

Information Visualization and Visual Analytics (M1522.000500)

Perception and Visual Patterns

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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

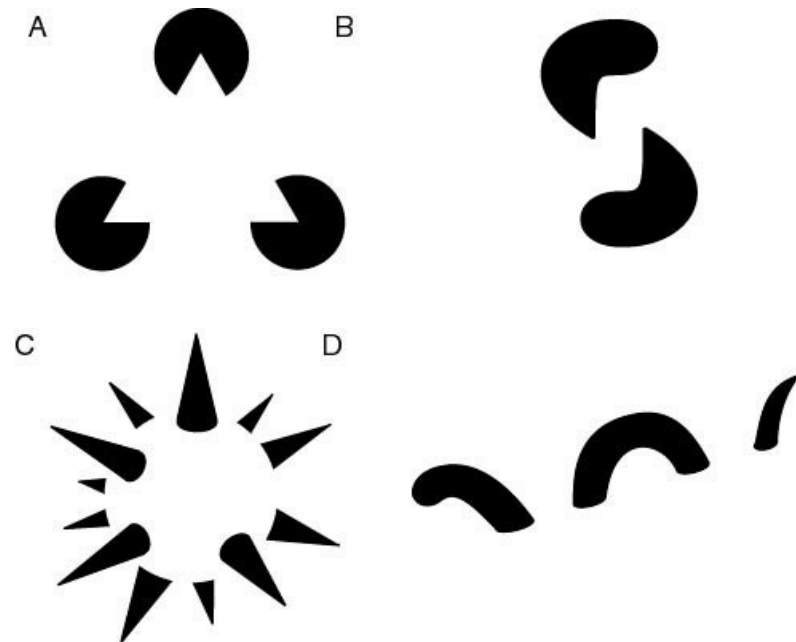


Principles



Emergence

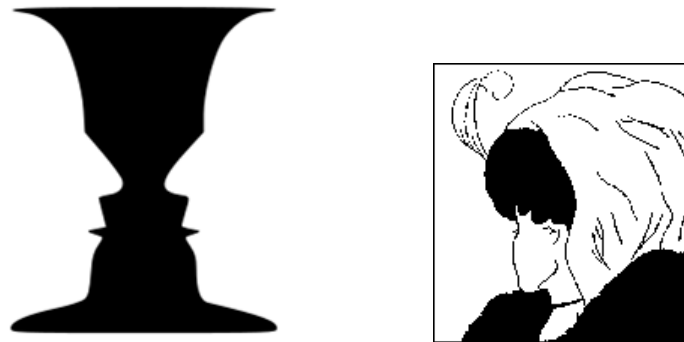
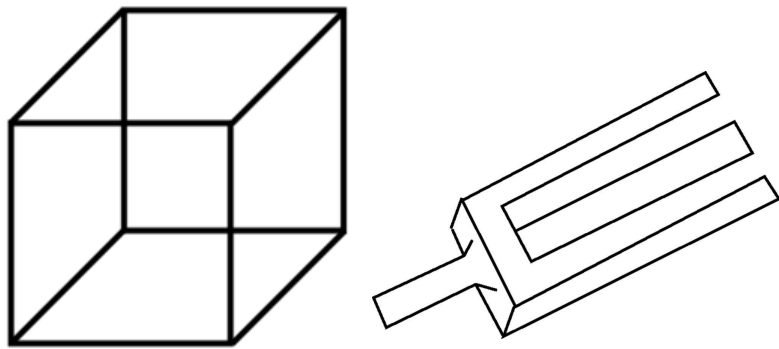
the dog is perceived as a **whole**



