

Information Visualization and Visual Analytics (M1522.000500)

Perception and Visual Patterns

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Visual Patterns

Visual Patterns

- Key to information visualization
- Understanding patterns to build knowledge
- Using vision to think (finding patterns)
 - Patterns showing groups
 - Patterns showing structure
 - When are patterns similar?
 - How should we organize information on the screen?

Gestalt Laws

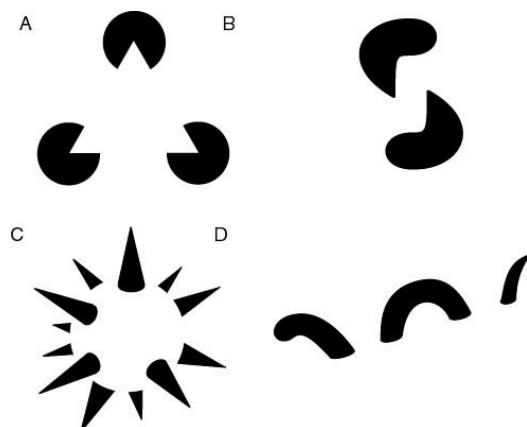
- Principles of perceptual organization
 - the **whole** is different from the **sum of its parts**
 - how smaller objects are grouped to form larger ones
 - "gestalt": German for "pattern/form/shape"
 - "leaving us with a set of *descriptive* principles, but without a model of perceptual processing"
 - rules themselves still very useful
- Law of Prägnanz
 - law of simplicity, law of good figure
 - fundamental principle of gestalt perception
 - tend to order our experience in a manner that is regular, orderly, symmetric, and simple
 - simplest possibility wins



Principles

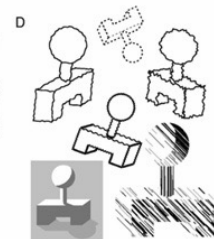
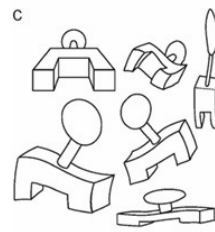
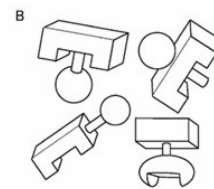
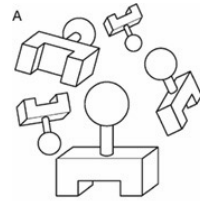
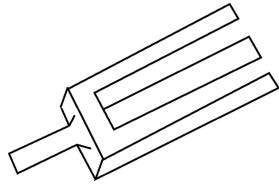
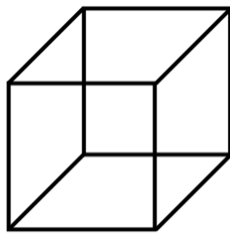
*Emergence*

the dog is perceived as a **whole**

*Reification*

the experienced percept contains **more explicit spatial information** than the sensory stimulus on which it is based

Principles



Multistability Perception

Invariance

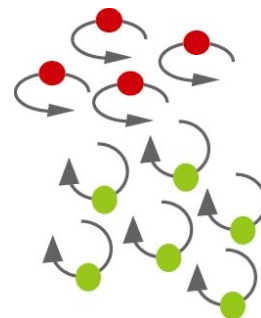
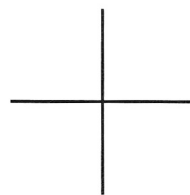
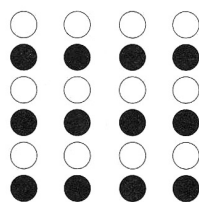
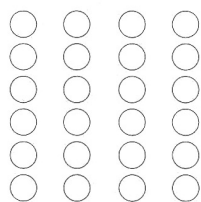
<http://www-personal.umich.edu/~esrabkin/pics/ThreeProngedTuningFork.jpg>

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Gestalt Principles

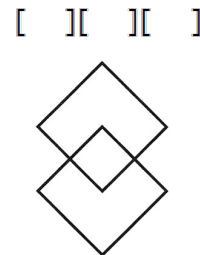
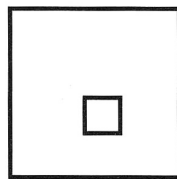
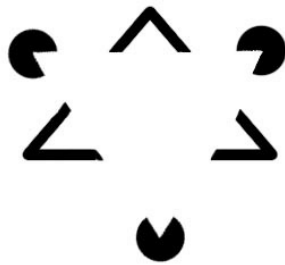
• Grouping

- **Proximity:** tendency of elements to be associated with nearby elements
- **Similarity:** tendency of elements to be associated with similar elements
- **Continuity:** preference for continuous, unbroken, smoothest contours with the *simplest possible physical explanation*
- **Common Fate:** things moving together

