# Visual Perception

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Slides adapted from John Stasko (Georgia Tech),
Petra Isenberg & Jean-Daniel Fekete (INRIA)

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# Agenda

- Visual Perception
  - Pre-attentive processing
  - Color
  - *Etc.*



# Semiotics

- The study of symbols and how they convey meaning
- Classic book:
  - J. Bertin, *Sémiologie Graphique,* 1967
  - (In English: J. Bertin, *The Semiology of Graphics*, 1983)



# Related Disciplines

- Psychophysics
  - Applying methods of physics to measuring human perceptual systems
    - How fast must light flicker until we perceive it as constant?
    - What change in brightness can we perceive?
- Cognitive psychology
  - Understanding how people think, here, how it relates to perception

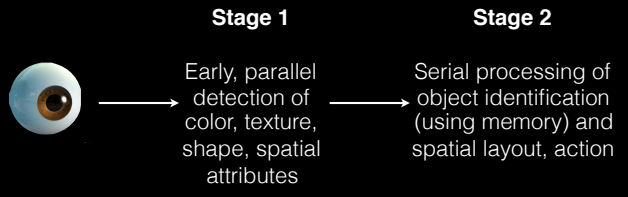
# Perceptual Processing

- Seek to better understand visual perception and visual information processing
  - Multiple theories or models exist
  - Need to understand physiology and cognitive psychology



# One (simple) Model

- Two stage process
  - Parallel extraction of low-level properties of scene
  - Sequential goal-directed processing




[Ware 2000]



# Stage 1 — Low-level, Parallel

- Neurons in eye & brain responsible for different kinds of information
  - Orientation, color, texture, movement, etc.
- Arrays of neurons work in parallel
- Occurs “automatically”
- Rapid
- Information is transitory, briefly held in iconic store
- Bottom-up data-driven model of processing
- Often called “pre-attentive” processing



# Stage 2 — Sequential, Goal-directed

- Splits into subsystems for object recognition and for interacting with environment
- Increasing evidence supports independence of systems for symbolic object manipulation and for locomotion & action
- First subsystem then interfaces to verbal linguistic portion of brain, second interfaces to motor systems that control muscle movements

# Stage 2 Attributes

- Slow serial processing
- Involves working and long-term memory
- More emphasis on arbitrary aspects of symbols
- Top-down processing



# Preattentive Processing

- How does human visual system analyze images?
  - Some things seem to be done preattentively, without the need for focused attention
  - Generally less than 200–250 msecs (eye movements take 200 msecs)
  - Seems to be done in parallel by low-level vision system



# How Many 3's?

12817687561389765469845069856049828267629809858458224509856458945098450980943585909103020990595959577256467505067890456788457898098216776548763649085609129496 86



# How Many 3's?

12817687561389765469845069856049828267629809858458224509856458945098450980943585909103020990595959577256467505067890456788457898098216776548763649085609129496 86

# What Kinds of Tasks?

- Target detection
  - Is something there?
- Boundary detection
  - Can the elements be grouped?
- Counting
  - How many elements of a certain type are present?



# Example

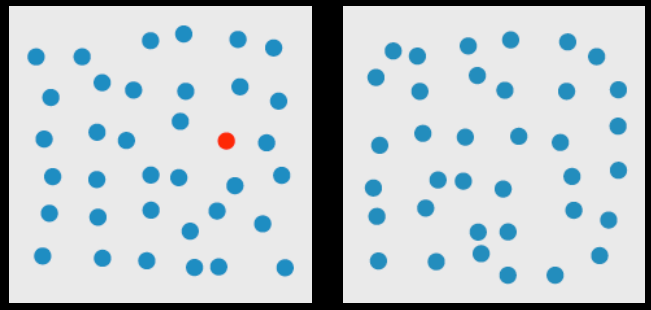
Determine if a red circle is present

# Hue

[Healey 2009]