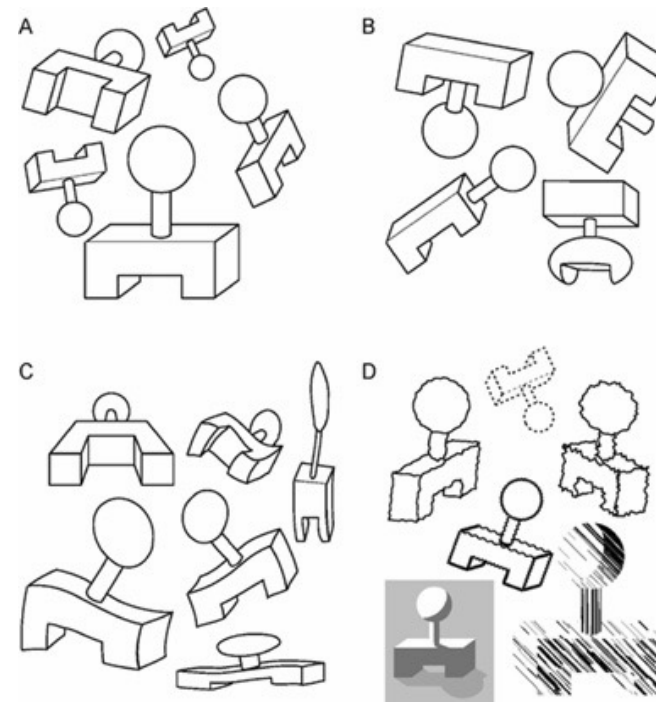
Reification

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

Principles



Multistability Perception

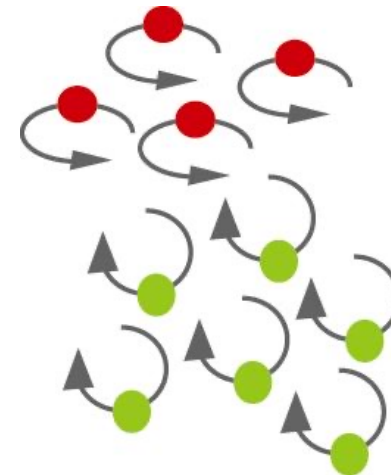
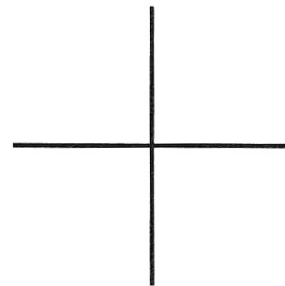
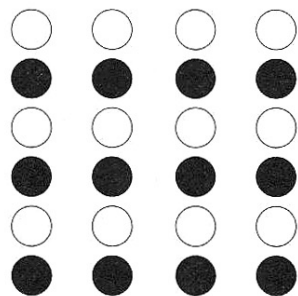
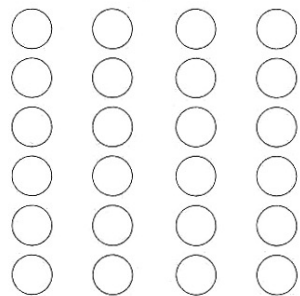


Invariance

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

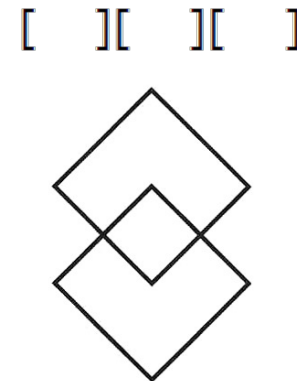
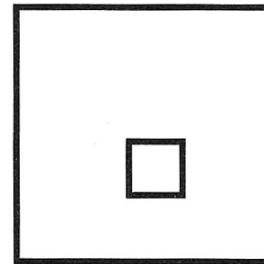
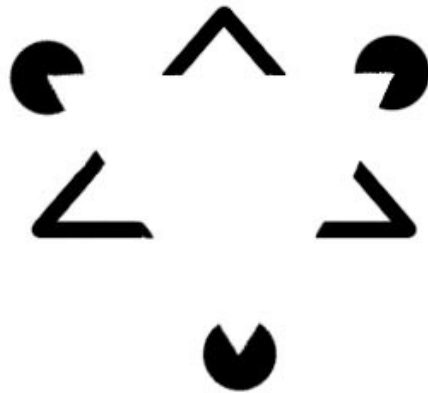
Gestalt Principles