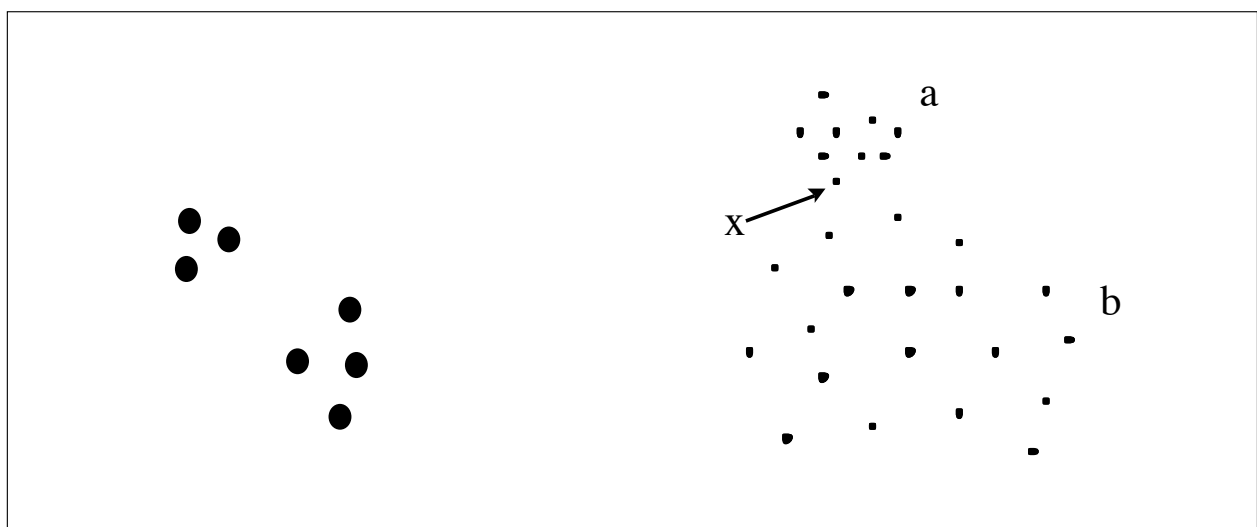


Gestalt Principles

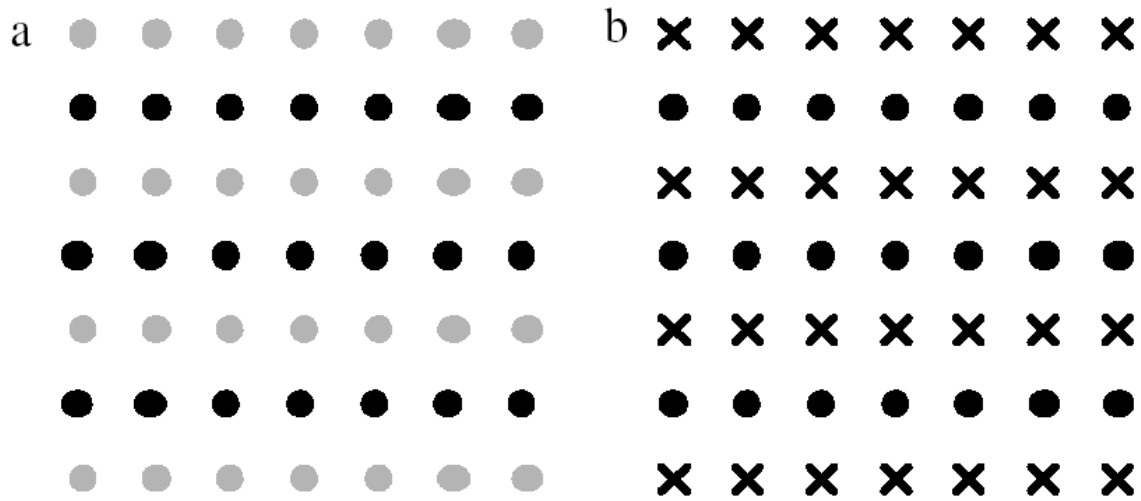
- Perception of Forms
 - **Closure**
 - form complete, closed figures to increase regularity
 - **Area/Figure and Ground/Relative size**
 - smaller one as figure, larger one as ground
 - **Symmetry**
 - when we perceive objects, we tend to perceive them as *symmetrical shapes that form around their center*.
 - symmetrical images are perceived collectively, even in spite of distance



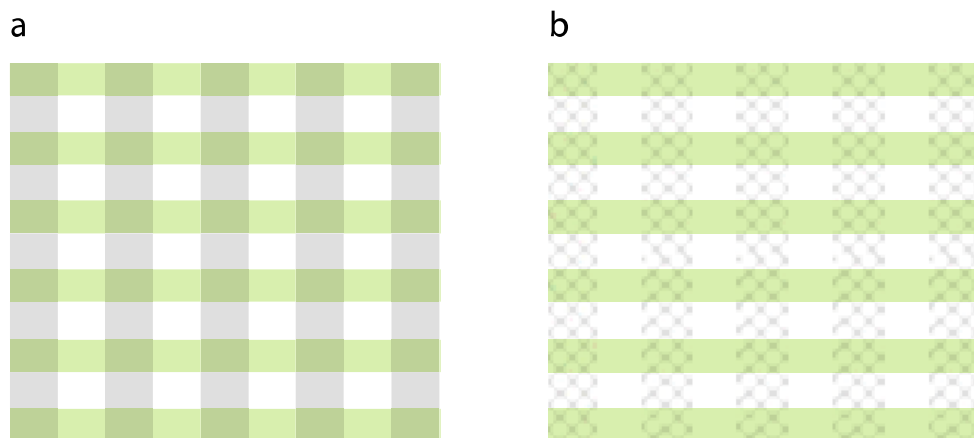
Proximity



Similarity



Similarity

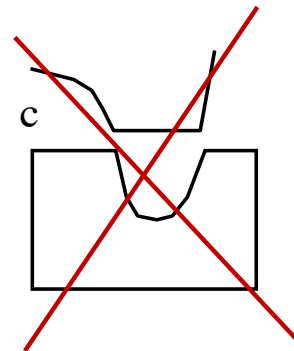
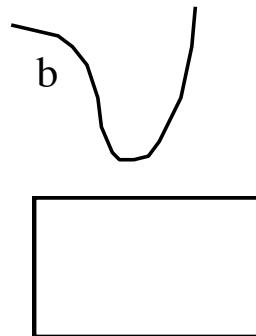
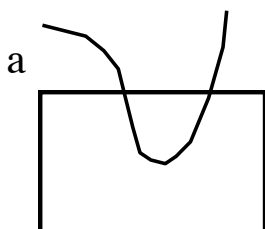


