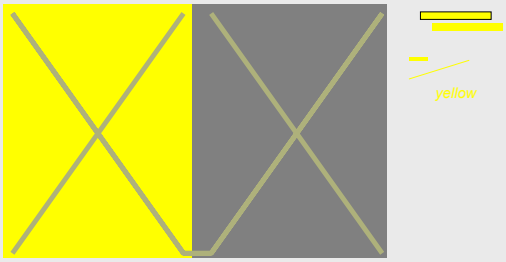
Designing Colors for Data

Maureen Stone
StoneSoup Consulting

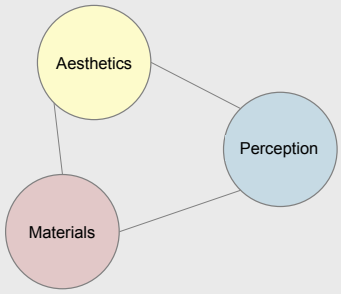
"Color is the most relative medium in art."
—Josef Albers, Interaction of Color



"Good painting, good coloring, is comparable to good cooking. Even a good cooking recipe demands tasting and repeated tasting while it is being followed. And the best tasting still depends on a cook with taste."

—Josef Albers

"Good ideas executed with superb craft"
—E.R. Tufte, Envisioning Information



Successful Recipes

"You can think of an RGB or CMYK file as containing, not color, but rather a recipe for color that each device interprets according to its own capabilities. If you give 20 cooks the same recipe, you'll almost certainly get 20 slightly different dishes as a result"

Real World Color Management
B. Fraser, C. Murphy, & F. Bunting

Recipe 1

bananas
sugar
egg
butter
baking soda
baking powder
salt
flour

Bake

What is it?

Could you make it?

Recipe 2

3	bananas
1/3	sugar
1	egg
1/3	butter
1	baking soda
1	baking powder
¼	salt
1 ½	flour

Bake at 375 for 15

What is it?

Could you make it?

Banana Muffins

3	bananas
1/3 c	sugar
1	egg
1/3 c	butter
1 t	baking soda
1 t	baking powder
¼ t	salt
1 ½ c	flour

Bake at 375°F for 15 minutes

Missing process?

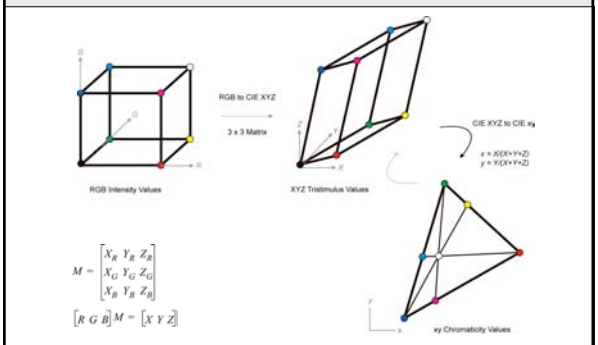
Could you make it?

Banana Muffins

3	bananas	Mash bananas
1/3 c	sugar	Melt butter
1	egg	Combine bananas, sugar, egg, butter
1/3 c	butter	
1 t	baking soda	Combine dry ingredients
1 t	baking powder	Add dry to wet, stir until just mixed
¼ t	salt	
1 ½ c	flour	Spoon into muffin tins

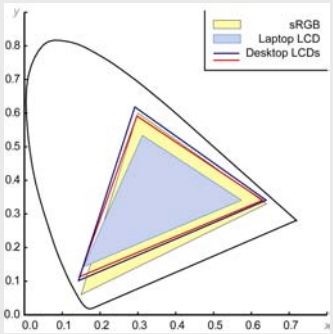
Bake at 375°F for 15 minutes

RGB to XYZ to xy



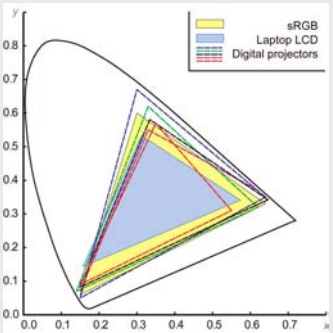
From *A Field Guide to Digital Color*, © A.K. Peters, 2003