- 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

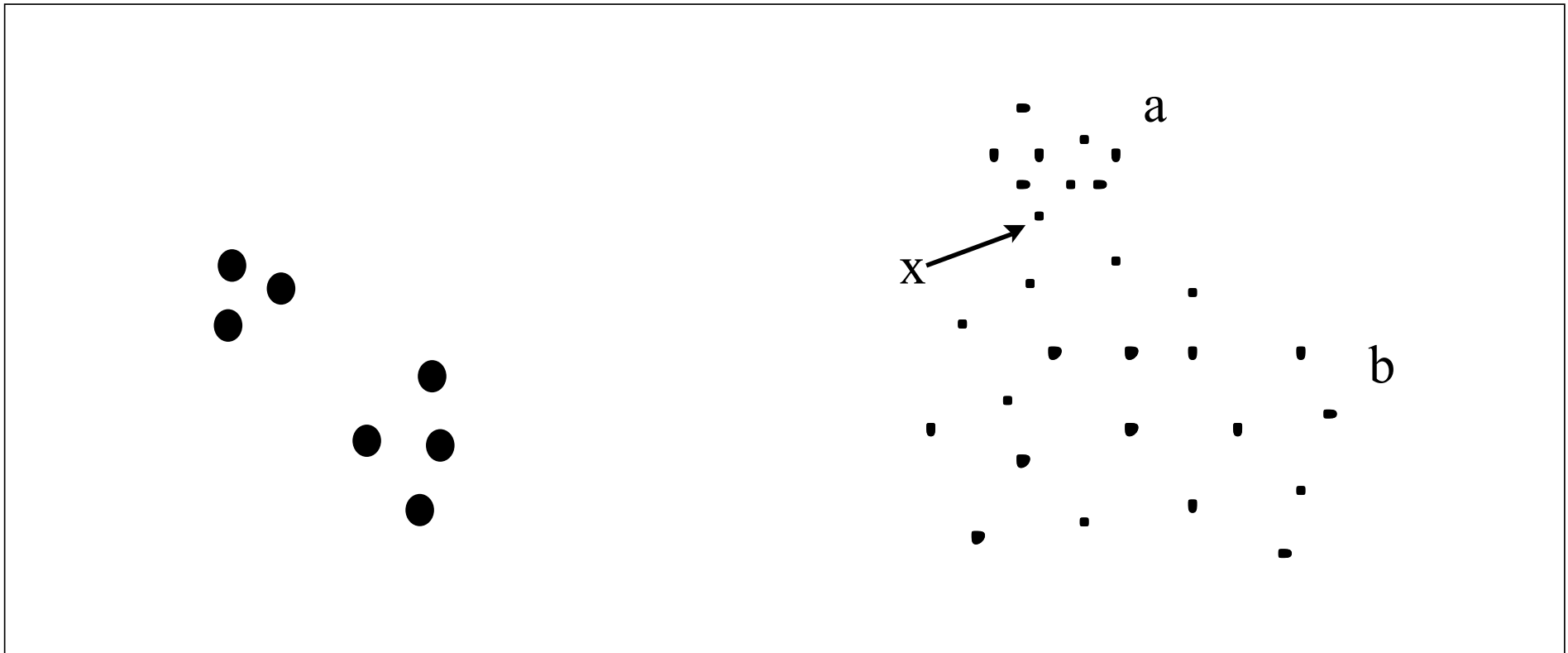


Gestalt Principles

- 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

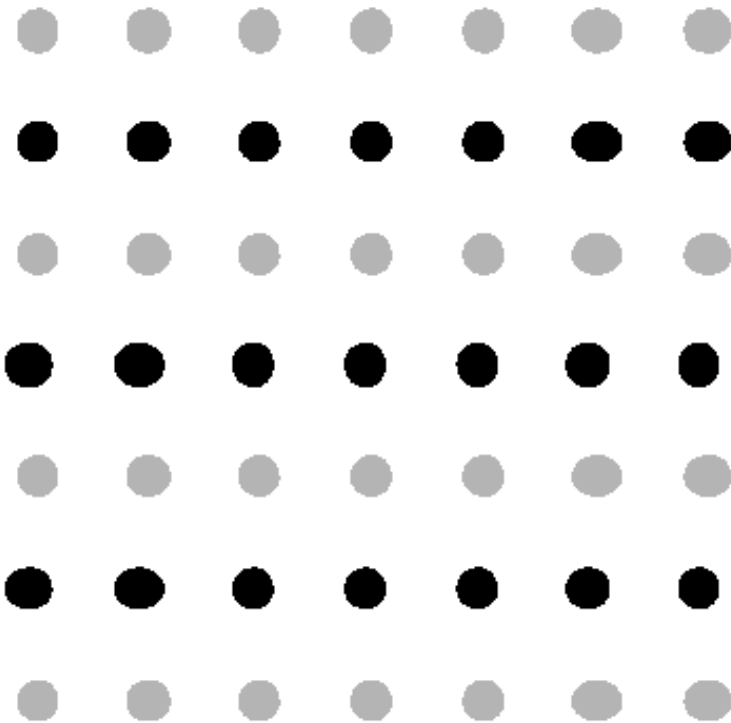


Proximity

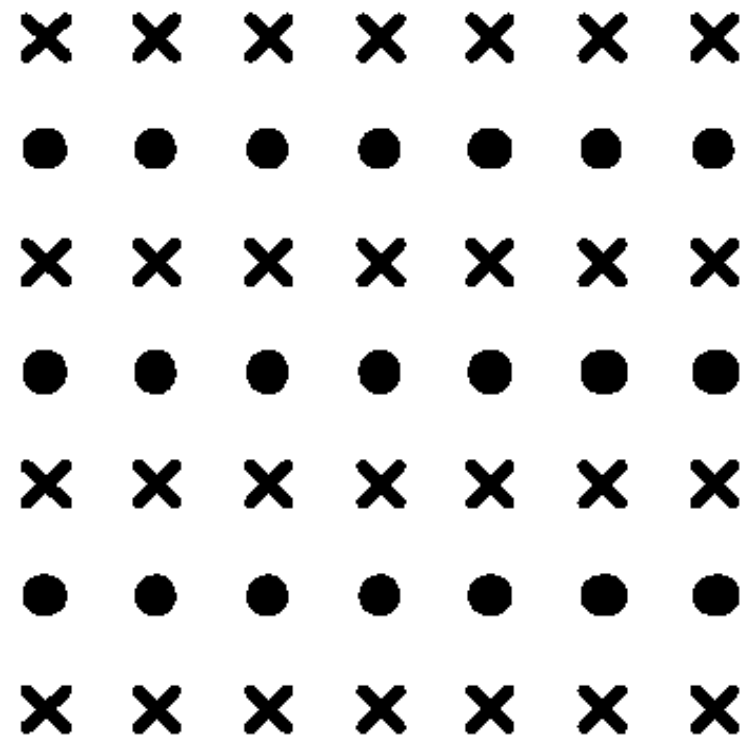


Similarity

a

