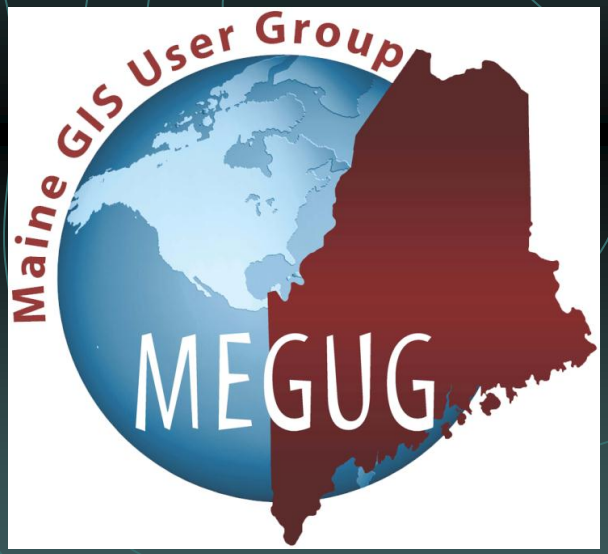
Map Design for the Color Vision Impaired



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What is Color Blindness?

- Misnomer
- Color Vision Impairment or
  Color Vision Deficiency (Amer. Optometric Assoc.)
- Most can see color
- They cannot differentiate color
  - shades of red and green most common
  - blues and yellows (rare)

Causes (Amer. Optometric Assoc. www.aoa.org)

- **Inherited** (X chromosome)
- **Injury**
- **Illness** (diabetes, glaucoma, macular degen., Parkinson's, MS, sickle cell anemia, etc.)
- **Medication** (heart, BP, infection)
- **Aging** (esp>60): tanning dims blue
- **Chemical Exposure** (fertilizers, styrene, toluene, PCE, solvents, mercury)

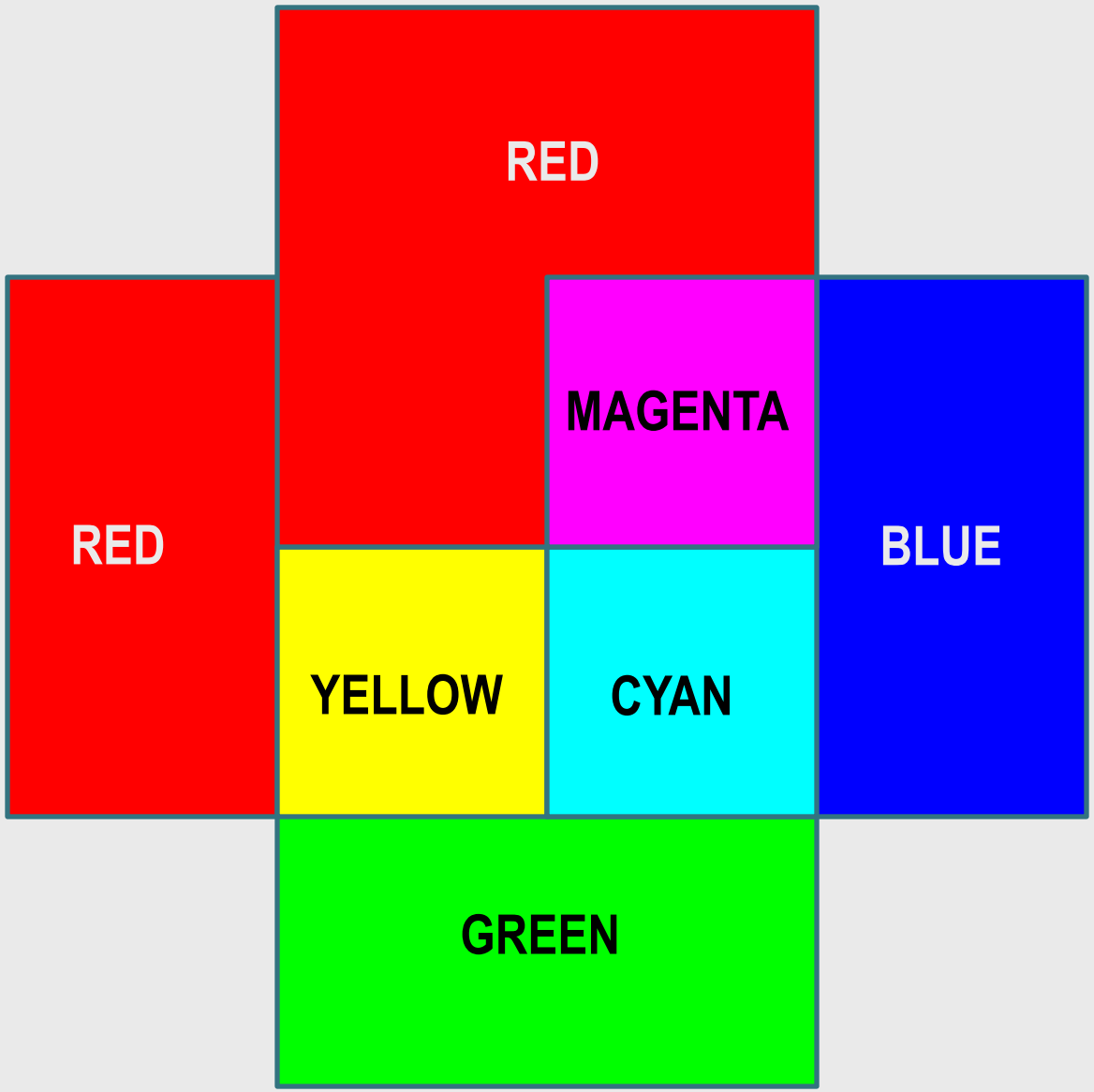
Classification (www.webexhibits.org)

