Colors

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Color

- **Results from research on visual attention can be used to assign visual features to data values**
- **One of the key components of visually representing data is choosing the appropriate color scale**
- **There is no "best" color scale**

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Color

- **Choice depends on[1,2]**
  - data type
  - problem domain
  - visual representation
  - Questions the analyst is asking of the data
- **While there is no "best" choice, there are design principles**

1 - H. Levkowitz and G. T. Herman, "Color scales for image data," IEEE Computer Graphics and Applications, vol. 12, pp. 72-80, 1992
2 - P. Rheingans, "Task-based color scale design," Proceedings of Applied Image and Pattern Recognition, pp. 35-43, 1999.

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Design Principles for Color Schemes

- ***Order*[1] – Given a univariate data type, the color scale that is chosen to map the data must represent a perceived ordering**
- ***Separation*[2] – Important differences between ranges of the variable should be represented by colors that can be perceived as being different**
  - Not only should they be perceived as different, but also equal

1 - B. E. Trumbo, "Theory for Coloring Bivariate Statistical Maps," *The American Statistician*, vol. 35, no. 4, pp. 220-226, 1981.
2 - H. Levkowitz and G. T. Herman, "Color scales for image data," IEEE Computer Graphics and Applications, vol. 12, pp. 72-80, 1992
3 - K. Moreland, "Diverging Color Maps for Scientific Visualization," *Proceedings of the 5th International Symposium on Visual Computing*, D ecember 2009.

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Design Principles for Color Schemes

- ***Aesthetics*[3] – color map should be aesthetically pleasing, contain a maximum perceptual resolution, and ordering should be intuitive**

1 - B. E. Trumbo, "Theory for Coloring Bivariate Statistical Maps," *The American Statistician*, vol. 35, no. 4, pp. 220-226, 1981.
2 - H. Levkowitz and G. T. Herman, "Color scales for image data," IEEE Computer Graphics and Applications, vol. 12, pp. 72-80, 1992
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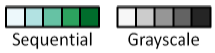
Univariate Color Schemes

- **Qualitative scheme**
  - Rainbow color scale is one of the most commonly used, but it is a poor color map in a large variety of domain problems
  - Ordering of the hues is unintuitive
  - Nominal data types can use this scale as no ordering is implied

1 - D. Borland and R. M. Taylor, "Rainbow Color Map (Still) Considered Harmful," *Computer Graphics & Applications*, vol. 27, no. 2, pp. 14-17, 2007.
2 -P. Rheingans, "Task-based color scale design," *Proceedings of Applied Image and Pattern Recognition*, pp. 35-43, 1999.
3 - M. A. Harrower and C. A. Brewer, "ColorBrewer.org: An online tool for selecting color schemes for maps," *The Catrtographic Journal*, vol. 40, no. 1, pp. 27-37, 2003.

Univariate Color Schemes

- **Sequential color scheme**
  - Simplest is the gray scale map where variable is mapped to brightness
  - Sequential maps represent ordered data
  - Dark colors typically represent high ranges
  - Benefits are that the scale is intuitive
  - Weakness is that limited number of distinguishable colors can be represented



1 - D. Borland and R. M. Taylor, "Rainbow Color Map (Still) Considered Harmful," *Computer Graphics & Applications*, vol. 27, no. 2, pp. 14-17, 2007.
2 -P. Rheingans, "Task-based color scale design," *Proceedings of Applied Image and Pattern Recognition*, pp. 35-43, 1999.
3 - M. A. Harrower and C. A. Brewer, "ColorBrewer.org: An online tool for selecting color schemes for maps," *The Catrtographic Journal*, vol. 40, no. 1, pp. 27-37, 2003.

Univariate Color Schemes

- **Divergent color scheme**

  - Provides means for variable comparisons
  - Best suited for ratio data where there is some meaningful zero point
  - Careful choices must be made in choosing high and low ends
  - Can use concept of cool (blues) and warm (reds and yellow) colors

1 - C. Hardin and L. Maffi, *Color Categories in Thought and Language*, Cambridge University Press, 1997.
2 -P. Rheingans, "Task-based color scale design," *Proceedings of Applied Image and Pattern Recognition*, pp. 35-43, 1999.
3 - M. A. Harrower and C. A. Brewer, "ColorBrewer.org: An online tool for selecting color schemes for maps," *The Catrtographic Journal*, vol. 40, no. 1, pp. 27-37, 2003.