Display Gamuts

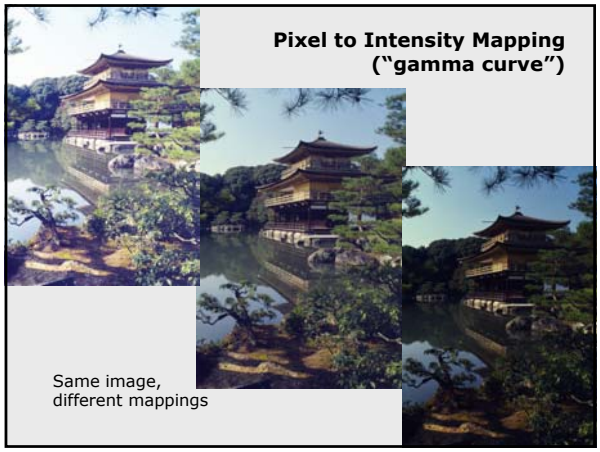


From *A Field Guide to Digital Color*, © A.K. Peters, 2003

Projector Gamuts

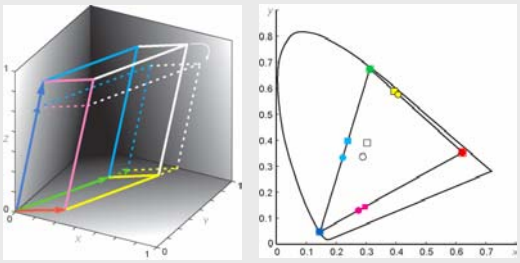


From *A Field Guide to Digital Color*, © A.K. Peters, 2003



White point changes

Change relative amounts of R, G, B



"… avoiding catastrophe becomes the first principle in bringing color to information:

Above all, do no harm."

—E. R. Tufte

Fundamental Uses

To label (identify or group)
To measure (color to quantity, color scales)
To represent or to imitate reality
To enliven or decorate

The problem

Design color for Tableau Software
"Visual Analysis for Everyday Data"

Goals

- Aesthetic "business graphics"
- Robust across displays and users
- UI encourages good practice, but allows choice

Commercial design task

Color design tasks

Categorical color palettes + UI

- Color as label
- Distinctly different, similar visual weight
- Scatter plots, line graphs, bar charts, text

Quantitative color palettes + UI

- Color as quantity
- Sequential and diverging scales
- Heat maps, scatter plots (but could be any above)

Formatting colors + UI

- Color to decorate (also group and label)
- Row, column and header shading
- Annotations (lines and text)

Global Issues

Subtlety vs. robustness
- What can we assume about the display?
- Not calibrated (except mine)

Clarity vs. expressiveness
- How many colors?
- What about the "color blind?"

Simplicity vs. power in the UI
- Optimized for good practice
- Data-to-color control, not color control

Color Design Process

Design on my calibrated (sRGB) display
Deliver RGB triples to client

Tools
- Photoshop
- Illustrator
- Visio
- Python
- Excel
- Tableau

Color spaces
- CIELAB
- HSB
- RGB

UI Design Process

Collaboration with Tableau implementers
- Meetings
- Design sketches
- Memos

Tableau developers did the implementation
- Jock Mackinlay, Andrew Beers, Chris Stolte, Iain Heath, Craig Hobbs
- Windows, C++

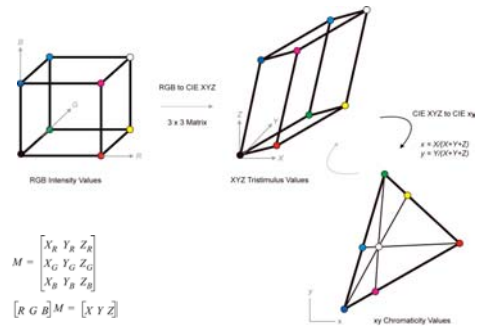
Key UI concepts
- Not editing colors, but defining data-to-color mapping
- Users are not experienced visual designers
- But may care very much about their colors

Roadmap

A bit on color spaces
Discuss each color task
For each
- Issues, process
- Solution, discussion
- Tableau visualization & UI demo

Color Vision Deficiencies ("color blindness")
Questions

RGB to XYZ to xy



From *A Field Guide to Digital Color*, © A.K. Peters, 2003

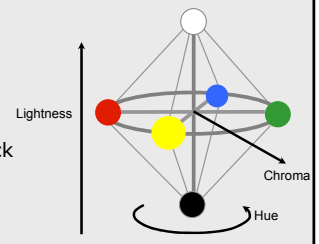
"Perceptual" Color Spaces

Hue
- Color's "name"
- Angular scale

Lightness (brightness)
- Linear scale

Chroma (saturation)
- Intensity or purity
- Radial scale

Relative to white & black



Color Design Terminology

Hue (color wheel)
- Opposites complement (contrast)
- Adjacent are analogous
- Many different color wheels*