Proximity and Similarity



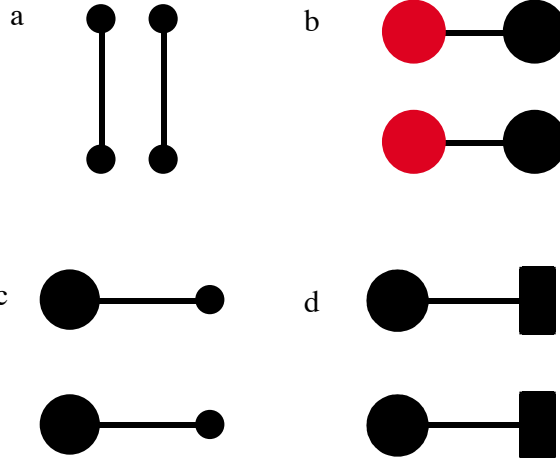
Continuity

- Visual entities tend to be smooth and continuous



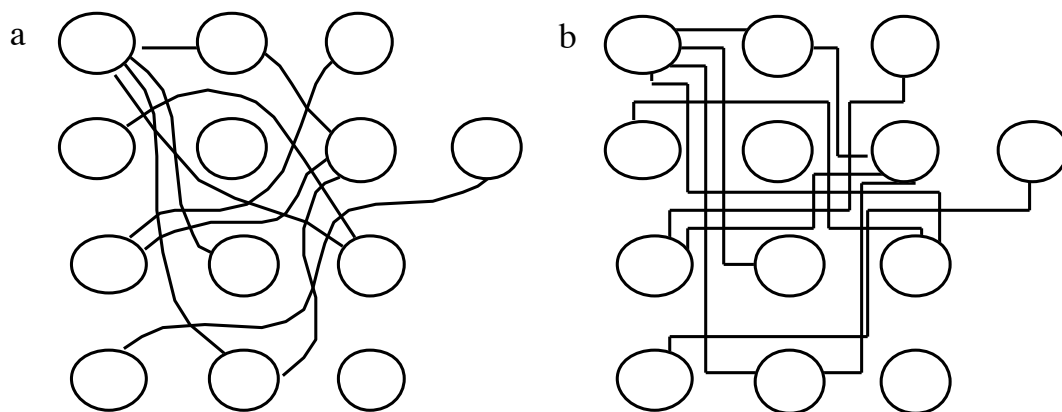
Connectedness

- assumed in Continuity
- can overrule size, shape



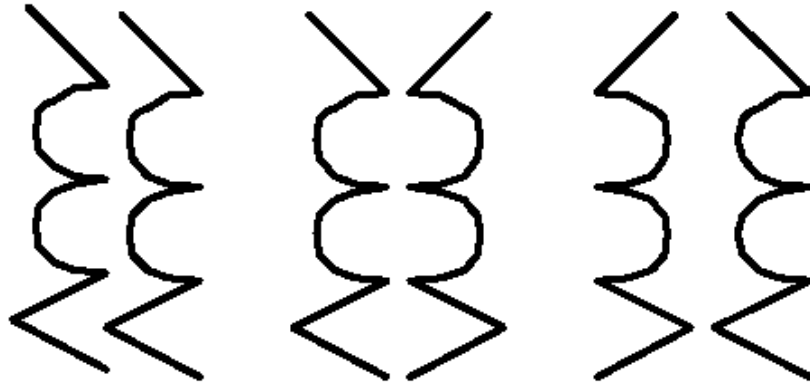
Continuity in Diagrams

- Connections using smooth lines
 - easier to perceive than using lines with abrupt changes



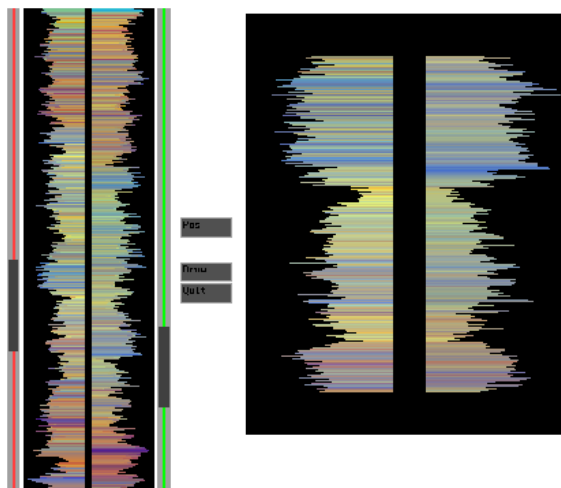
Symmetry

- sense of a **holistic** figure
- emphasizes relationships



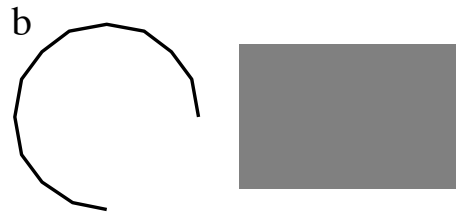
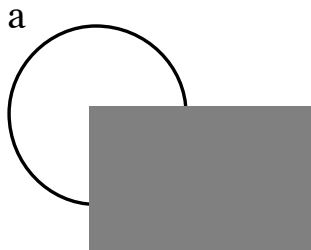
Symmetry

- symmetry to show Similarities between time series data

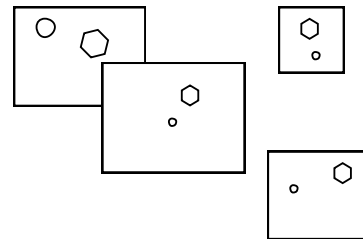


Closure

- Prefer closed contours

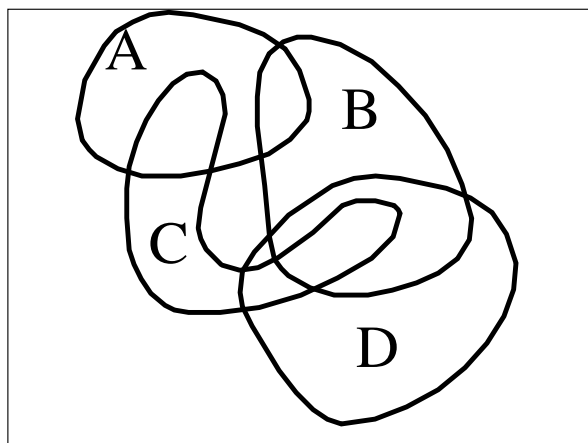


- Overrule proximity
- Segment visual field
- Provide reference frames



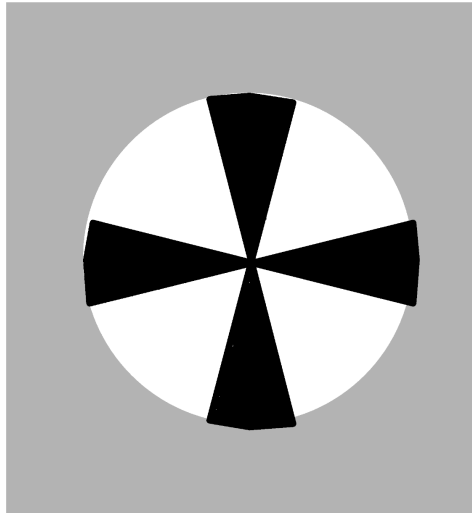
Closure

- Closed contours to show set relationship



Area / Figure & Ground / Relative Size

- smaller components perceived as objects



Area / Figure & Ground / Relative Size

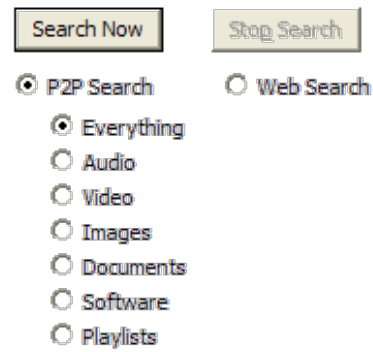
- determined by combination of previous laws
 - symmetry, contour