	Male	Female
Anomalous Trichromacy (weak sensitivity)		
protanomaly (red)	1.3%	0.02%
deuteranomaly (green)	5.0	0.35
tritanomaly (blue)	.0001	.0001
Dichromacy (cone absent)		
protanopia (red)	1.3	0.02
deuteranopia (green)	1.2	0.01
tritanopia (blue)	.001	?
Illness, Aging, Chemicals, etc.	No data	

Why Does it Matter?

- Aging population
- Universal design and accessibility
  - Avoids discrimination
  - Complies with regulations
- Expands audience (Gardner 2005 on web design)
  - More clients
- Increases user satisfaction
- Increased productivity
- The right thing to do!

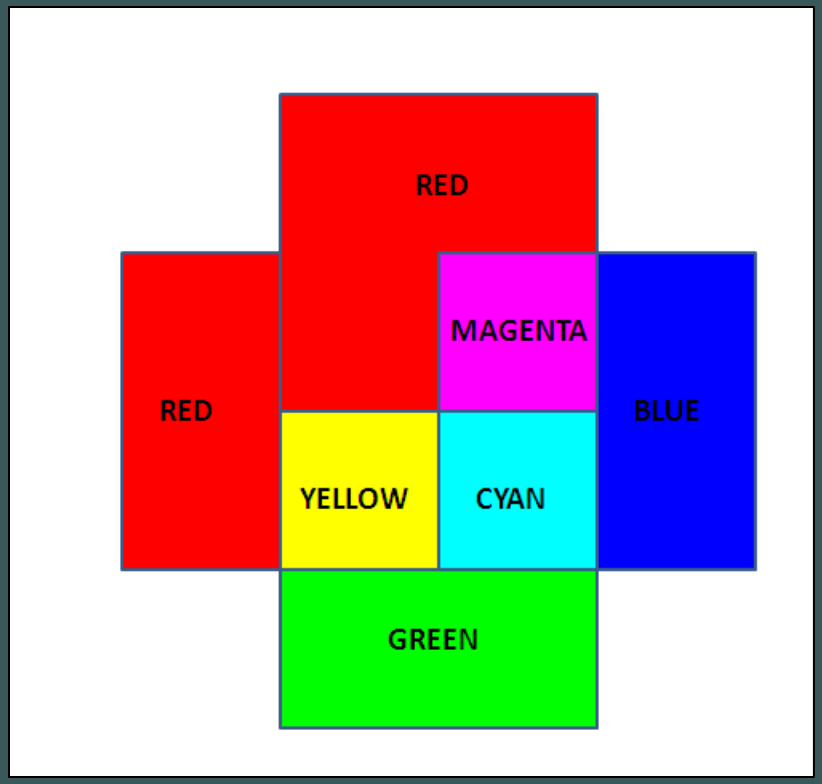
Trichromacy theory and the opponent-process theory