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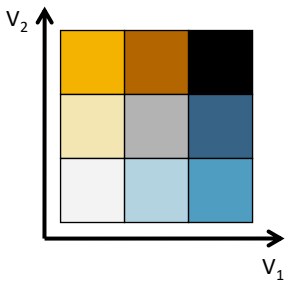
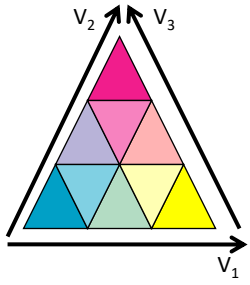
Multivariate Color Schemes





- http://colorbrewer2.org/#type=sequential&scheme=BuGn&n=3

M. A. Harrower and C. A. Brewer, "ColorBrewer.org: An online tool for selecting color schemes for maps," *The Catrtographic Journal*, vol. 40 , no. 1, pp. 27-37, 2003.

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Using Color

- Use blue in large regions, not thin lines
- Use red and green in the center of the field of view (edges of retina not sensitive to these)
- Use black, white and yellow in the periphery
- Use adjacent colors that vary in hue
- For large regions, don't use highly saturated colors (try pastels)

Information on this slide borrowed from John Stasko's Visual Perception Lecture: http://www.cc.gatech.edu/~stasko/7450/Notes/perception.pdf

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Using Color

- Do not use adjacent colors that vary in amount of blue
- Use color for grouping and search
- Beware effects from adjacent color regions

Information on this slide borrowed from John Stasko's Visual Perception Lecture: http://www.cc.gatech.edu/~stasko/7450/Notes/perception.pdf

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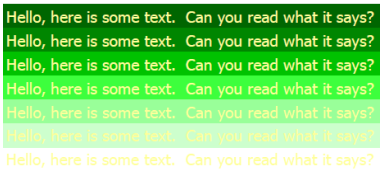
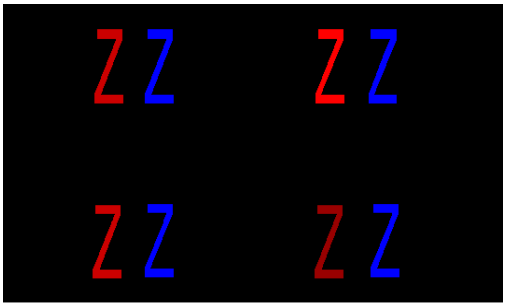
Using Color





Since these letters are all presented on your video monitor, they obviously are all located in the same plane. But do all the Z's appear to be in the same plane or do some appear closer than others?

Information on this slide borrowed from John Stasko's Visual Perception Lecture: http://www.cc.gatech.edu/~stasko/7450/Notes/perception.pdf

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Definitions

- **Dominant Wavelength:**
  - The wavelength of color we "see" when viewing light
- **Excitation Purity:**
  - Proportion of pure light of the dominant wavelength and of white light needed to define the color
- **Luminance:**
  - The amount/intensity of light

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Definitions

- **Hue:**
  - What we usually call “color” of the light
- **Saturation (chroma)**
  - Amount of white mixed in the color
  - “Saturated” color has no white in it
  - Saturation of white is 0%
- **Intensity**
  - Lightness for reflecting objects
  - Brightness for self- luminous objects
  - Is proportional to energy
  - May be reduced by adding water to the color
- **Artists use hue, saturation and intensity to describe colors.**

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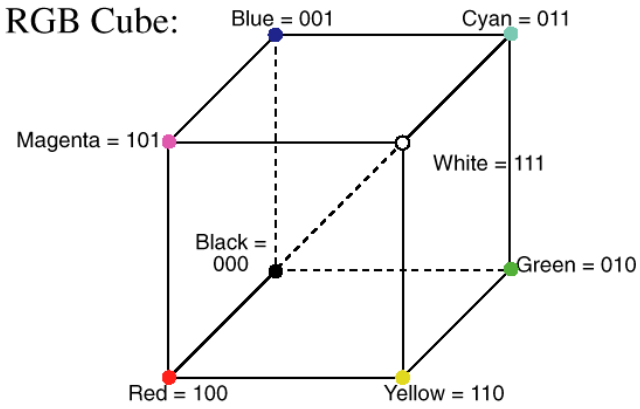
RGB Color Space



Grays are on dotted main diagonal.