Proximity Examples



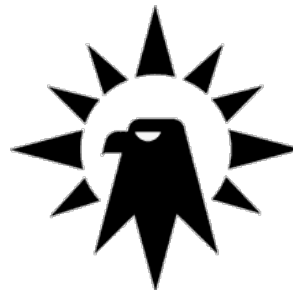
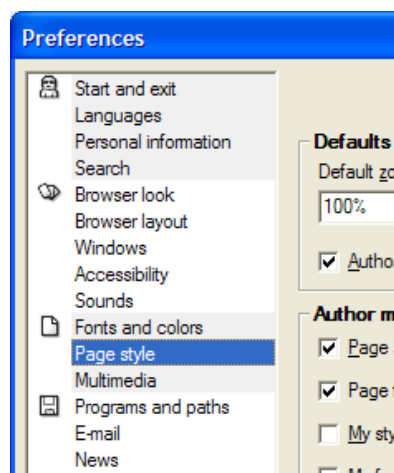
MTV Music Awards 2002



http://www.interaction-design.org/encyclopedia/gestalt_principles_of_form_perception.html

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Similarity Examples



http://www.interaction-design.org/encyclopedia/gestalt_principles_of_form_perception.html

<http://graphicdesign.spokanefalls.edu/tutorials/process/gestaltprinciples/gestaltprinc.htm>

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Grouping

- Help users parse the display into sub-units
 - Rely on Gestalt principles
 - Avoid explicit grouping

A dialog box titled "Composite" with four distinct sections, each enclosed in a rounded rectangle. The sections are: "Source 1" (Document: concept.1, Channel: RGB), "Mask" (Document: concept.1, Channel: RGB), "Source 2" (Document: concept.1, Channel: RGB), and "Destination" (Document: New, Channel: New). Each section has its own "OK" and "Cancel" buttons.

A dialog box titled "Composite" with a flat layout. It contains four rows of controls: "Source 1" (Document: concept.1, Channel: RGB), "Mask" (Document: concept.1, Channel: RGB), "Source 2" (Document: concept.1, Channel: RGB), and "Destination" (Document: New, Channel: RGB). The controls are not grouped into separate sections.

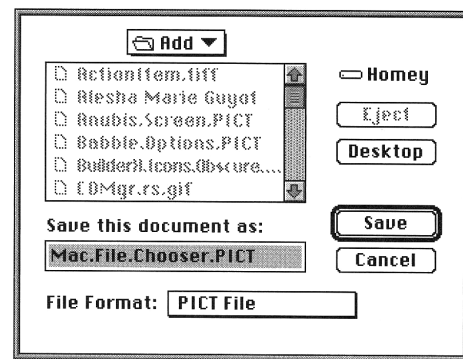
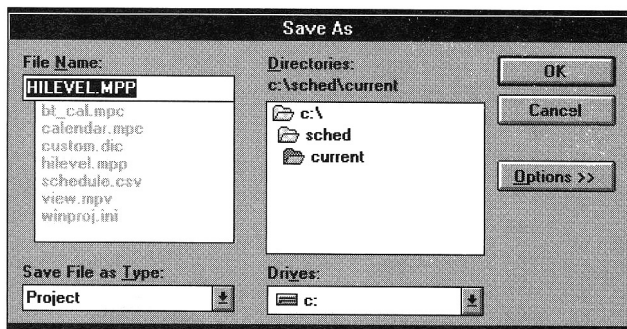
Hierarchy

- Provide a context for each piece of information
 - Example: distinctive style for labels

A dialog box titled "Pizza: Pizza Pie Properties" with a hierarchical structure. It has two main sections: "BOTTOM STUFF" and "TOPPING STUFF". "BOTTOM STUFF" includes "Style" (Thin, Thick, crust) and "Sauce" (Regular, Spicy, Pesto). "TOPPING STUFF" includes "Toppings" (Meat: Ham, Bacon, Sausage; Veggies: Olive, Pepper, Onion; Other: Cheese, Pesto, Anchovy) and "Options" (Red Peppers, Extra Cheese). The labels "Style", "Sauce", "Toppings", and "Options" are in a bold, sans-serif font, while the other labels are in a regular, sans-serif font. The "Apply" and "Reset" buttons are at the bottom.

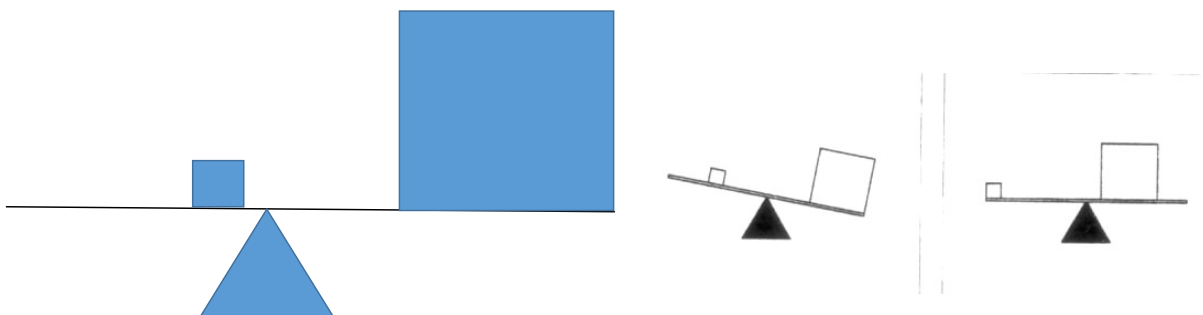
Relationship

- Parallel between presentation and relationship
 - Example: present folder before its content



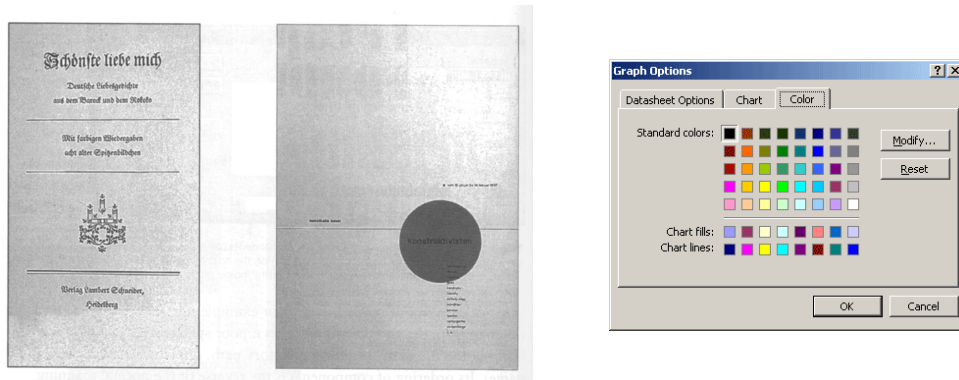
Balance

- Harmonious global arrangement
 - Can be symmetrical or asymmetrical
 - smaller elements can offset the **visual weight** of larger elements, how?