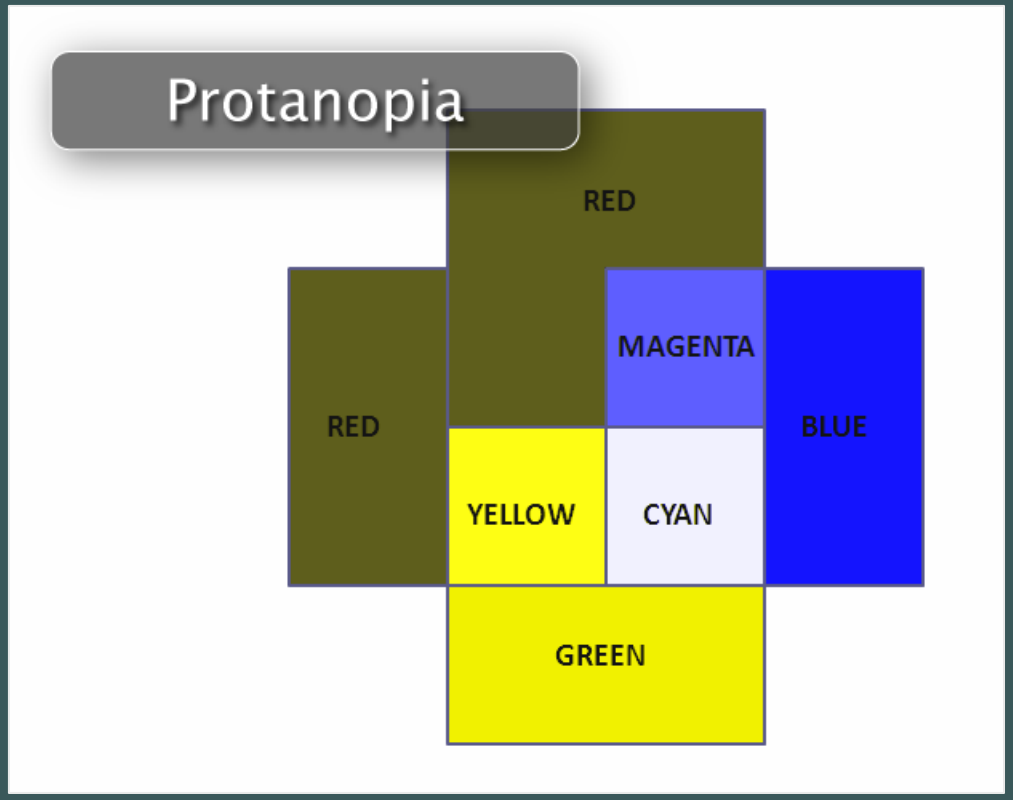


Effects for Protanopia (red) Clark 2003

- cannot distinguish red and greens
- reds appear dark
- red and black can look the same if red is dim
  - So, lightness ("~~brightness~~") matters

