Visual Perception and Visualization

William B. Thompson
School of Computing
University of Utah
Discussion question:

- Is a picture really worth $10^3$ words?
Is a picture really worth $10^3$ words?

- By most measures, vision is the most important sensory modality

Light:
- travels far
- travels fast
- travels in straight lines
- interacts with stuff
- bounces off things
- is produced in nature
- has lots of energy

Steven Shafer
Is a picture really worth $10^3$ words?

- **Visualization allows people to offload cognition to the perceptual system...** The human visual system is a very high-bandwidth channel to the brain, with a significant amount of processing occurring in parallel...

Tamara Munzner
Is a picture really worth $10^3$ words?

- Visualization allows people to offload cognition to the perceptual system... The human visual system is a very high-bandwidth channel to the brain, with a significant amount of processing occurring in parallel...

Tamara Munzner
Is a picture really worth $10^3$ words?

- **Visualization allows people to offload cognition to the perceptual system…**
  
  Tamara Munzner

- It’s more complicated than this:
  
  – Some aspects of visual perception are fast and near effortless:
    
    • (Some) saliency-based visual search
    • (Some) aspects of space perception
    • (Some) aspects of object recognition
Is a picture really worth $10^3$ words?

• Visualization allows people to offload cognition to the perceptual system…  
  Tamara Munzner

• It’s more complicated than this:
  – Many aspects of visual cognition are slow and effortful:
    • Acquisition, manipulation, and representation of knowledge about objects and the environment
Is a picture really worth $10^3$ words?

- **Illusion of visual bandwidth**
  - Overestimation of breadth
    - Mistaken assumption that viewers can take in most/all details of a scene at once
  - Overestimation of countenance
    - Mistaken assumption that viewers attend to a higher proportion of a display than they really do
  - Overestimation of depth
    - Mistaken assumption that attending to an object necessarily results in improved comprehension
Is a picture really worth $10^3$ words?

• Attention matters a lot!
  – Eye movements
    • The *rule of thumb* rule of thumb
  – Selective processing
    • Both bottom-up (*early*) and top-down (*late*)
  – Ineffective visual displays:
    • Key information not visually salient
    • Non-key information diverts attention
    • Learned attentional avoidance
      – Web ads!
• *Attention* $\neq$ *cognition*!!!
Visual perception for graphics and vis

- How do we know what really works?

- Current practice: “It looks pretty good to me…”

- *Performance-preference dissociation*
  
  Bailey (1993)
  Andre and Wickens (1995)
The design of effective visualizations is as much a challenge for cognitive science as for computer and information science, and ... these disciplines must collaborate closely on the development of new information technologies and visualization design.

Computer Science
- Computational theoretical framework
- Testable theories
- Application problems

Perceptual Science
- Theoretical frameworks based on cognitive and neuroscience
- Testable theories
- Basic science problems

Mary Hegarty
IEEE Vis 2010
Discussion question:

- Does visual motion help perceive 3D shape?
- What about interactivity?
Does motion help perceive 3D shape?

• Practical lessons:
  – Know what motions aid in perception of 3D structure
  – Know the difference between moving through a (virtual) space and moving objects in that space
  – Accommodate individual differences in spatial abilities among your users
Discussion question:

- To what question is this the answer?

[large phone video]
To what question is this the answer?

• Practical lessons:
  – Looking at displays of 3D structures is different than looking at real 3D structures
    • Perception of pictorial space
  – Viewing conditions matter
  – Accurately perceiving absolute size and distance is often difficult
What is color?

• Color is *not*:
  – A particular wavelength of light
  – RGB

• Color *is*:
  – A spectral distribution of light
  – Perceptual response to spectral distribution of light
  – A way of encoding a spectral distribution of light
What is color?

• Color is *not*:
  – A particular wavelength of light
  – RGB

• Color *is* (vision science):
  – A spectral distribution of light
  – *Perceptual response to spectral distribution of light*
  – A way of encoding a spectral distribution of light
What is color?

• Color is *not*:
  – A particular wavelength of light
  – RGB

• Color *is* (computer graphics):
  – A spectral distribution of light
  – Perceptual response to spectral distribution of light
  – A way of encoding a spectral distribution of light

► Multiple meanings often leads to confusion!
How important is color vision?

- Likely that no mammals other than primates have human level color vision
- Many “lower” animals have well developed color vision

Key observation:

- Two colors can be additively mixed to give a third color in which constituents cannot be identified.
  - Compare with sound: combining notes results in a cord.

- Metamers
  - Colors that look identical but have dramatically different spectra.

---


- Color is a perceptual quality not closely tied to a physical quality!!!
Metamers make color displays possible
Color constancy

• Color perception largely invariant to illumination

What is color?

• Practical lessons:
  – RGB:
    • Non-intuitive, uncalibrated
  – HSV/LUV:
    • Somewhat intuitive…
    but
    • Uncalibrated and therefore of limited use
  – CIE L*a*b:
    • Non-intuitive, calibrated
    • “perceptual uniformity” is only sometimes useful
What is color?

- Munsell
  - Intuitive
  - Calibrated (sort of)

http://en.wikipedia.org/wiki/Munsell_color_system
What is color

• Practical lessons:
  – Use color management throughout the whole of the image generation pipeline
    • Color specification
    • Color representation
    • Color display
  – Most of the time you don’t have control of display
    • Can’t depend on color to represent information precisely
What is color?

• Practical lessons:
  – Most discussions of color apply to single color patches or comparisons between two patches
  – Color constancy is a powerful effect that makes much of this information of limited value
    • Color perception strongly affected by surrounding spatial context
    • Color perception strongly affected by ambient viewing environment
Take home messages

• Designing effective visualization requires consideration of end-to-end performance
  – Validation is difficult!
    • Evaluating saliency is in principle straightforward
    • Evaluating cognition in a methodologically sound manner is really hard

• Visual perception is really complicated
  – Much practical value in considering perceptual issues in design of visualizations but…
  – … beware of the specifics of generalizations
• CS 5650/6650 -- Visual Perception from a Computer Graphics and Visualization Perspective
  – Spring 2013, Tu/Th, 3:40pm-5:00pm

• Ties together image generation and the resulting perceptual phenomena
• Includes topics rarely if ever part of intro perception classes
• Emphasis on visual performance, with coverage of neuroscience limited to issues of practical importance