Balance

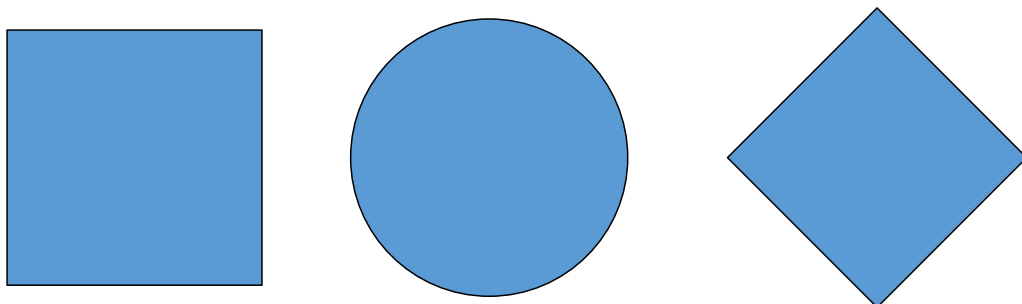
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Human Size Perception

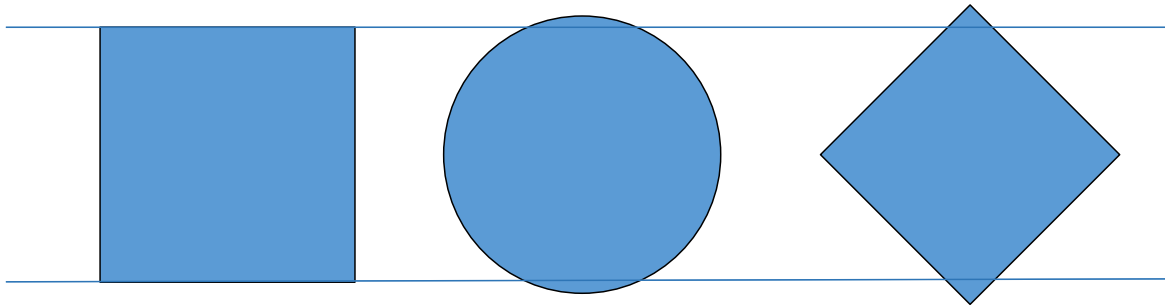
Human Size Perception

- Straight edges appear larger than curved edges
- Curved edges appear larger than sharp edges
- Optical adjustment



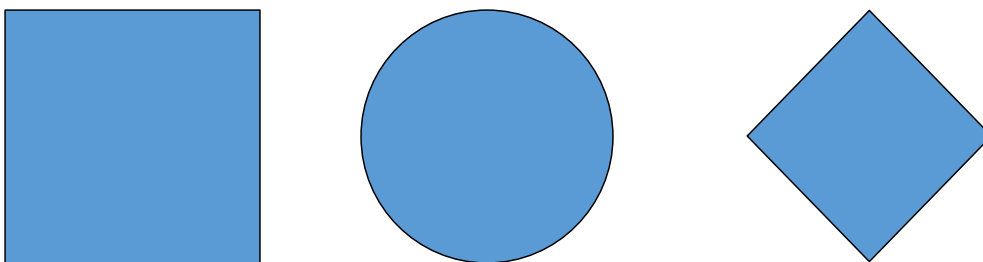
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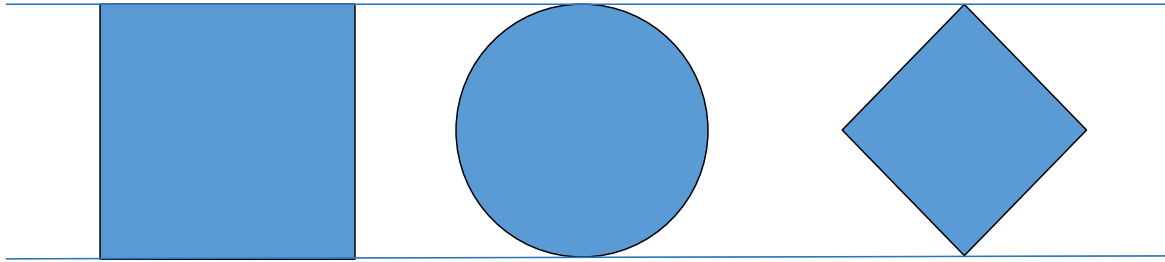
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Human Size Perception

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How human visual system works

- “What **visual properties** draw our eyes, and therefore our **focus of attention** to a particular object in a scene?”
- **Visual attention**: mechanisms that help determine **which regions of an image are selected for more detailed analysis**
- **Detailed vision** for shape and color is only possible within a small portion of the visual field (1 degree of visual angle, **foveal vision**)
- **fixation-saccade cycle**

Fixation-Saccade Cycle



http://www.outofmygord.com/images/outofmygord_com/eyetrackingsaccades.gif

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Fixation-Saccade Cycle

- **fixation**: brief stationary period when detail information is acquired
- **saccade**: flicking rapidly to a new location during a brief period of blindness
 - saccade takes at least 200 *ms* to initiate
- repeats 3~4 times each second
- makes seeing highly dynamic
- bottom-up: information from fixation → mental experience
- top-down: current mental states (tasks and goals) → guiding saccades

Visual Expectation and Memory

- “What do we **remember** about an object or a scene when we stop attending to it and look at something else?”
- role of memory and expectation in seeing
- current state of mind plays a critical role
 - determining what is being seen, what is not being seen, what will be seen next
- postattentive amnesia, memory-guided search, change blindness, inattention blindness, attentional blink

Christopher G. Healey, James T. Enns: Attention and Visual Memory in Visualization and Computer Graphics. IEEE Trans. Vis. Comput. Graph. 18(7): 1170-1188 (2012)

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Postattentive Amnesia

- Does previewing of stimuli make search faster?
 - Extract detail rapidly on demand?
- Human vision is not an optical camera
 - Region of the most recent focus of attention
 - Detail is only available there

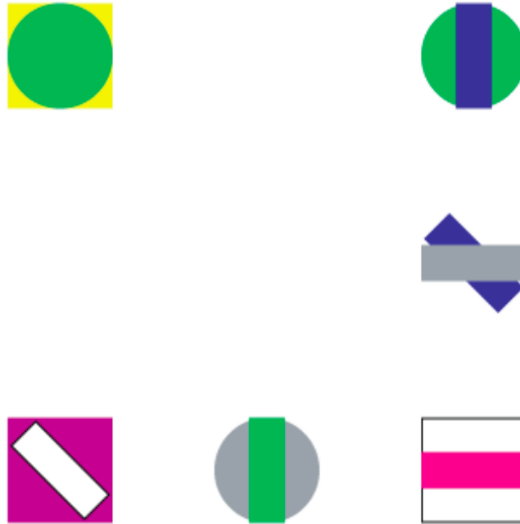
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Can studying a display offers assistance in searching for specific data values?