*See www.handprint.com for examples

Chroma (saturation)
- Intensity or purity
- Distance from gray

Value (lightness)
- Dark to light
- Applies to all colors, not just gray

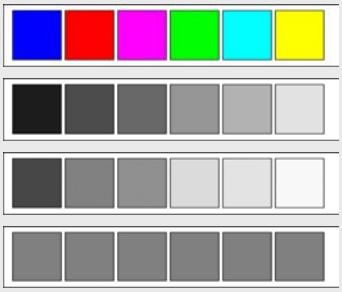
Wucius Wong, *Principles of Color Design*

Psuedo-Perceptual Models

HLS, HSV (HSB)
NOT perceptually accurate
Simple renotation of RGB
- View along gray axis
- See a hue hexagon
- L or V is grayscale pixel value

L & V do NOT predict perceived lightness

L vs. Luminance, L*



Corners of the RGB color cube

Gray based on luminance (Y)

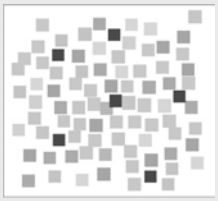
Gray based on L* (Munsell value)

L from HLS
All the same

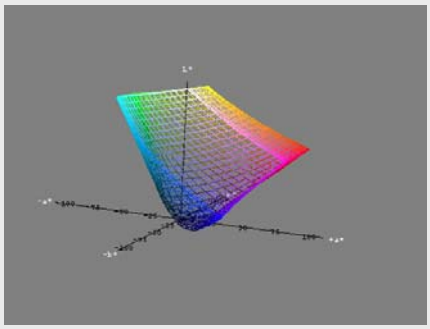
Get it right in black & white

Value defines shape
- No edge without lightness difference
- No shading without lightness variation

Value difference (contrast)
- Defines legibility
- Controls attention
- Creates layering



CIELAB Space



Categorical Colors Issues

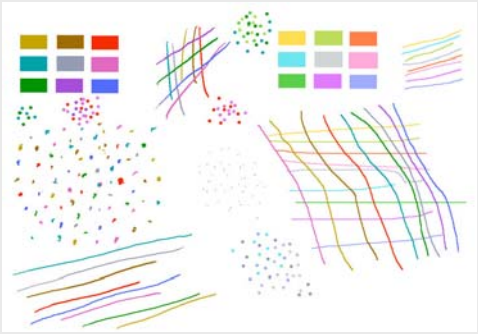
Color palettes
- How many? Algorithmic?
- Basic colors (regular and pastel)
- Extensible? Customizable?

Color appearance
- As a function of size
- As a function of background

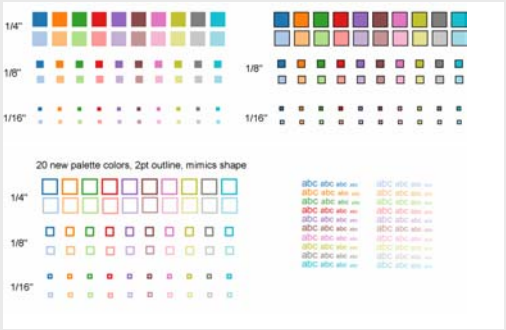
Robust and reliable color names

UI to encourage good practice
- But, must allow for personal expression

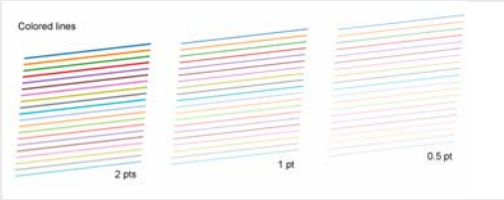
Sketching example



Sample pages



Sample Pages



Questions

- What are parameters for legibility?
- Can we adapt color to size?
- Richness vs. clarity

Categorical Colors

10 basic colors

- Simple names
- Increase number with lightness variation

Designed to balance

- Legibly colored dots, lines and text
- But not too gaudy for bars
- Tasteful, yet colorful

