number of Labels

- Distinctness (Rapid)
- Number of Labels
  - 5-10 (Healey)
- Unique Hues
- Contrast with Background



Other Issues (1/2)

- Color Blindness
  - Most red/green color blind (10% of males, 1% females)



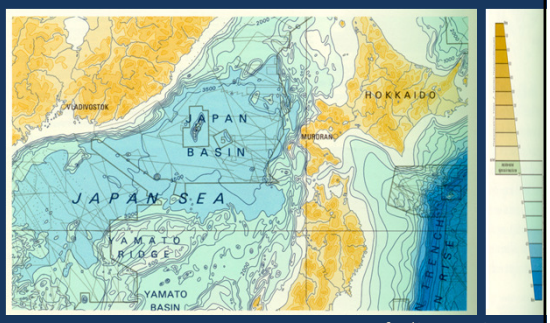
Other Issues (2/2)

- Field Size
  - Avoid small spots, especially in yellow/blue
  - Small areas: strong, highly-saturated colors
  - Large areas: low saturation with slight differences
- Conventions
  - U.S.: Red = danger, Green = life
  - Some parts of China: Red = life, Green/white = death
  - Some scientific domains have color conventions

Trumbo's Univariate Principles

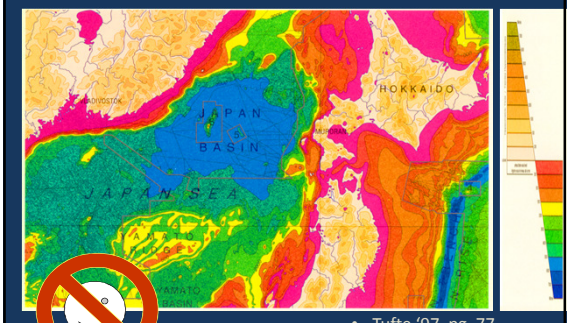
- Univariate
  - *Order*: ordered values should be represented by perceptually-ordered colors
  - *Separation*: significantly different levels should be represented by distinguishable colors

Ordered (and double-ended)



- Tufte '97, pg. 76.

Not ordered (red in both halves)



- Tufte '97, pg. 77.

Not Perceptually Ordered

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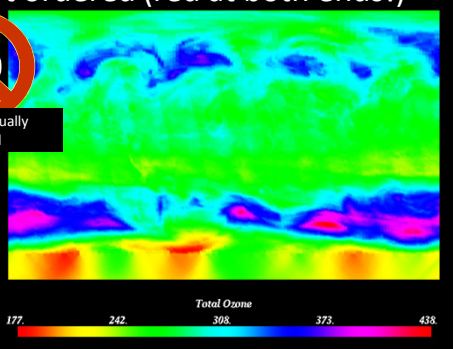
Not ordered (red at both ends!)

Not Perceptually Ordered



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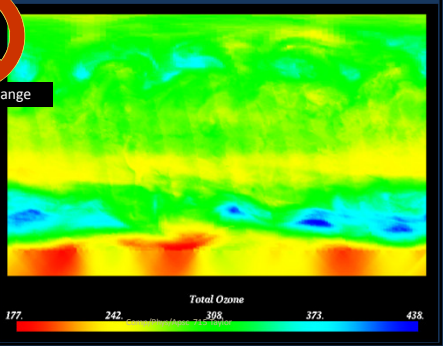
(non-perceptually) Ordered, choppy separation

Non-uniform change



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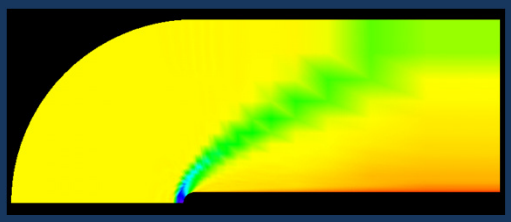
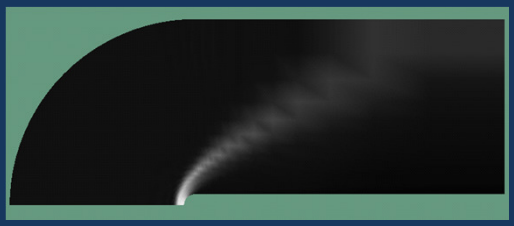
Ordered?



Ordered, Separation?

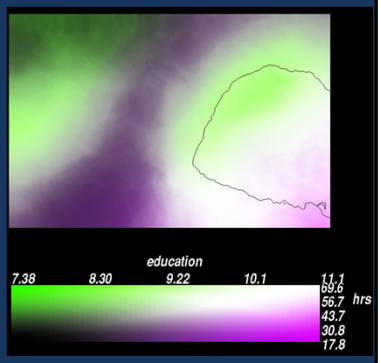


Ordered, More separation?