- traditional search vs. postattentive search

**GREEN
VERTICAL**

Traditional Search

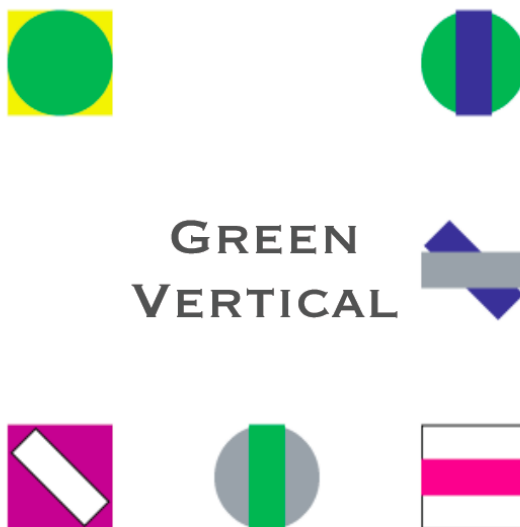


Wolfe, Klempe, Dahlen, "Post Attentive Vision," JEP: HPP 26 (2), 2000.

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Traditional Search



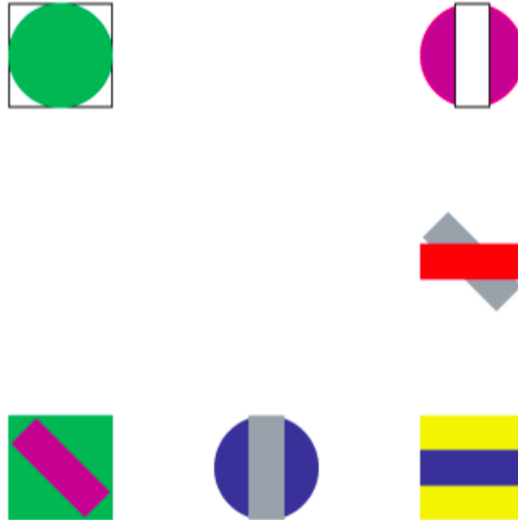
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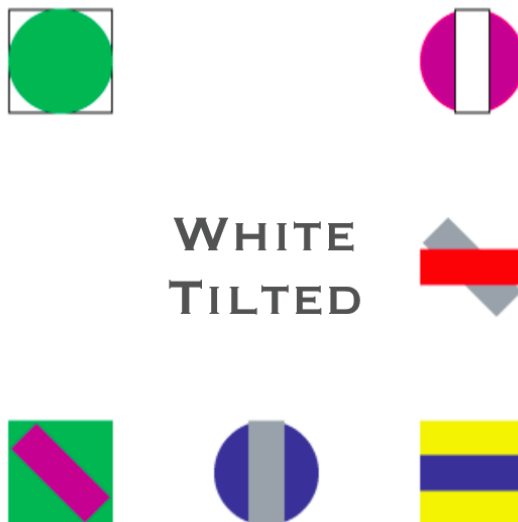
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Postattentive Search



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Postattentive Search



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Postattentive Amnesia

- Postattentive search was as slow (or slower) than the traditional search
 - with approximately 25-40 *ms* per object
 - studying a display offers no assistance in searching for specific data values
- Implications for visualization design
 - In most cases, visualization displays are novel
 - their contents cannot be committed to LTM
 - **preattentive methods are critical for efficient data exploration**
 - draw attention to areas of potential interest

Christopher G. Healey, James T. Enns: Attention and Visual Memory in Visualization and Computer Graphics. IEEE Trans. Vis. Comput. Graph. 18(7): 1170-1188 (2012)

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Preattentive Tasks

- visual features that are detected very rapidly by low-level, fast-acting visual processes
- seems to precede focused attention
 - occurring within a single fixation
 - attention plays a critical role in what we see in this early stage
- preattentive tasks: performed on large multi-element displays in less than 200-250 *ms*
 - saccade takes at least 200 *ms* to initiate
- “pop out” of a display
 - easily detected *regardless of the number of distractors*
 - vs. time-consuming visual search
- Target detection, Boundary detection, Region tracking, Counting and estimation

Christopher G. Healey, James T. Enns: Attention and Visual Memory in Visualization and Computer Graphics. IEEE Trans. Vis. Comput. Graph. 18(7): 1170-1188 (2012)

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How many sevens?

2398419309213985874506209348952034809502
3984210293841909238740129384610329849238
4265293845013945594858601239480234958728
4596394058640598239485802394895029348658
4561024596234851604569828309458673049561
3045916459086130495298646658956405196809
5866304598683049561835601830459680345907
6283486510465183560241620945613045618304
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Slide Idea from Colin Ware

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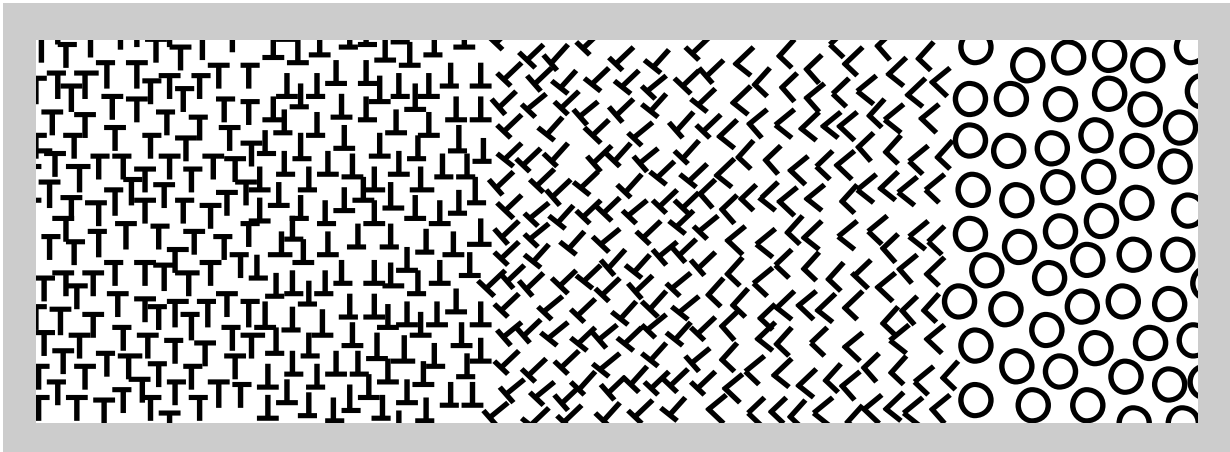
Color Makes Them Pop Out