missing red cones



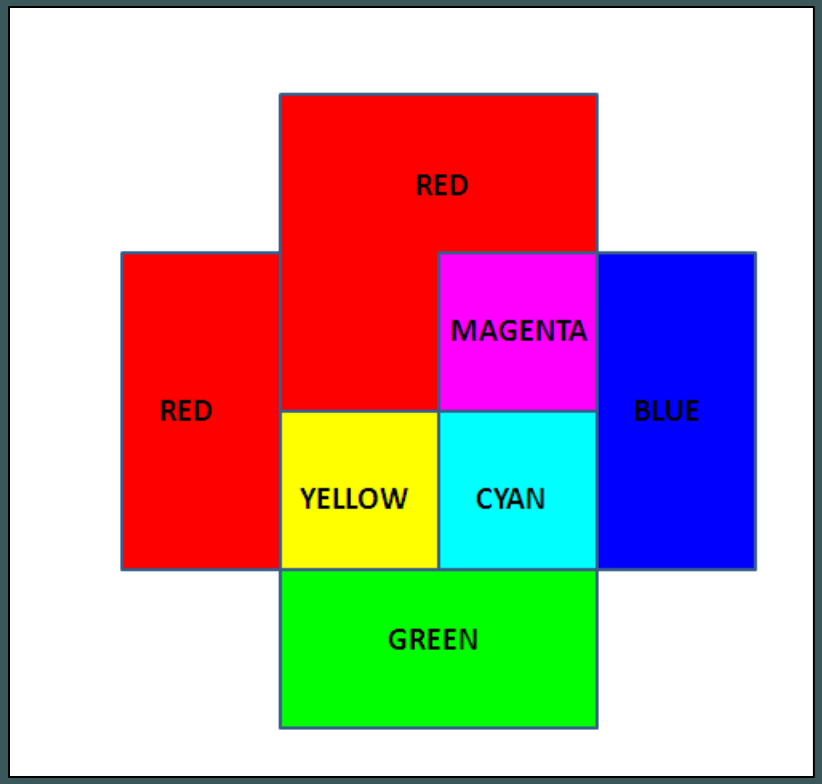


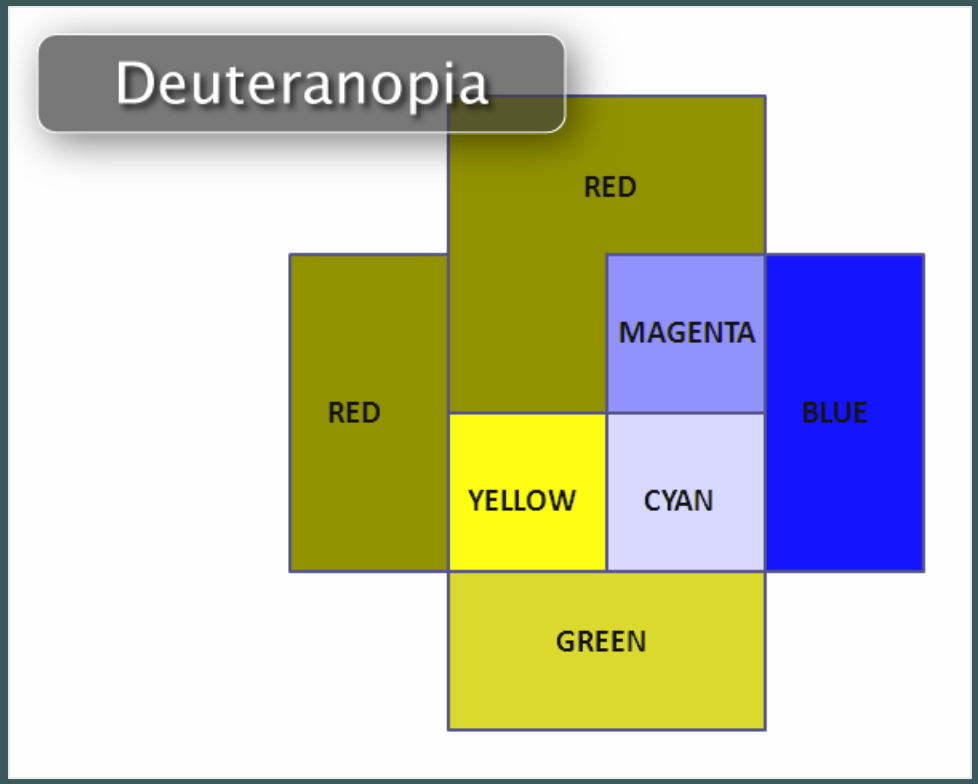
ColorOracle
http://colororacle.cartography.ch/

Effects for Deuteranopia (green) Clark 2003

- cannot distinguish red and greens
- reds do not appear red or dark
  - No lightness ("~~brightness~~") compensation
- Deuteranomalous – better red-green discrimination and better differentiation of shades