Pop-out vs. Distinguishable

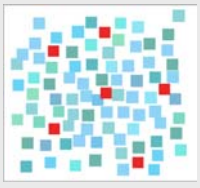
Pop-out

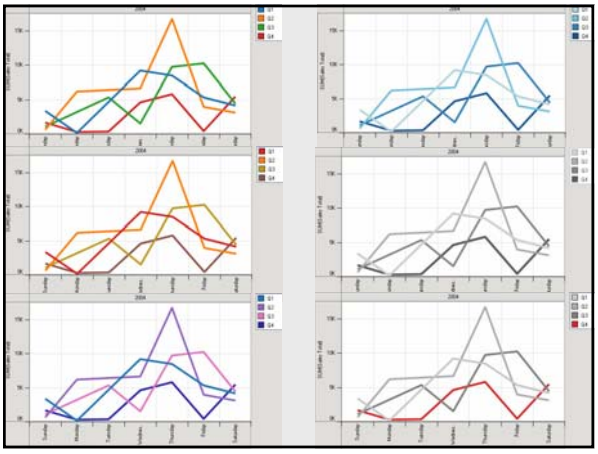
- Typically, 5-6 distinct values simultaneously
- Up to 9 under controlled conditions

Distinguishable

- 20 easily for reasonable sized stimuli
- More if in a controlled context
- Usually need a legend

Task and style





Color Names

Basic names (Berlin & Kay)

- Linguistic study of names across 20 languages
- Found 11 basic names, similar linguistic evolution
  - Black, white, gray
  - Red, green, blue, yellow
  - Orange, purple, brown, pink

Controversy about original hypothesis

Recent work by Kay et. al.

- Redefines as constraints, modulated by language
- World Color Survey

Recommended by Ware for labels

Tableau names

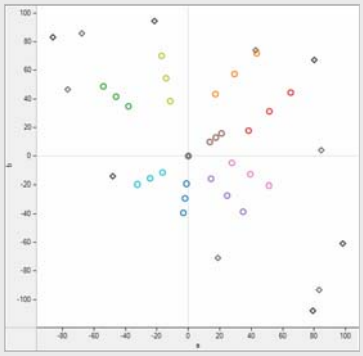
Basic names (11)

- Black, white, gray
- Red, green, blue, yellow
- Orange, purple, brown, pink

Tableau names (10)

- Minus black & white
- Plus teal
- Yellow => gold

Tableau Visualization



Quantitative Color Issues

Color sequences

- What colors, what sequences?
- Continuous or quantized? (and how?)
- Work at all sizes, and in isolation

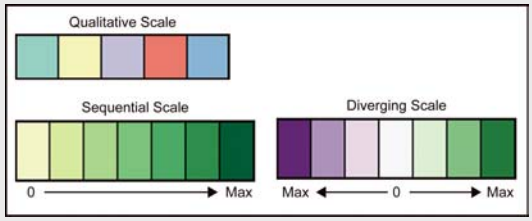
Real numeric data

- All distributions, including outliers
- Can't visualize the histogram

UI to encourage good practice

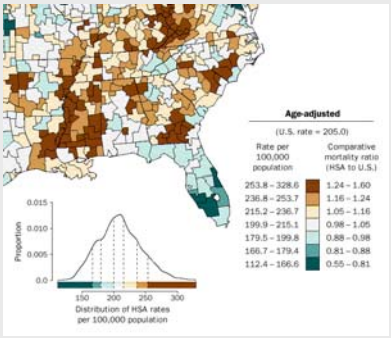
- UI must be simple, not intimidating
- Users not expert in color or statistics