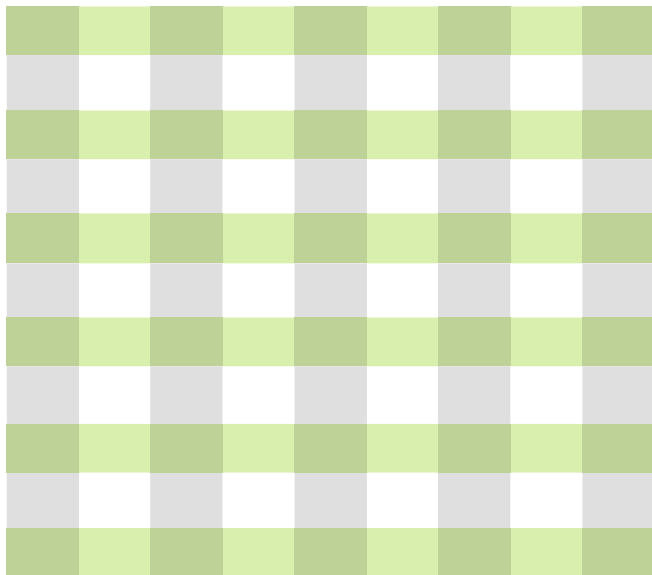


b

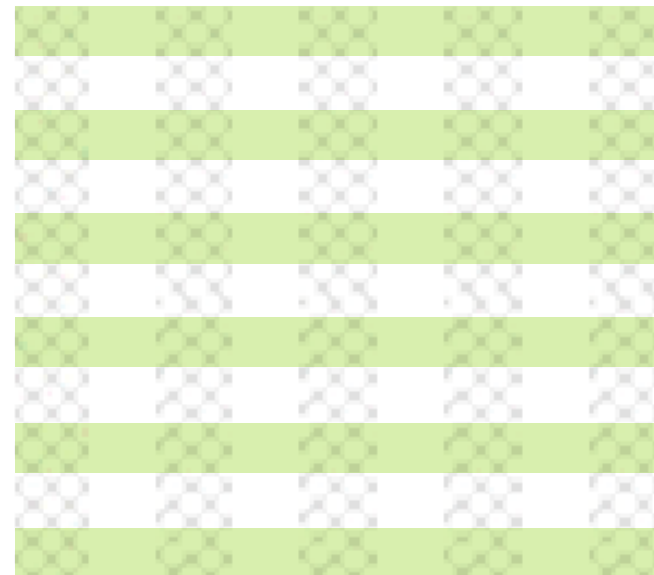


Similarity

a



b

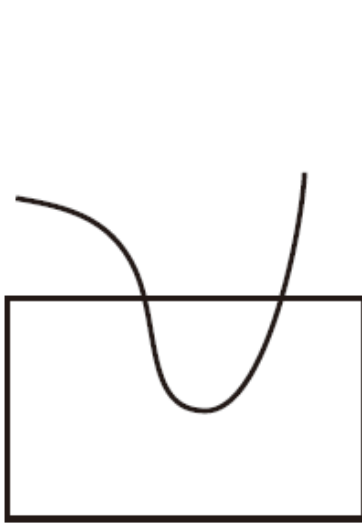


Proximity and Similarity

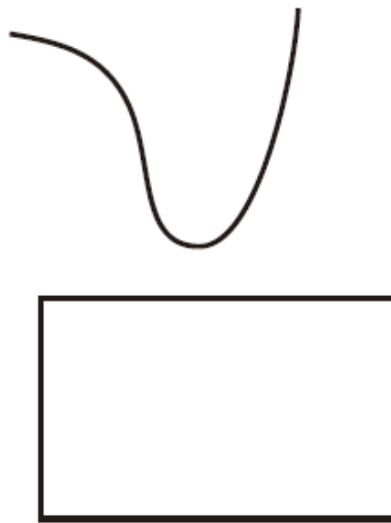


Continuity

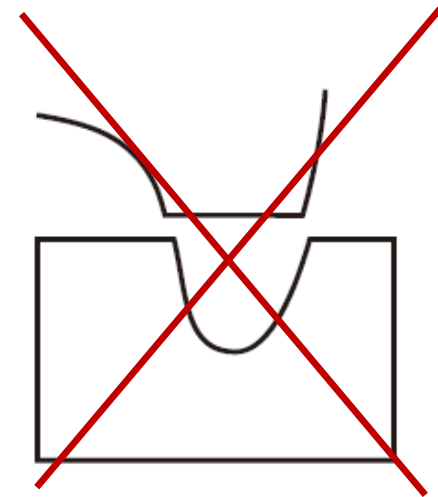
- Visual entities tend to be smooth and continuous