missing green cones





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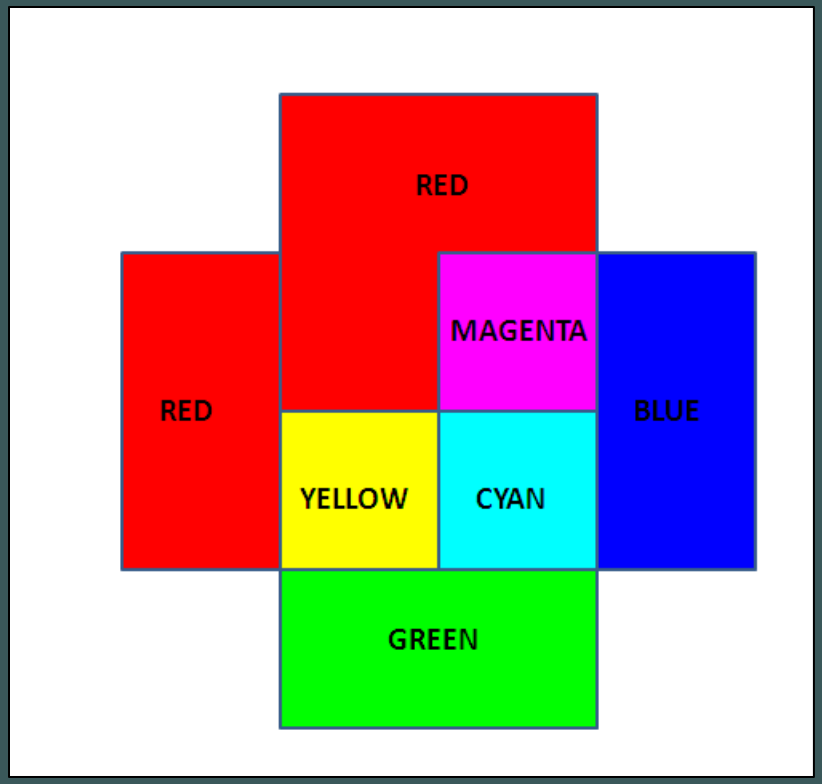
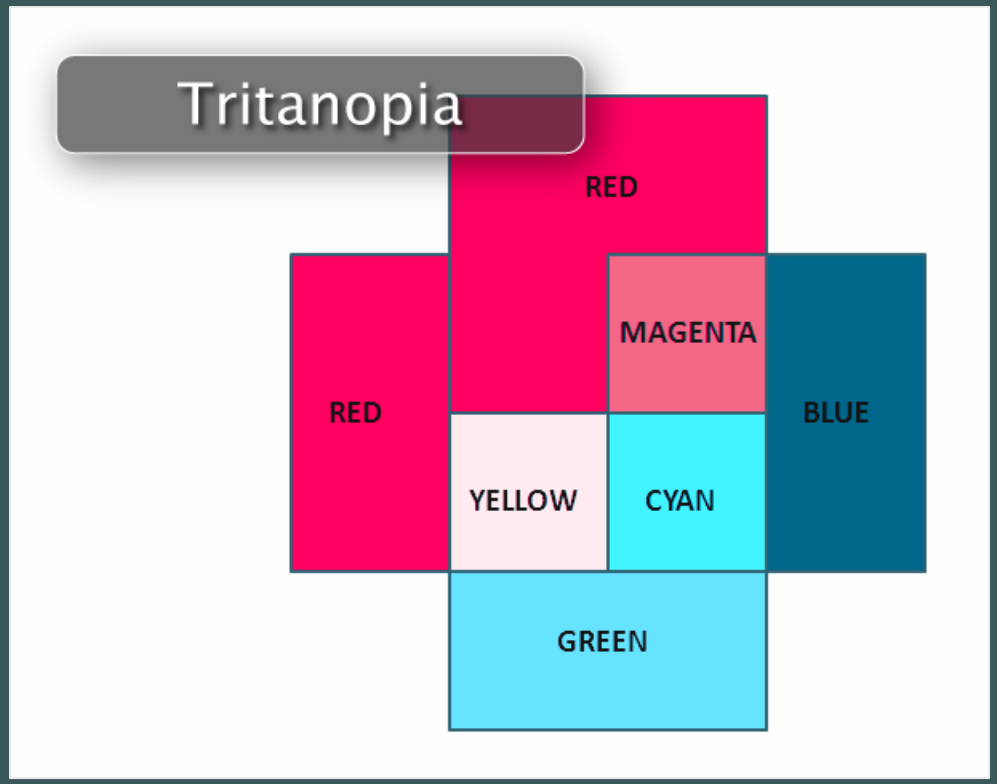
Effects for Tritanopia (blue) Clark 2003

- blues and greens confused
- yellows and violets confused

missing blue cones





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Points to Remember

- Color is a three dimensional
  - hue - lightness - saturation
    hue - value (reflectance) - chroma (purity)
- Color has perceptional dimensions
- Red and green are most common problem
- Blue is “universally recognizable”

Recommendations

(Brewer 1997, 2005; Jackson *et. al.* 1994; Jenny & Kelso 2007)

- Choose unambiguous color combinations
  - use complementary pairs or “color sets”
- Avoid colors for class differentiation
  - use another visual variable (e.g. size, shape, etc.)
- Annotate features
- Reduce the number of classes