2398419309213985874506209348952034809502
3984210293841909238740129384610329849238
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4596394058640598239485802394895029348658
4561024596234851604569828309458673049561
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5866304598683049561835601830459680345907
6283486510465183560241620945613045618304
5968230459630459860395620349568204385362

Slide Idea from Colin Ware

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Segmentation



Slide Idea from Colin Ware

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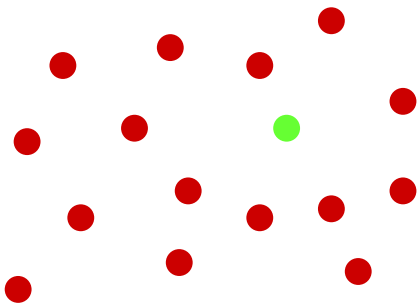
What Kinds of Tasks?

- Target detection
 - Is something there?
- Boundary detection
 - Can the elements be grouped?
- Region tracking
 - Can a distinctive moving group be traced?
- Counting and estimation
 - How many elements of a certain type are present?
 - Estimate the number of elements with a unique visual feature

John Stasko

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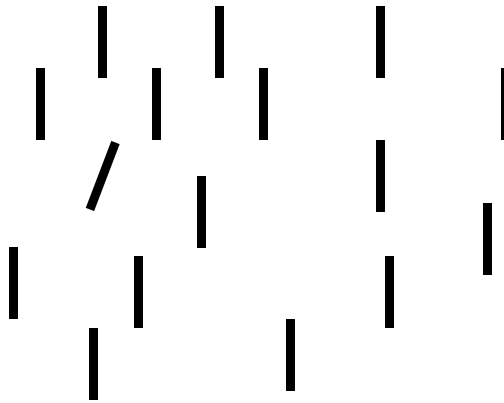
Color-Hue



Colin Ware

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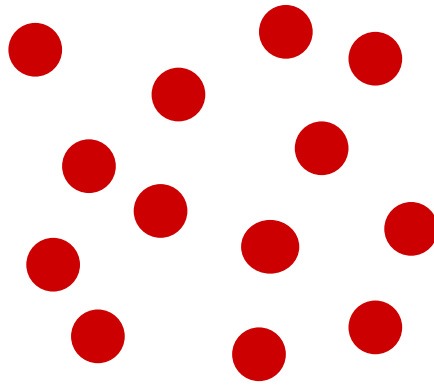
Orientation



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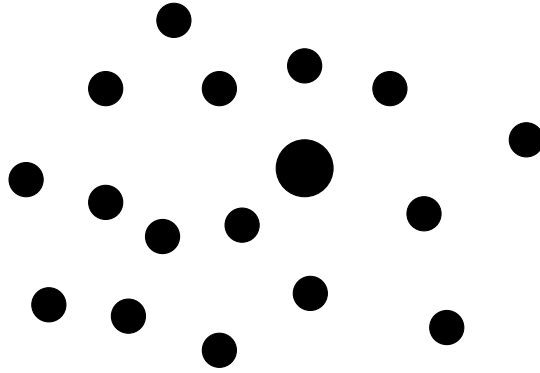
Motion



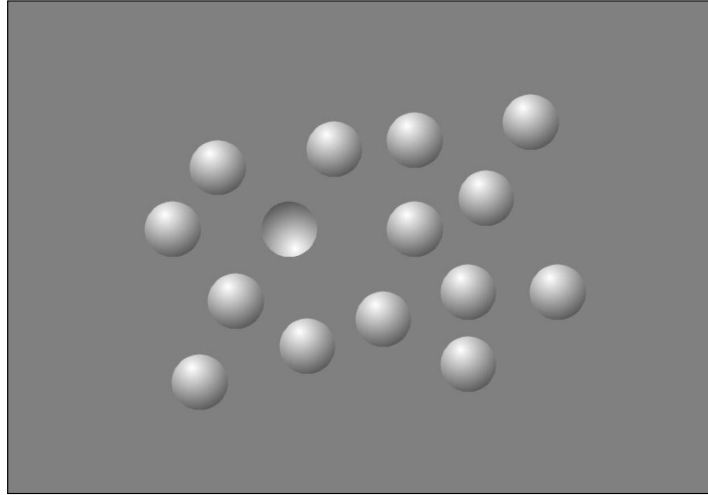
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Size



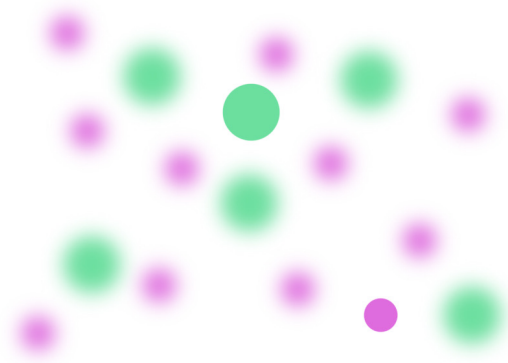
Simple shading



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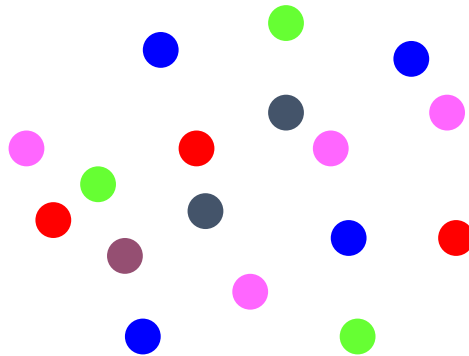
Semantic Depth of Field



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Surrounded colors do not pop out



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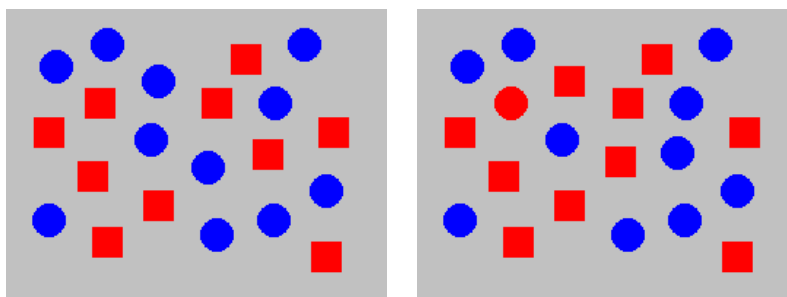
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Laws of preattentive display