(a)



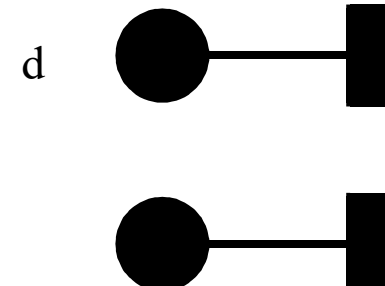
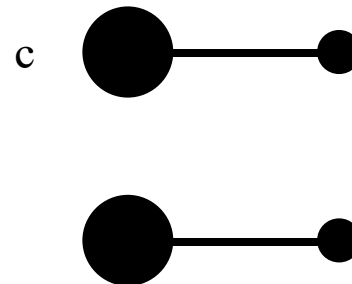
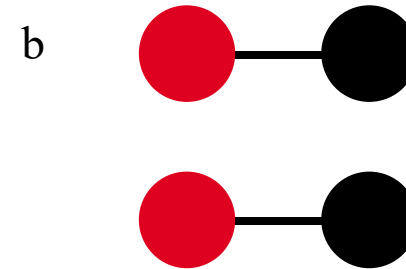
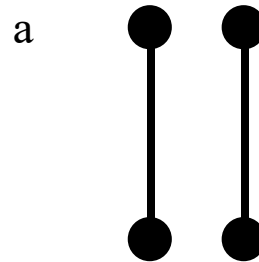
(b)



(c)

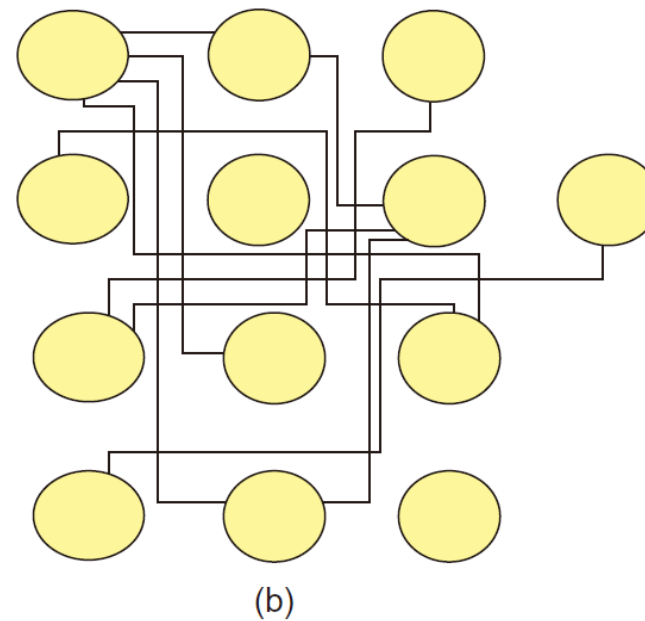
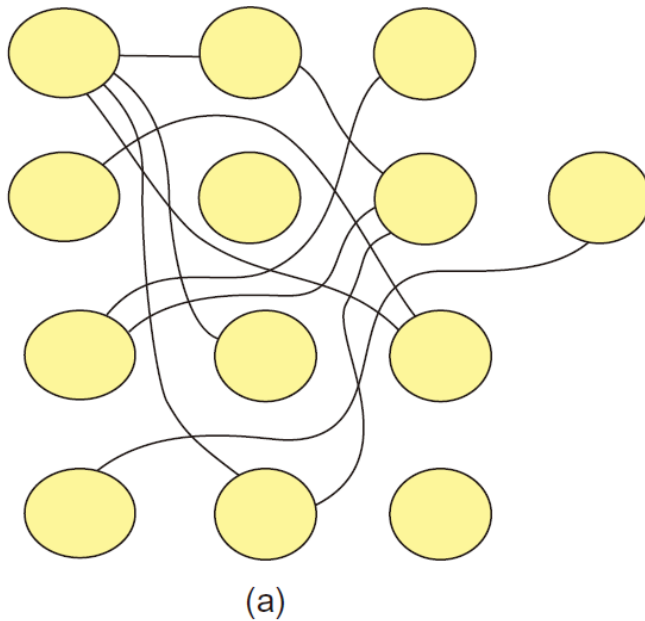
Connectedness