# Hue



Can be done rapidly (preattentively) by people
Surrounding objects called “distractors”

[Healey 2009]

# Example

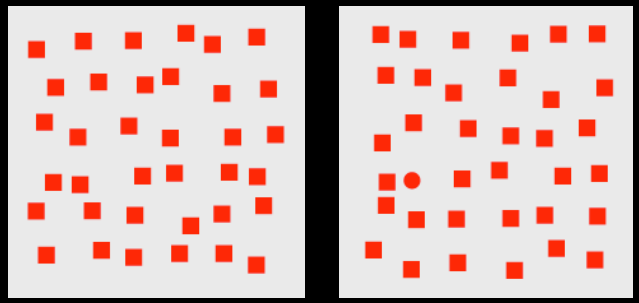
Determine if a red circle is present

# Shape

[Healey 2009]



# Shape





Can be done preattentively by people

[Healey 2009]



# Example

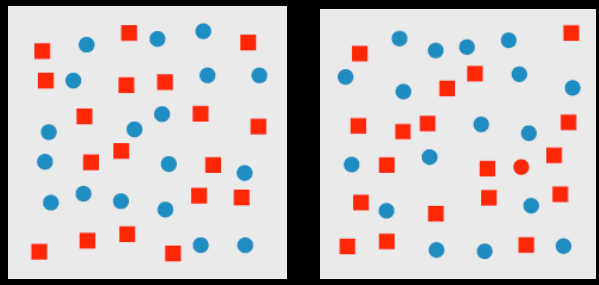
Determine if a red circle is present

# Hue & Shape

[Healey 2009]



# Hue & Shape



- Cannot be done preattentively
- Must perform a sequential search
- Conjuction of features (shape and hue) causes it

[Healey 2009]



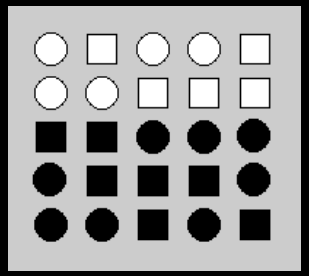
# Example

Is there a boundary in the display?

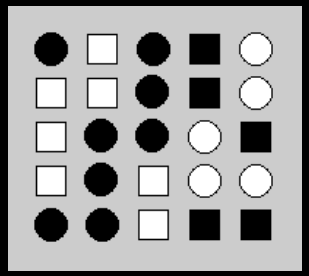
# Fill & Shape

[Healey 2009]

# Fill & Shape



Can be done preattentively since each group contains one unique feature



Cannot (there is a boundary!) since the two features are mixed (fill and shape)

[Healey 2009]



# Example

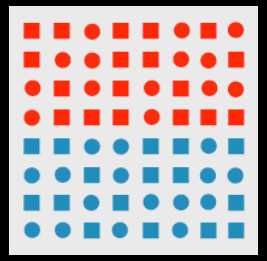
Is there a boundary in the display?

# Hue & Shape

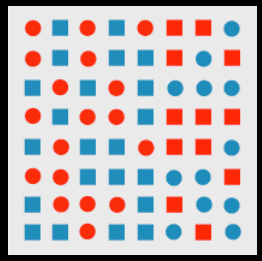
[Healey 2009]



# Hue & Shape



Boundary detected preattentively based on hue regardless of shape



Cannot do mixed color shapes preattentively

[Healey 2009]

# Example

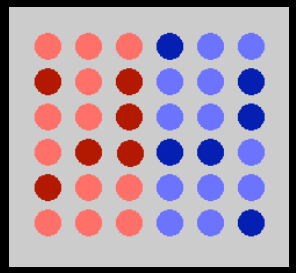
Is there a boundary in the display?