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What's Wrong with RGB?

- Interpolation in RGB will not give correct perceptual information
- RGB linear color maps will give incorrect information

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Possible Alternative for RGB Interpolation

- Use Hue, Saturation, and Value
- HSV color space
- https://en.wikipedia.org/wiki/HSL_and_HSV

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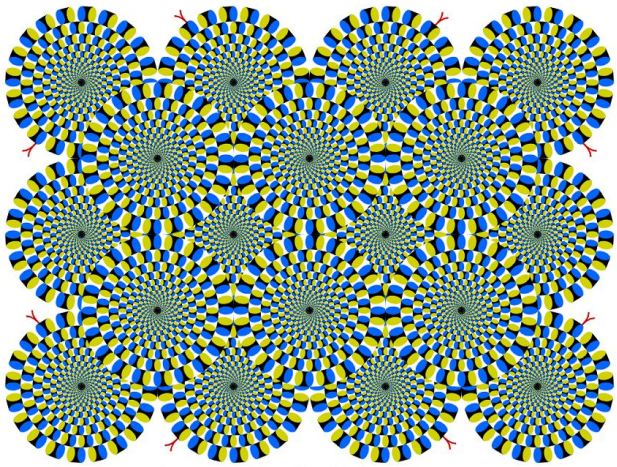
Visualization in the Periphery



Picture created by Akiyoshi Kitaoka

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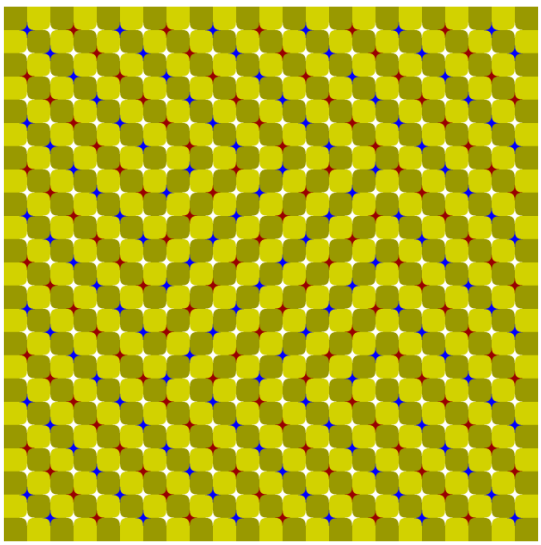
Visualization in the Periphery



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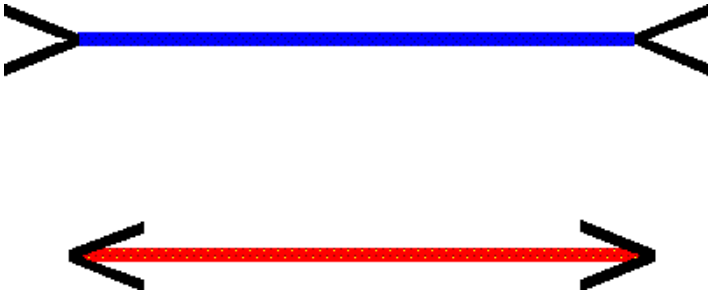
Another Illusion



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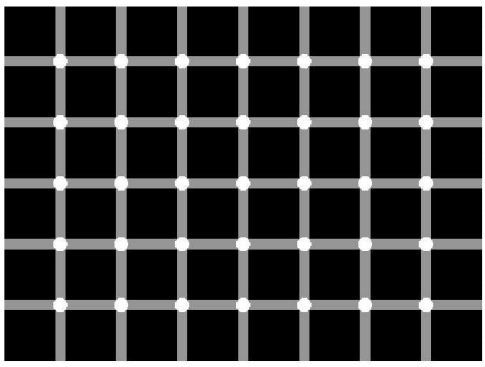
Count the Black Dots



Count the black dots! :o)

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Questions?

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