- assumed in Continuity
- can overrule size, shape



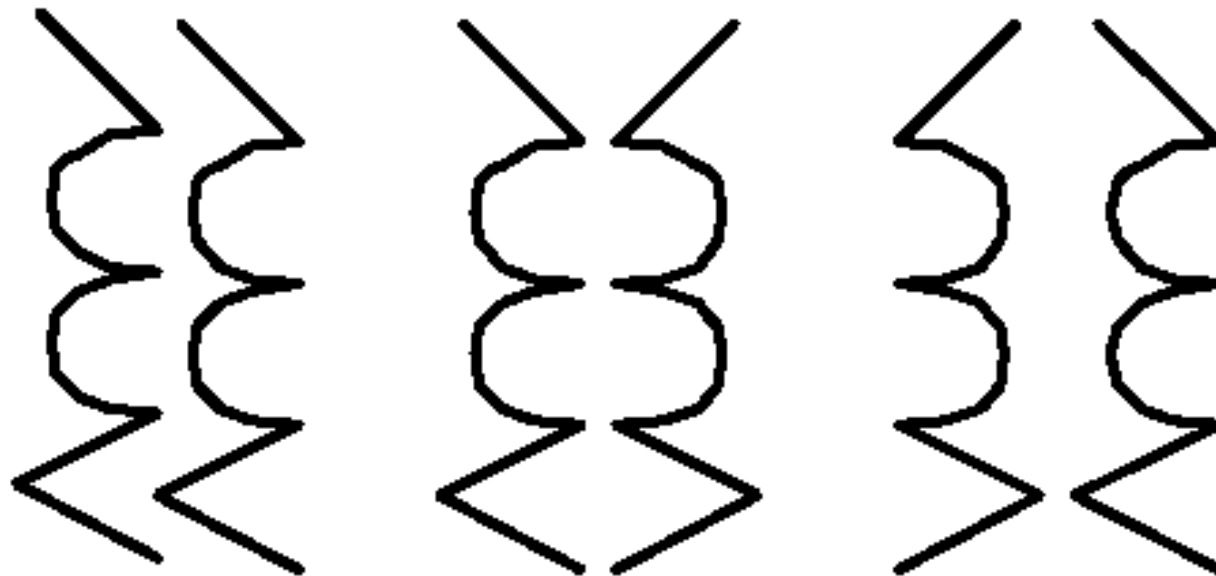
Continuity in Diagrams

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



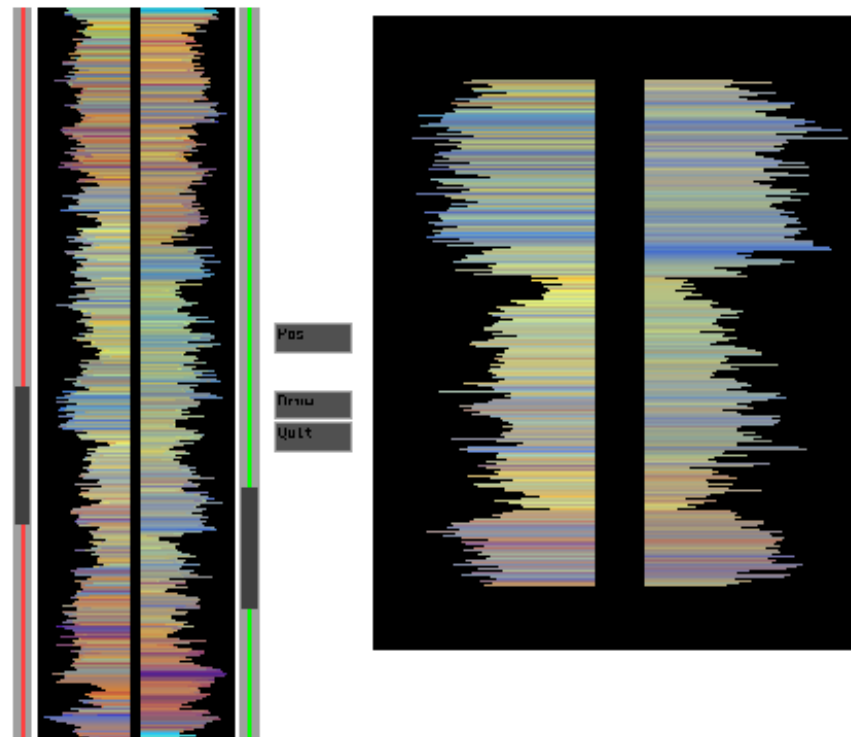
Symmetry

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



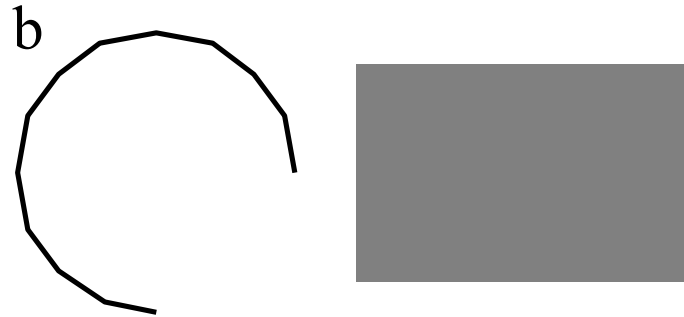
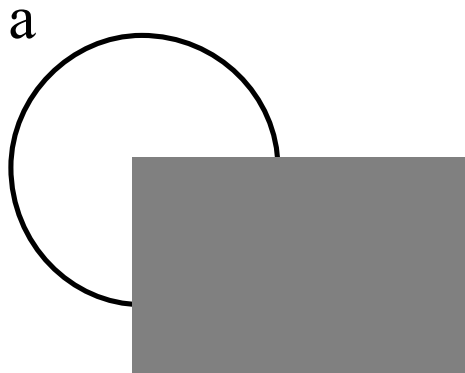
Symmetry