# Luminance & Hue

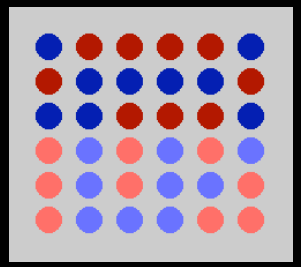
[Healey 2009]



# Luminance & Hue



Varying brightness interferes



Boundary based on brightness can be done preattentively

[Healey 2009]



# Example Applet

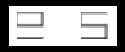
- Nice on-line tutorial and example applet
  http://www.csc.ncsu.edu/faculty/healey/PP/index.html
  - Chris Healey, NC State
  - Prior pictures taken from site

# Preattentive Features

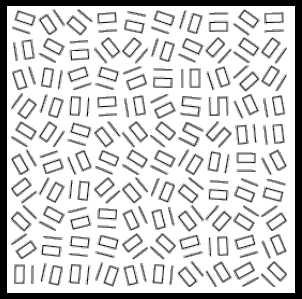
- Certain visual forms lend themselves to preattentive processing
- Variety of forms seem to work



# Textons



1. Elongated blobs
2. Terminators
3. Crossings of lines



All detected early

[Healey 2009]

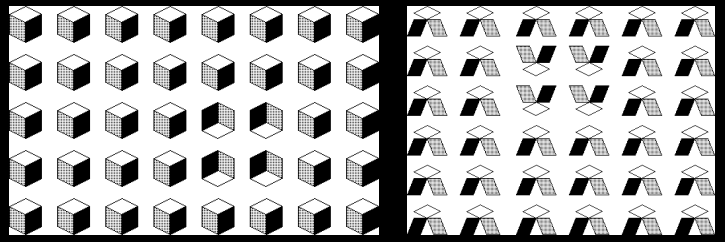


# 3-D Figures

[Healey 2009]



# 3-D Figures



3-D visual reality has an influence

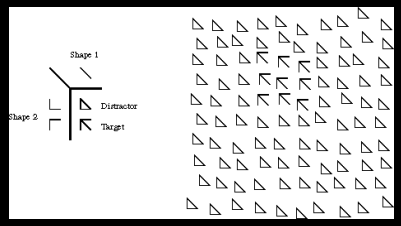
[Healey 2009]

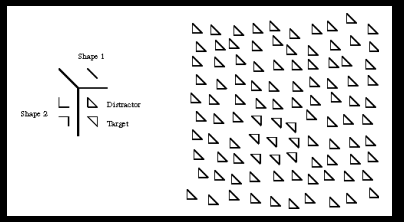
# Emergent Features

[Healey 2009]



# Emergent Features




[Healey 2009]



# Potentially Preattentive Features

- length
- width
- size
- curvature
- number
- terminators
- intersection
- closure
- hue
- intensity
- flicker
- direction of motion
- binocular lustre
- stereoscopic depth
- 3-D depth cues
- lighting direction



# Key Perceptual Properties

Brightness

Color

Texture

Shape

# Luminance/Brightness

- Luminance
  - Measured amount of light coming from some place
- Brightness
  - *Perceived amount of light coming from some place*



# Brightness

- Nonlinear function of the amount of light emitted by a source
  - Typically a power function
  - $S = aI^n$
    - S = sensation
    - I = intensity
- Very different on screen versus paper

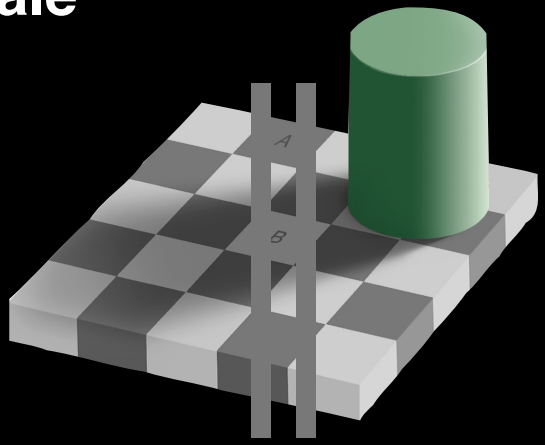


# Greyscale

- Probably not best way to encode data because of contrast issues
  - Surface orientation and surroundings matter a great deal
  - Luminance channel of visual system is so fundamental to so much of perception
    - We can get by without color discrimination, but not luminance