Types of Scales



Cynthia Brewer, Pennsylvania State University

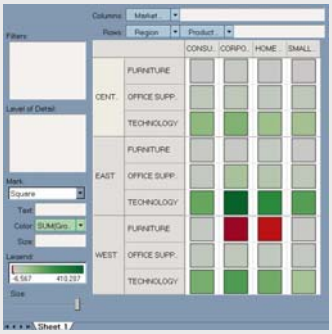
Data Distribution



Mapping Census 2000: The Geography of U.S. Diversity

Proportional Distribution

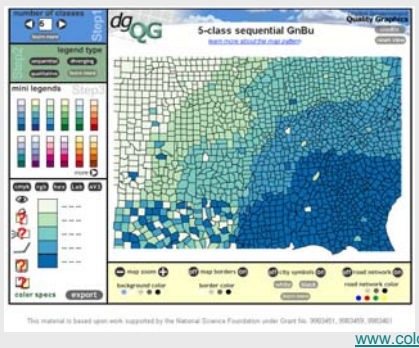
Full Range



Stepped

Threshold

Color Brewer



Ramp Design

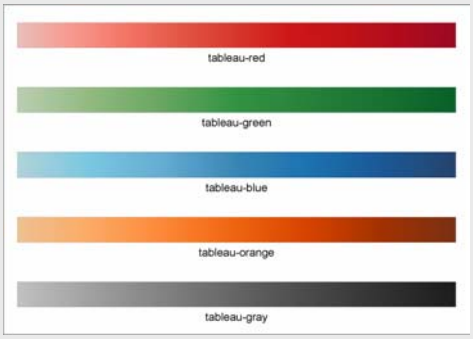
Start with Brewer ramps
- Available as RGB
- Not calibrated

Modify
- For sRGB
- Eliminate darkest colors
- Reduce hue shift

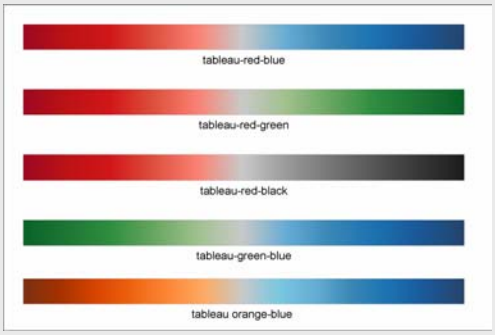
Interpolate
- Custom Python code
- CIELAB, RGB
- Piecewise linear

From ColorBrewer

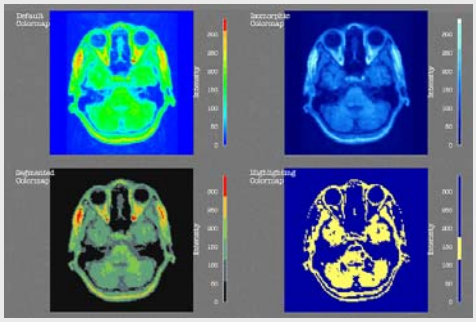
Sequential Ramps



Diverging Ramps

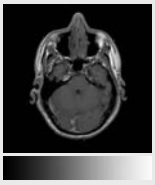


Color scales in Vis

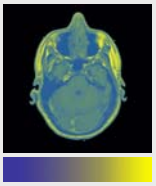


Rogowitz & Treinish, "How not to lie with visualization"

Density Map Example

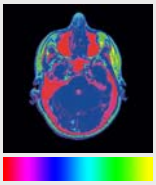


Lightness scale



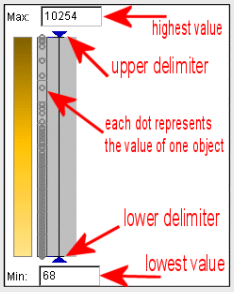
Lightness scale with hue and chroma variation