- symmetry to show Similarities between time series data

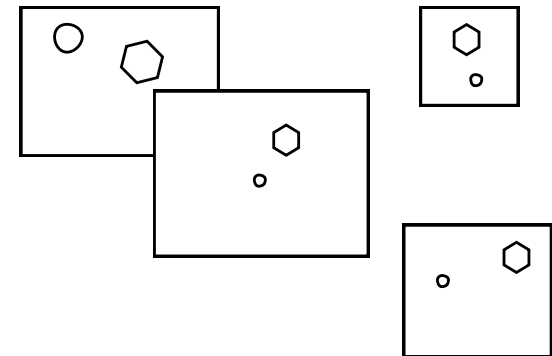


Closure

- Prefer closed contours

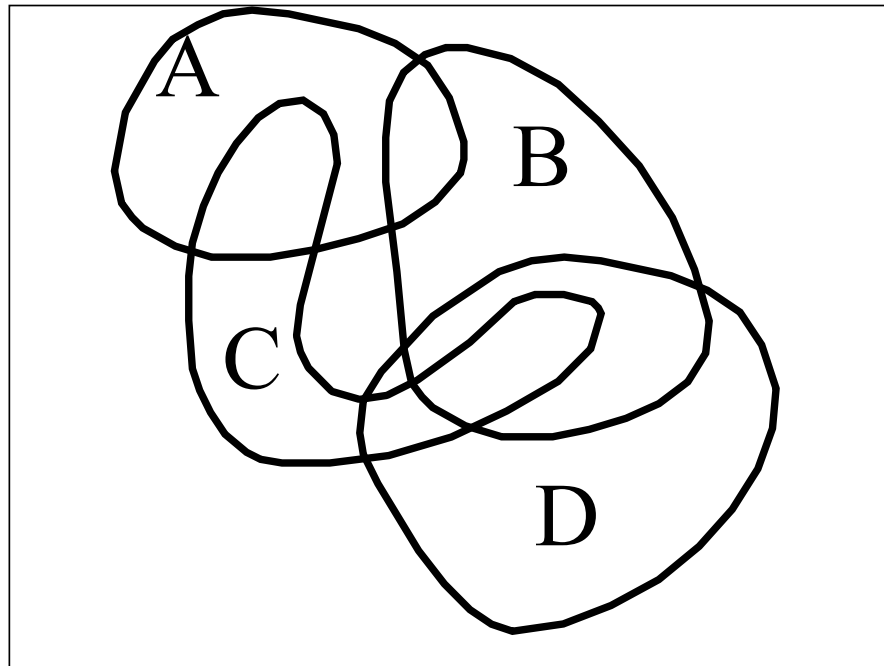


- Overtake proximity
- Segment visual field
- Provide reference frames



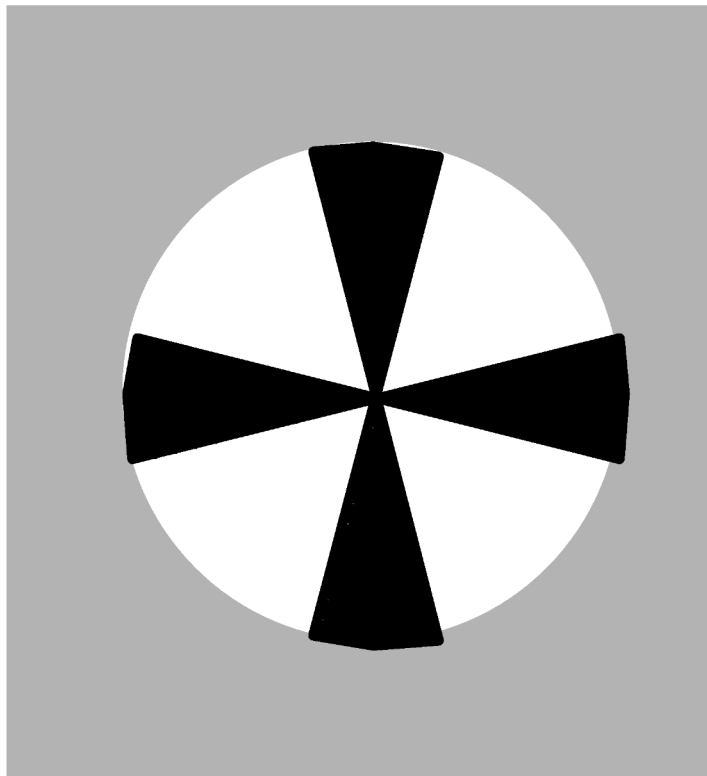
Closure

- Closed contours to show set relationship