- Must stand out on some simple dimension
 - color,
 - simple shape = orientation, size
 - motion,
 - depth
- Lessons for highlighting – one of each

Hue and Shape

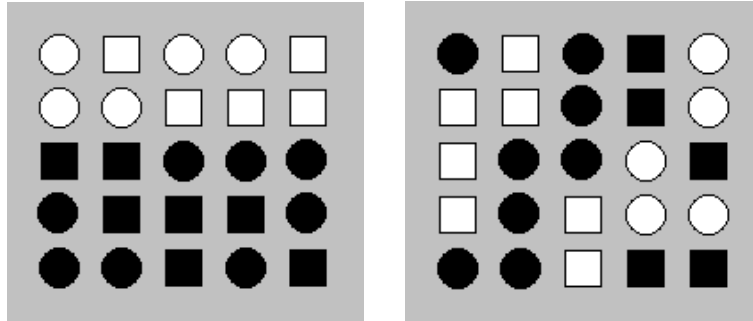
- Determine if a red circle is present



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

Fill and Shape

- Is there a boundary?



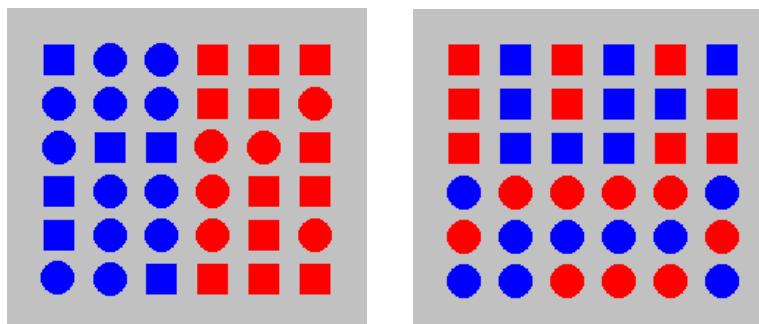
- Left can be done preattentively since each group contains one unique feature
- Right cannot since the two features are mixed (fill and shape)

<http://www.csc.ncsu.edu/faculty/healey/PP/PP.html>
John Stasko

Information Visualization and Visual Analytics – Perception & Visual Patterns

Hue versus Shape

- Is there a boundary?



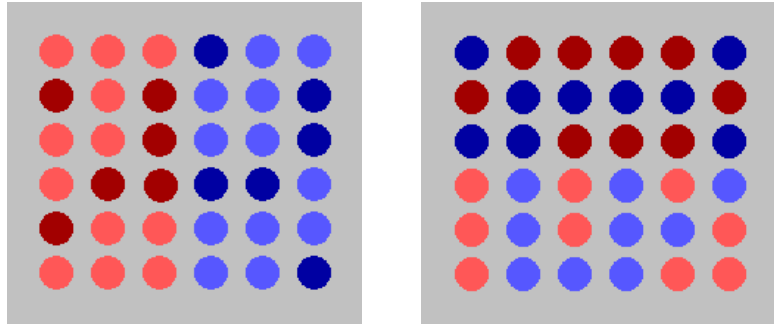
- Left: Boundary detected preattentively based on hue regardless of shape
- Right: Cannot do mixed color shapes preattentively

<http://www.csc.ncsu.edu/faculty/healey/PP/PP.html>
John Stasko

Information Visualization and Visual Analytics – Perception & Visual Patterns

Hue versus brightness

- Is there a boundary?



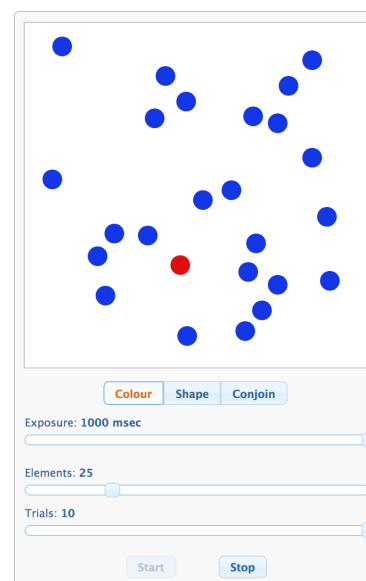
- Left: Varying brightness seems to interfere
- Right: Boundary based on brightness can be done preattentively

<http://www.csc.ncsu.edu/faculty/healey/PP/PP.html>
John Stasko

Information Visualization and Visual Analytics – Perception & Visual Patterns

Preattentive Visual Features

- Perception in Visualization (by Chris Healey, NC State)
- Preattentive Visual Features
 - line (blob) orientation
 - length, width
 - closure
 - size
 - curvature
 - density, contrast
 - number, estimation
 - colour (hue)
 - intensity, binocular lustre
 - intersection
 - terminators
 - 3D depth cues, stereoscopic depth
 - flicker
 - direction of motion
 - velocity of motion
 - lighting direction
 - 3D orientation
 - artistic properties



<http://www.csc.ncsu.edu/faculty/healey/PP/PP.html>

Information Visualization and Visual Analytics – Perception & Visual Patterns

Readings

- Perception in Visualization, Christopher G. Healey,
<http://www.csc.ncsu.edu/faculty/healey/PP/index.html>
- **Attention and Visual Memory in Visualization and Computer Graphics**, Christopher G. Healey & James. T. Enns, TVCG, Vol 18(7), pp. 1170-1188, 2012
- Chapter 4, Organization and visual structure, Designing Visual Interfaces: Communication Oriented Techniques, Kevin Mullet and Darrell Sano, Prentice Hall PTR, 1994, ISBN 978-0133033892
- Chapter 5, **Visual Attention and Information that Pops Out**, Chapter 6, **Static and Moving Patterns**, Information Visualization: Perception for Design, 2nd ed. Colin Ware, Morgan Kaufmann, 2004, ISBN 1-55860-819-2.

Credits

- John Stasko, Georgia Tech
 - www.cc.gatech.edu/~stasko/7450/
- Colin Ware, U of NH
 - <http://ccom.unh.edu/vislab/VisCourse/index.html>
- Tamara Munzner, UBC
 - people.cs.ubc.ca/~tmm/courses/533-09/

- Questions?