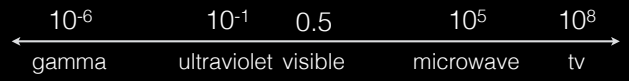


# Greyscale



# Color

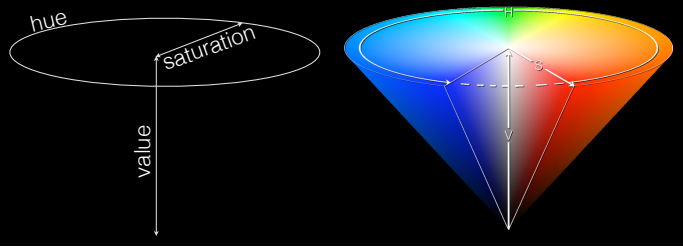
- Sensory response to electromagnetic radiation in the spectrum between wavelengths 0.4 – 0.7 micrometers






# Color Models

- HSV model
  - Hue — what people think of color
  - Saturation — intensity, ranges hue↔gray
  - Value — light/dark, ranges black↔white






# Luminance

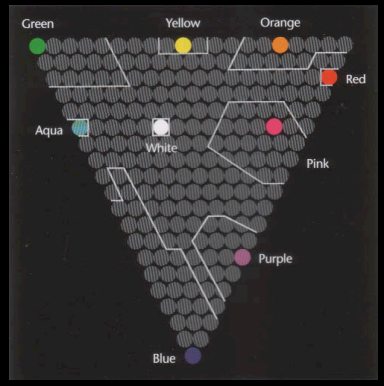
- Important for foreground/background colors to differ in brightness.

Bonjour, voici un peu de texte. Can you read it?
Bonjour, voici un peu de texte. Can you read it?
Bonjour, voici un peu de texte. Can you read it?
Bonjour, voici un peu de texte. Can you read it?
Bonjour, voici un peu de texte. Can you read it?
Bonjour, voici un peu de texte. Can you read it?
Bonjour, voici un peu de texte. Can you read it?

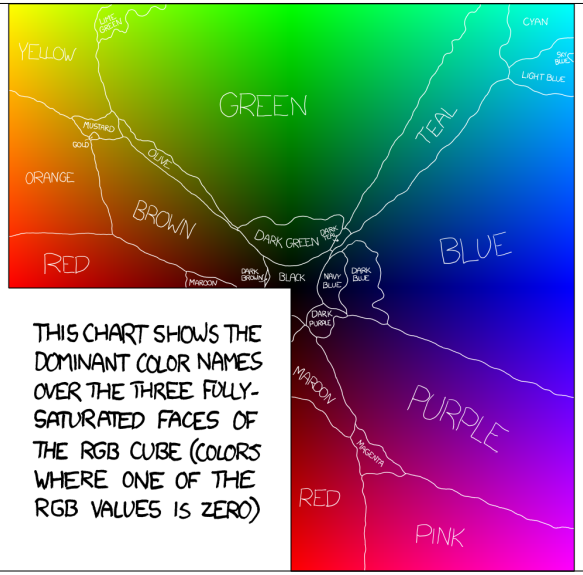


# Color Categories

- Are there certain canonical colors?
- Post & Greene ’86 had people name different colors on a monitor
- Pictured are ones with > 75% commonality




[Ware 2004]

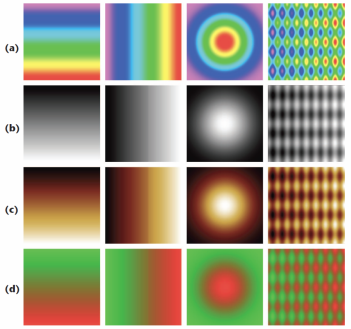



[ xkcd ]