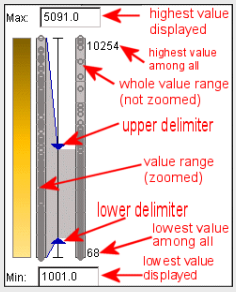
Bad



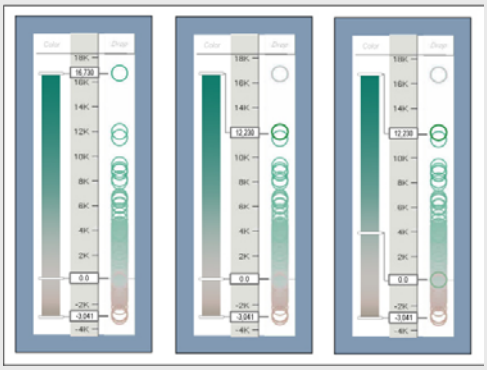
Hue scale with lightness variation

Common GIS Project



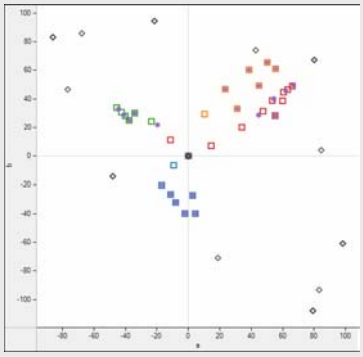


http://commongis.jrc.it/

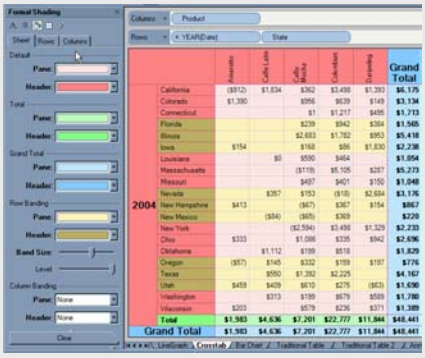


StoneSoup Consulting, 2005

Visualizing Ramps



Formatting Colors



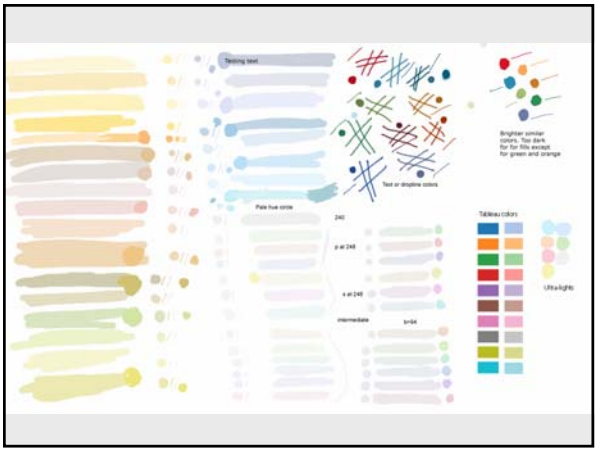
Formatting Color Issues

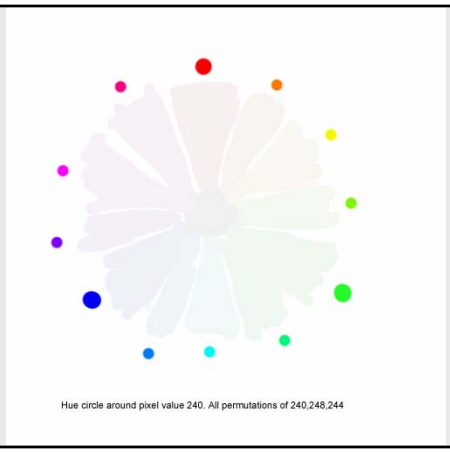
Taste and style
- Aesthetic, professional
- Lots of choices

Shading colors
- How light can we go?
- Visibility in the UI

Annotation colors
- Text legibility
- Relationship to shading colors

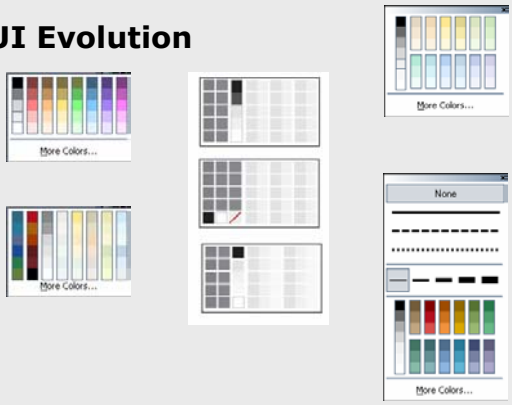
Limited space and time for UI implementation



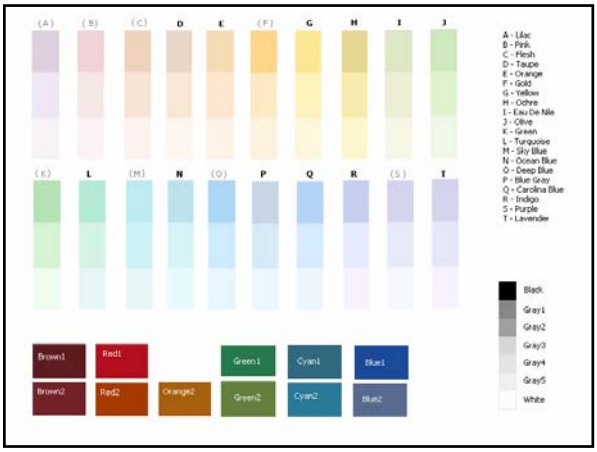


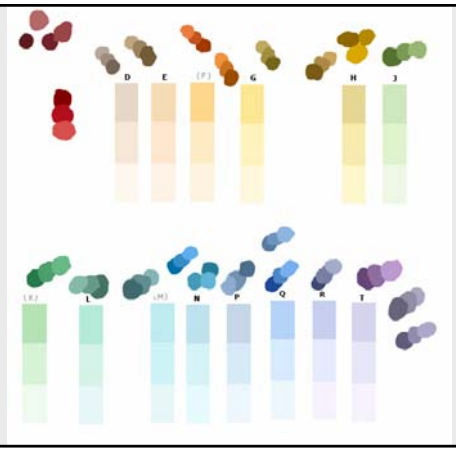
Hue circle around pixel value 240. All permutations of 240,248,244