Recommendations (Brewer 2005, Clark 2003)

- Hues of concern
  - red, orange, brown (B), yellow, beige (C), green (confusing)
  - magenta, gray, cyan (indistinguishable)
- Do not use red and black combinations
- Color important only where “actual meaning” is attached to the color
- Use lightness steps to differentiate a range

Recommendations (Brewer 2005, Clark 2003)

- Safe color pairs for web/map use
  - red/blue, red/purple
  - orange/blue, orange/purple,
  - brown/blue, brown/purple,
  - yellow/blue, yellow/purple,
  - yellow/gray
  - blue/gray

Point/Line Features (Jenny & Kelso 2007)

- Saturation changes only slight help to red-green impaired
- Better to shift hue from green to blue
- Best solution – vary shape and combine with variable hue and saturation, and annotation
- The best maps are easy to decode

Jenny & Kelso 2007

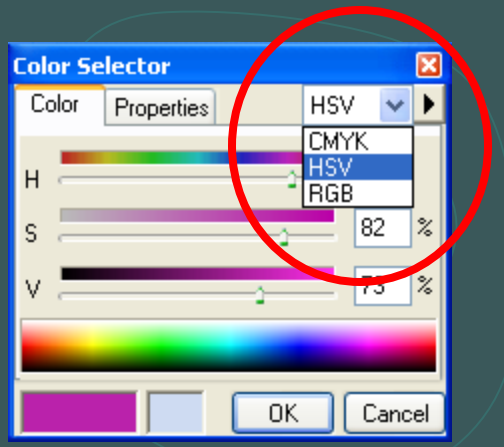
Areas / Raster (Brewer 1997, Jenny & Kelso 2007)

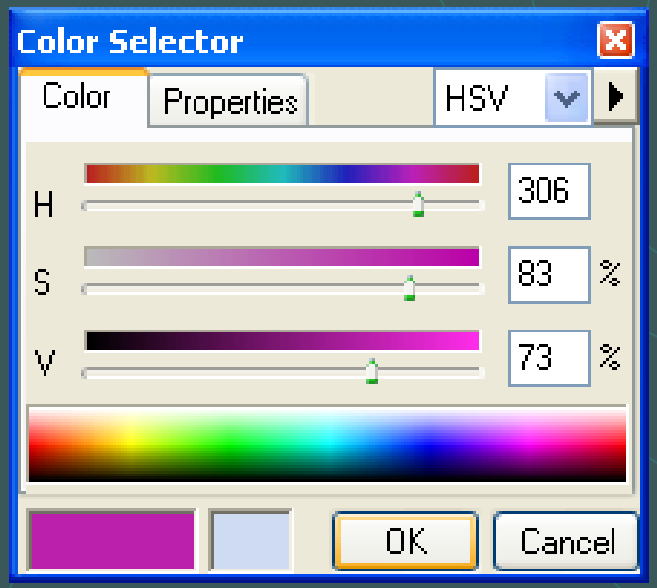
- Vary lightness on red-orange-yellow end
- Omit yellow green to avoid green confusion
- Avoid green
  - *Use red, orange, yellow, light blue, dark blue*
  - Align yellow-blue transition with data pivot point

See: Jenny, B. and N.V. Kelso. 2007. Color Design for the Color Vision Impaired. *Cartographic Perspectives* 58: 61-67.

C Brewer, Penn State (Brewer 2005)

- tools not perceptually scaled (HSV poor approx.)
- Do it by eye!





C Brewer, Penn State (Brewer 2005)

- Brewer, C.A. 2005. *Designing Better Maps: A Guide for GIS Users.* E.S.R.I. Redlands, Ca. 203 p.

Color Brewer

- Brewer developed color-blind confusion zones
- http://colorbrewer2.org/

- http://colororacle.cartography.ch/

Resources

- http://colorbrewer2.org/
- http://www.vischeck.com/
- http://colororacle.cartography.ch/

Bibliography/Citations

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- Gardner, S.D. 2005. *Evaluation of the ColorBrewer Color Schemes for Accomodation of Map readers with Impaired Color Vision.* M.S. Thesis. Penn. State Univ. 151 p.
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- Karagol-Ayan, B. 2001. Color Vision Confusion. Universal Usability in Practice. University of Maryland. http://otal.umd.edu/uupractice/color/ Accessed 25 August 2011.

Thank you!

Questions?

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