## *Color Scale Transitions*

- Rainbow color scale
  - appears separated into bands of almost constant hue
  - sharp transitions between hues are perceived as sharp transitions in the data




rainbow color scale

gray scale

heated color scale

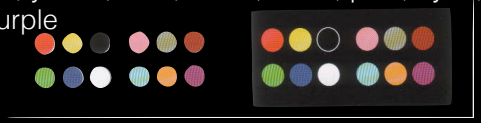
isoluminant green-red scale

From: Rainbow Color Map (Still) Considered Harmful, CG&A 07

[ Slide courtesy of Petra Isenberg, INRIA ]

# Using Color for Categories

- Can different colors be used for categorical variables?
  - Yes (with care)
  - Ware's suggestion: ≤12 colors
    - red, green, yellow, blue, black, white, pink, cyan, gray, orange, brown, purple



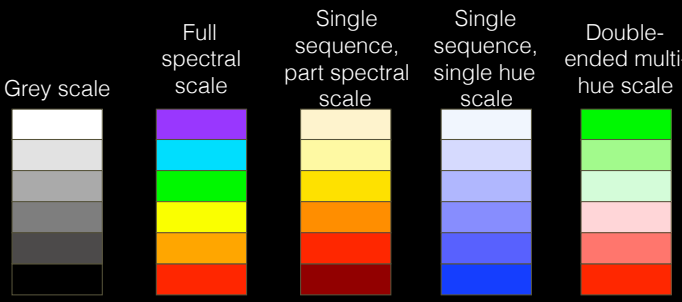
[Ware 2004]



# Using Color for Sequences

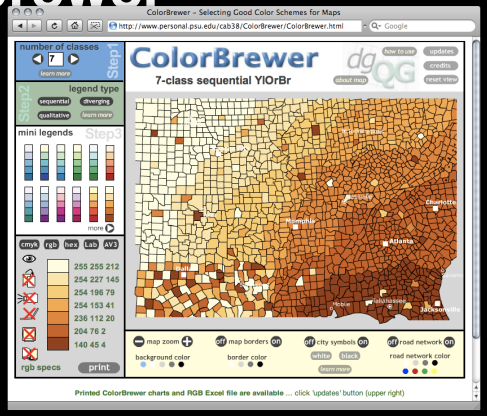
Can you order these (low→high)?

# Possible Color Sequences






# ColorBrewer




http://www.personal.psu.edu/cab38/ColorBrewer/ColorBrewer.html



# Color Properties

- Call attention to specific data
- Increase appeal, memorability
- Increase number of dimensions for encoding data
  - Example, Ware and Beatty ’88
    - x,y - variables 1 & 2
    - amount of r,g,b - variables 3, 4, & 5



# Using Color

- Modesty!  Less is more
- Always have high luminance contrast between foreground and background
- Use only few distinct colors
- Red, green, yellow, blue are hard-wired into the brain. Use them first.

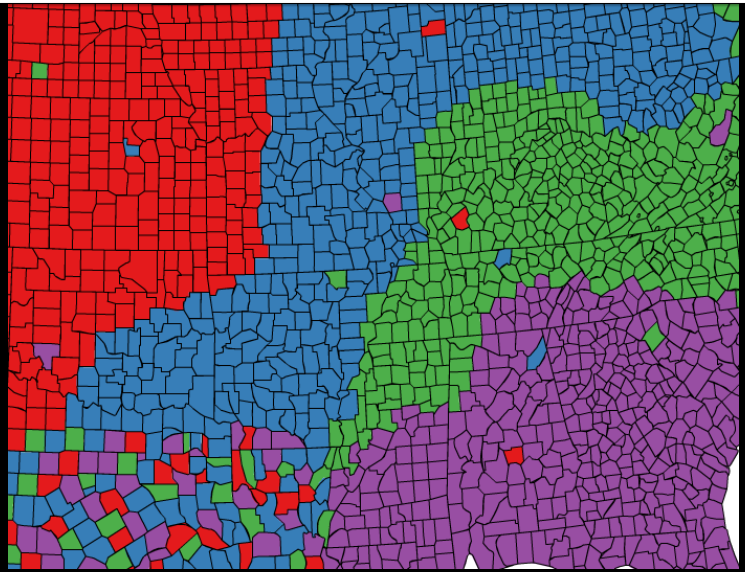
[ Ware, Information Visulization ]