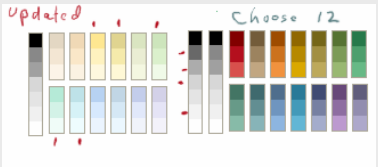
UI Evolution



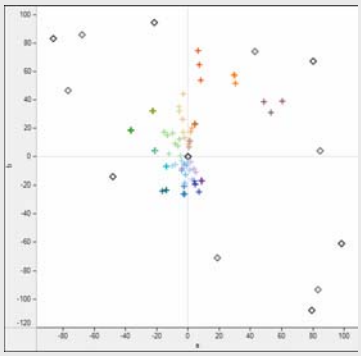
Expanded Palette







Visualize in Tableau

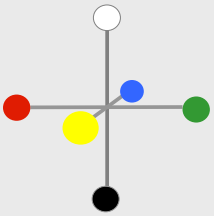


Color Vision Deficiencies (CVD)

Non-standard cone (SML) response
- Genetic
- Medical
- Mild to missing

Three modes
- L-weak (protanope)
- M-weak (deuteranope)
- S-weak (tritanope)

Modeled in opponent space
- Achromatic axis
- R-G and Y-B axis



Incidence of CVD

Monochromacy - 0.003%

Dichromacy

- Protanopia 1%
- Deuteranopia 1.1%
- Tritanopia 0.002%

Anomalous trichromacy

- Protanomaly 1%
- Deuteranomaly 4.9%
- Tritanomaly -

Total - 8.005%

R. W. G. Hunt. *Measuring Colour*. Fountain Press,1998.

Vischeck

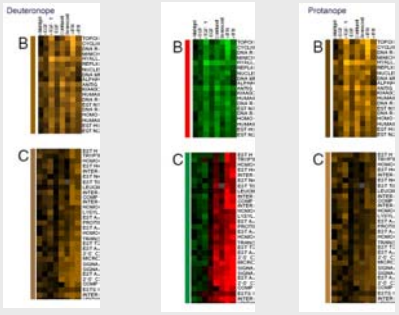
Simulates dichromatic color vision deficiencies

- Web service or Photoshop plug-in
- Robert Dougherty and Alex Wade

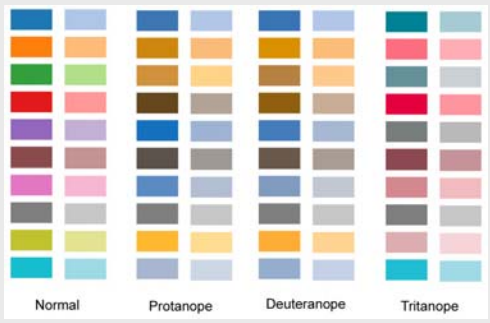
www.vischeck.com

Deuteranope Protanope Tritanope

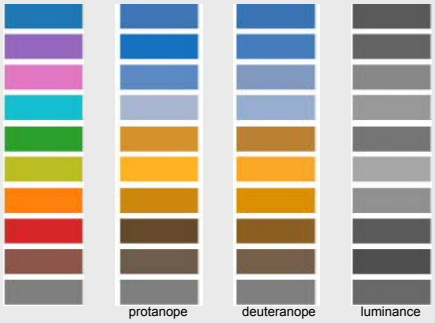
Genes in Vischeck



2D Color Space



Similar Colors



Accommodation

No color set that works for all viewers
Even accommodating most common is limiting

Options:

- Minimize dependency on color
- Double encode
- Provide choices/customization

But the diagramatic maps of muscles in our illustrated anatomies are not "transcripts" of things seen, but the work of trained observers who build up the pictures of a specimen that has been revealed to them in years of patient study.

From Art and Illusion, E.H. Gombrich