Color design
From seeing red to feeling blue

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Color in Information Display
Graphical presentation of information
• Charts, graphs, diagrams, maps, illustrations
• Originally hand-crafted, static
• Now computer-generated, dynamic
Color is a key component

Emotional Design
Emotion, not just function
• Attractive things work better
• Compensates for lack of function
• People choose with their emotions

Don Norman, Emotional Design
Emotional Color?
Can we predict behavior from color preferences?  
Do colored environments affect behavior?
- Calm or stimulate behavior?
- Make the room feel warmer or cooler?
- Affect what and how much people buy?
Are there inherent color "messages?"
- At a psychological level?
- At a cultural level?
- At a marketing level?

Color & Language
Language for color
- Color names (simple & complex)
- Basic names (Berlin & Kay)
Color in language
- Seeing red, red-letter day
- Feeling blue, true blue
- Green-eyed monster
- Purple prose, purple heart
- Yellow streak, white feather
- Black-hearted, in the black

Colorful language

How important is color?

Maps courtesy of the National Park Service (www.nps.gov)
Visualization of isoelectron density surfaces around molecules
Marc Levoy (1988)

People LIKE color

FactMonster.com

Does color add any information?
Which would you rather look at?
People LIKE color
Norman’s Design Levels

Visceral
- “I want it…what does it do?”
- Immediate emotional response

Behavioral
- User, task, solution
- Functional design
- Feels good to use

Reflective
- Message, culture, meaning
- Reflects self-image
- Thought & emotion

“Made in the Shade”
Color Marketing Group

What creates good color design?

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

Materials
- Pigments & Paints
  - Scattered light
  - The Bright Earth, Philip Ball

Materials: Pigments & Paints

Materials: Dyes
- Organic molecules
  - Biological origin (snails, bugs, plants, etc.)
  - Synthetic (William Perkin)
  - Dyed pigments are “lakes”

Mauve, Simon Garfield
**Print & Film**

Layered color
- CMY primaries
- Film: dye layers
- Print: Halftone patterns
- Black for contrast

**Light**

Summed spectra
- RGB primaries
- Displays, projectors
- Basis for digital color

**Materials, Perceptions, Aesthetics**

Physical World
- Lights, surfaces, objects

Visual System
- Eye, optic nerve, visual cortex

Mental Models
- Red, green, brown
- Apple, leaf, bark
- Stop, go, state park
- Warm, cool, neutral
- Attractive, ugly, blah
- Powerful, nurturing, …

**“Perceptual” Color Spaces**

Hue
- Color’s “name”
- Angular scale

Lightness (brightness)
- Linear scale
- Black to white

Chroma (saturation)
- Intensity or purity
- Radial scale
**Munsell Atlas**

Courtesy Gretag-Macbeth

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**Art & Design**

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*

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**RGB: Pseudo-Perceptual Models**

HLS, HSV (HSB)
- NOT perceptually accurate
- Do NOT predict perceived lightness (Value or Luminance)

- Hue: 110
  - Sat: 255
  - Lum: 128

- Hue: 160
  - Sat: 100
  - Lum: 128

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“Color is the most relative medium in art.”
—Josef Albers, *Interaction of Color*

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**Effective Color Design**

Use color for a purpose
- Identify your information & messages
- Identify its function
- Assign relative importance
- Map colors accordingly

Design using contrast & analogy
- Contrast emphasizes
- Analogy groups
- Legibility, attention & layering

Design, test, evaluate
Practice, practice, practice

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“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
Envisioning Information

“... avoiding catastrophe becomes the first principle in bringing color to information: Above all, do no harm.”
—E. R. Tufte

Fundamental Uses
To label
To measure
To represent or to imitate reality
To enliven or decorate

Color and Function
To label
- Primarily hue variation
- Associated with color names
To measure
- Vary lightness & chroma
- Map to data distribution

Color and Function
To evoke nature
- Metaphor, symbolic
- Illustration: distilled experience

Color and Function
To decorate, beautify
- Emotional design
- Visceral & reflective

Contrast and Analogy
Contrast & Analogy
- Contrast (difference) separates
- Analogy (similarity) groups

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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

Creates robustness
- Across viewers
- Across media

Controls Legibility

Can you read this?
Can you read this?
Can you read this?
Can you read this?

Must have value contrast, NOT just hue contrast

Creates Layers

In brief

"Get it right in black & white"
Use neutral backgrounds
- Grays or near gray
- RGB all nearly equal
- Prefer light backgrounds
Avoid overly saturated colors
- RGB: No values are zero
- Exception: yellow
Use hue contrast sparingly
- Small differences are fine
- If many hues, then use similar value, saturation

Tableau Case Study

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

Task
- Design color palettes
- Collaborate on color selection UI

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

### Categorical Colors Issues

Color palettes
- How many? Algorithmic?
- 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

### Sample pages

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

### Sample pages

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

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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

Palette-based UI

1. Select whole palettes
2. Individual colors from different palettes
3. Standard color picker

Formatting Colors

- Taste and style
  - Aesthetic, professional
  - Lots of choices
- Shading colors
  - How light can we go?
  - Visibility in the UI
- Annotation colors
  - Text legibility
  - Different from data colors
  - Harmonious with formatting, data colors
- Limited space and time for UI implementation
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

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

Sequential Ramps

Diverging Ramps
**Data Distribution**


**Proportional Distribution**

- Skewed Data
- Slightly negative

**Full Range**

- Skewed Data

**Stepped**

- Skewed Data

**Threshold**

- Skewed Data

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Quantitative UI

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
- Protaganopia 1%
- Deuteranopia 1.1%
- Tritanopia 0.002%
Anomalous trichromacy
- Protanomaly 1%
- Deuteranomaly 4.9%
- Tritanomaly -
Total - 8.005%

Vischeck
Simulates dichromatic color vision deficiencies
- Web service or Photoshop plug-in
- Robert Dougherty and Alex Wade
vischeck.com

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

Additive Color

Combine red, green, blue lights

Primaries
- red
- green
- blue

Subtractive Color

Filter white light to modulate R, G, B

Primaries
- cyan
- magenta
- yellow