# Using Color

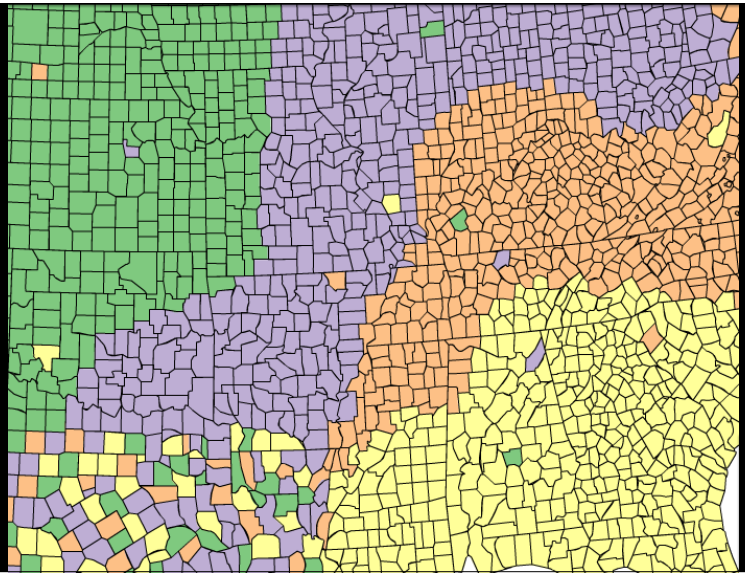
- Always have high luminance contrast between foreground and background
- Use only few distinct colors
- Red, green, yellow, blue are hard-wired into the brain. Use them first.
- For large areas use muted colors

[ Ware, Information Visulization ]