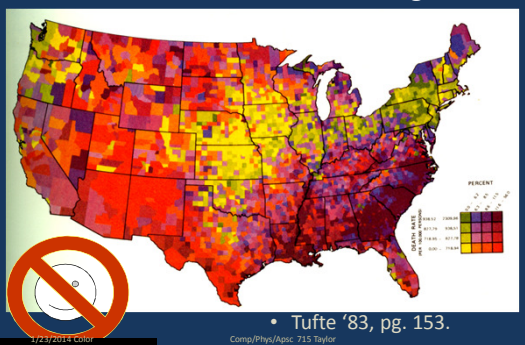
Trumbo's Bivariate Principles

- Bivariate
  - *Rows and columns*: to preserve univariate information, display parameters should not obscure one another
  - *Diagonal*: to show positive association, displayed colors should group into three perceptual classes: diagonal, above, below

Rows & Columns, Diagonal



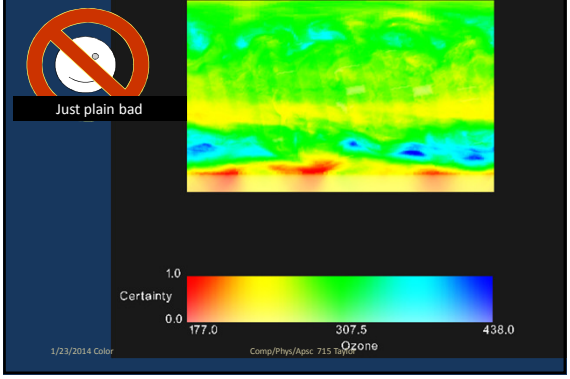
Not Rows & Columns or Diagonal



- Tufte '83, pg. 153.

Mixes two dimensions

Hue vs. Saturation (Hmm…)



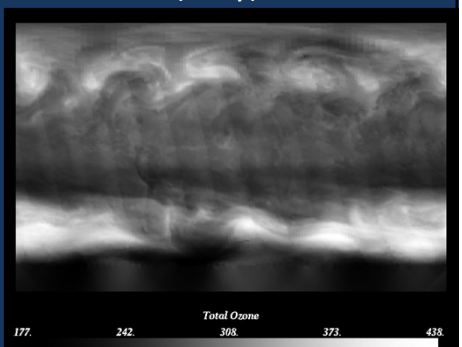
Some Univariate Color Scales

- Color model component
- Redundant scales
- Double-ended

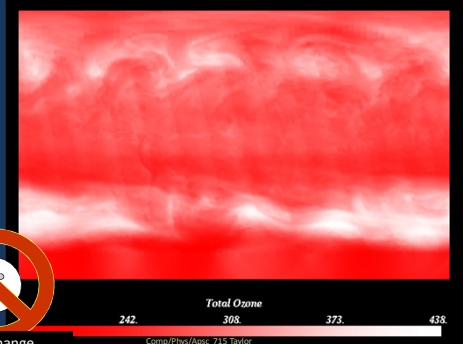
Color Model Component Scales

- Change a single color model component with other components held constant
- Examples
  - Grey scale
  - Saturation scale
  - Spectrum (hue, rainbow) scale (BOO, HISS!)

Luminance (Gray) Scale

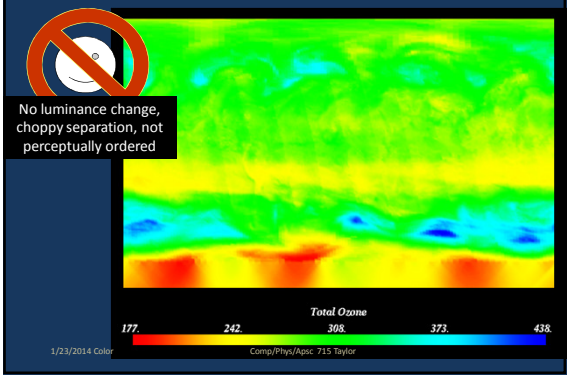


Saturation Scale



Sudden change

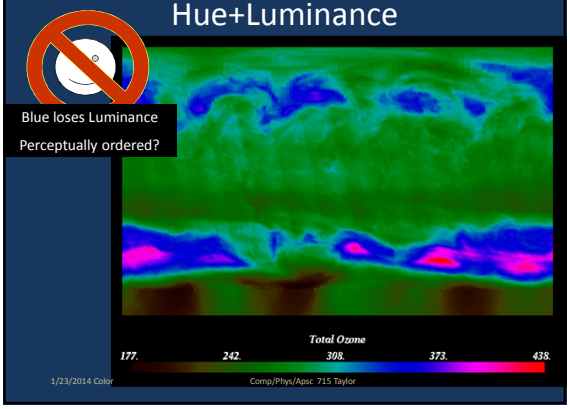
Hue Scale



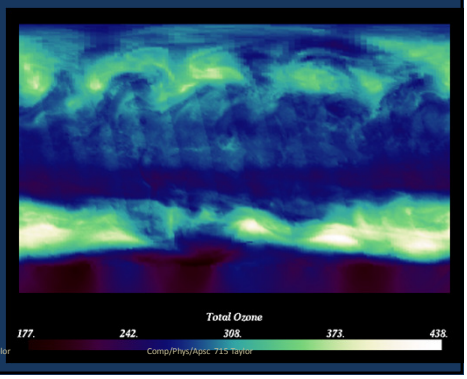
Redundant Color Scales

- Two or more color components varied together
- Examples
  - Hue with luminance
  - Heated object scale (black body radiation)
- Characteristics
  - Reinforces signal
  - Combines characteristics of simpler scales