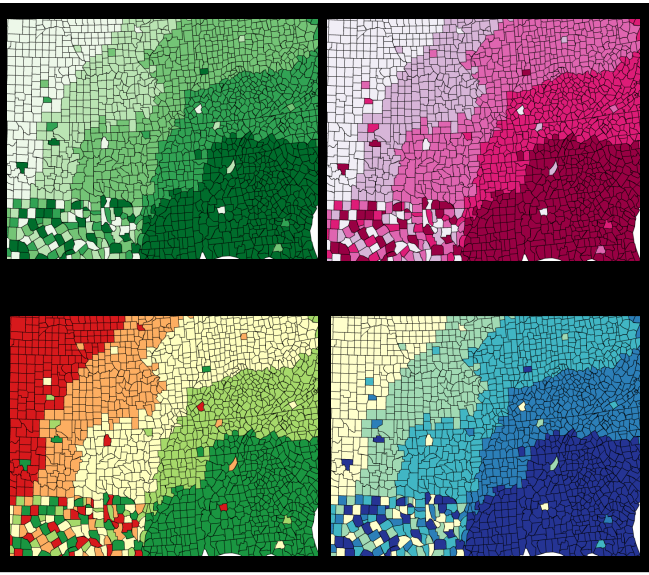


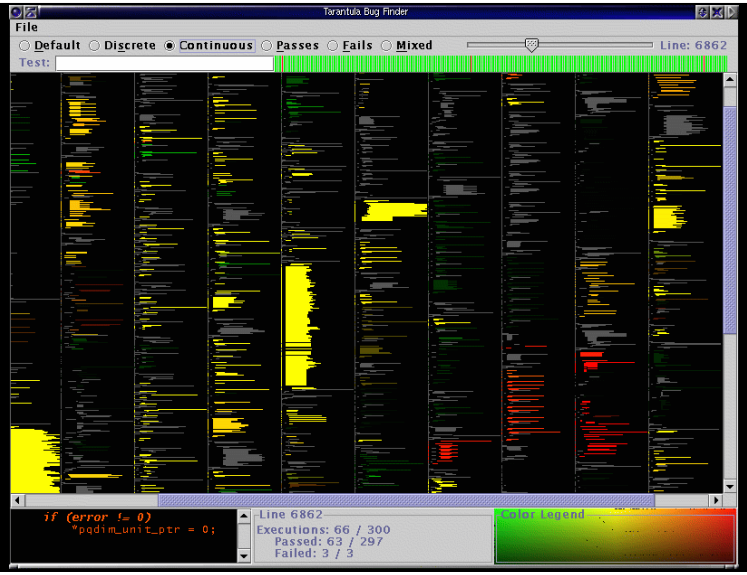






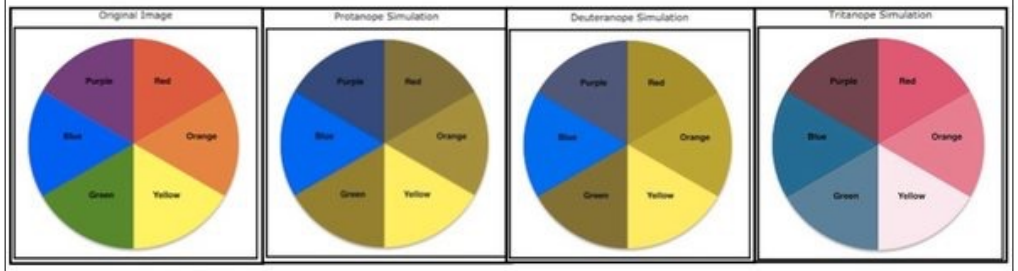









## Red, Yellow & Blue primary and secondary color wheel with color deficiency tests.




[ Source: ]



# Glyph Construction

- Suppose that we use two different visual properties to encode two different variables in a discrete data set
  - color, size, shape, lightness
- Will the two different properties interact so that they are more/less difficult to untangle?
  - Integral - two properties are viewed holistically
  - Separable - Judge each dimension independently



# Integral–Separable

- Not an either-or; more of a spectrum


[Ware 2004]

# Graphical Properties

| | Spatial properties | Object properties |
|---|---|---|
| Expressing extent | position<br>size | greyscale |
| Differentiating marks | orientation | color<br>shape<br>texture |



# Change-Blindness

- Is the viewer able to perceive changes between two scenes?
  - If so, may be distracting
  - Can do things to minimize noticing changes



# Change Blindness Demos











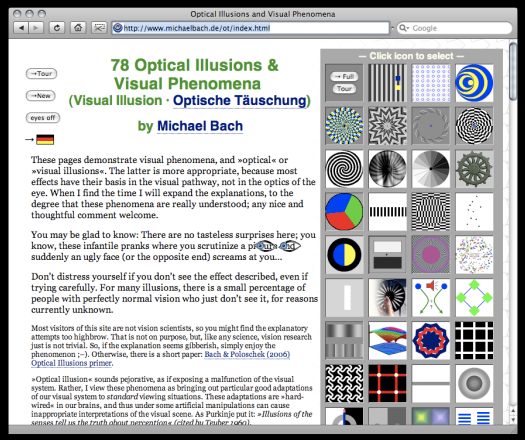

69

70


71


72

# Optical Illusions






# Stage 2

- Object recognition and locomotion/action
- Perhaps we'll talk about this some day :-)



# Information Visualization

- Perception for Design, 2nd Edition, by Colin Ware
- Perception in Information Visualization, by Chris Healey

www.csc.ncsu.edu/faculty/healey/PP/index.html