Hue+Luminance



Hue+Luminance



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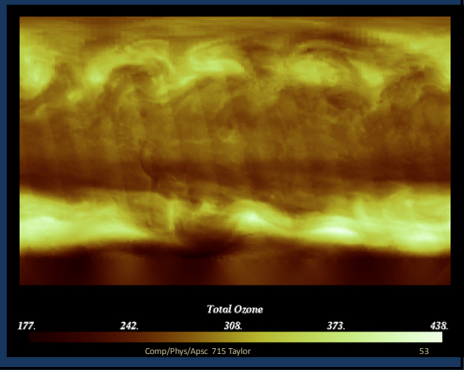
Approximates Black Body Radiation



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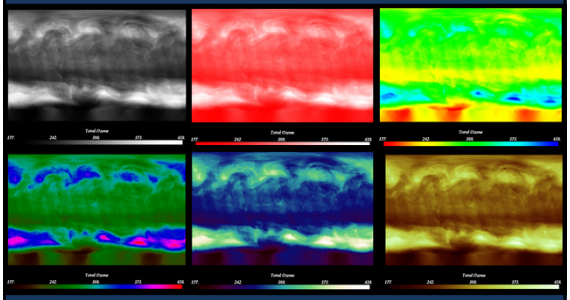
All Together Now



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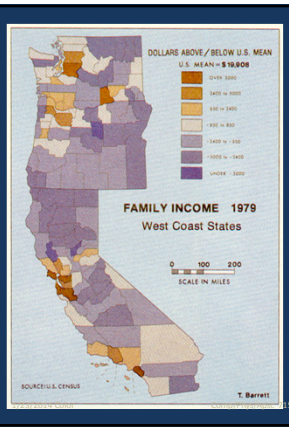
Double-ended Scale

- Two distinct scales joined at neutral middle
- Characteristics
  - segments values into two groups
  - can emphasize both extremes of data range

Double-Ended Income



- Olson '97, fig. 11-8.

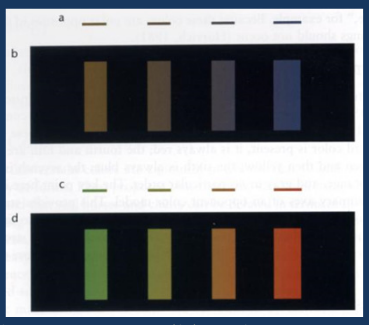
Consider Data

- Interesting values?
  - Position striking colors at interesting values
- Zero in range?
  - Double-ended scale
- High spatial frequency?
  - Vary lightness in addition to hue

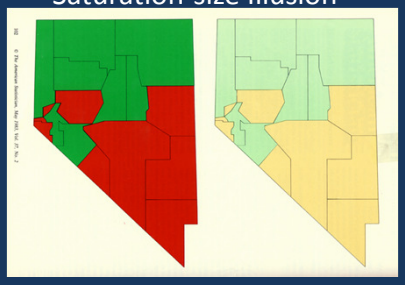
Consider Audience

- Color deficient viewers?
  - Don't depend on red-green differentiation
  - Use redundant scales
- Application area conventions?
  - Use familiar scales (or at least know when you're not)
- Color associations with variables?
  - Use associated color
- Color associations with data ranges?
  - Use red for bad range (in U.S.)
  - Use red for hot

Size and Background Effects

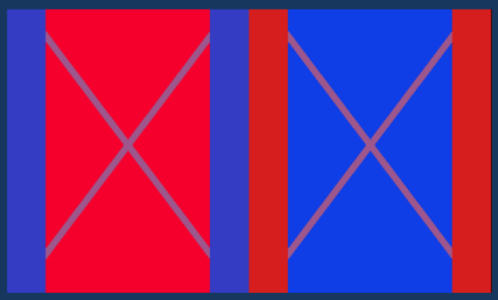


Saturation-size Illusion



Cleveland and McGill '83.

Chromatic Contrast



Brown…

- Brown is dark yellow…
  - But not when it is alone in a dark room
- Must be surrounded by brighter patches
  - Otherwise some shade of yellow
- Be aware that it may not be seen as belonging to the family of yellows.

"I cannot pretend to feel impartial about colours. I rejoice with the brilliant ones and am genuinely sorry for the poor browns." - Sir Winston Churchill

Web Pointers

- Color Brewer
  - Colorbrewer2.org
- Color FAQ
  - http://www.poynton.com/ColorFAQ.html
- Penny Rheingans' Color Perception and Apps
  - http://www.cs.umbc.edu/~rheingan/SIGGRAPH/color.intro.pdf

References:

- Uses of Color and the four examples, Color Models and the three examples, Univariate, Color Model component (and examples), Redundant (and examples), Color-size illusion, Double-ended (and examples), Multivariate scales (and examples), Evaluating color scales (and examples), Consider Data, Consider Audience: Penny Rheingans
- The remainder are from Colin Ware's book "Information Visualization."