Area / Figure & Ground / Relative Size

- smaller components perceived as objects



Area / Figure & Ground / Relative Size

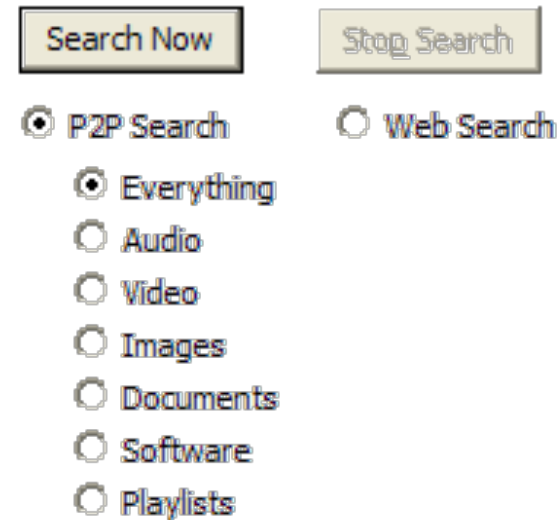
- determined by combination of previous laws
 - symmetry, contour



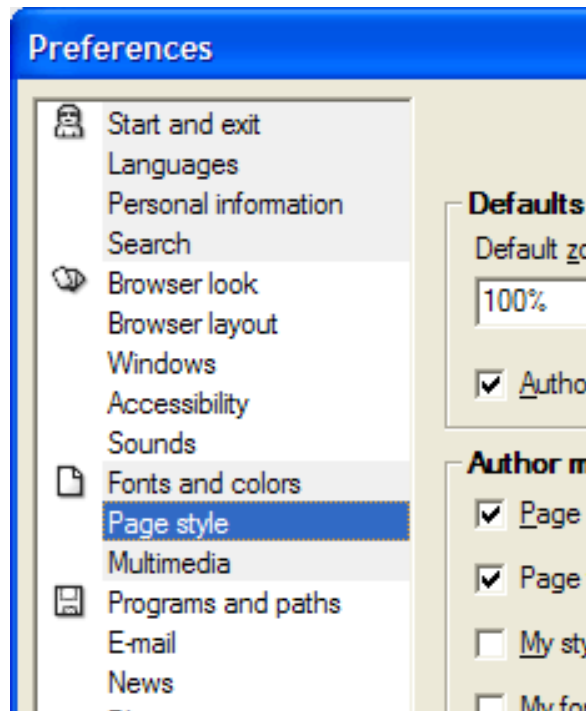
Proximity Examples



MTV Music Awards 2002



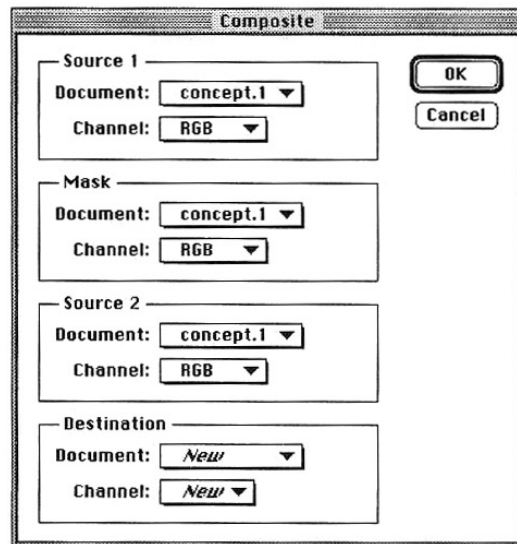
Similarity Examples



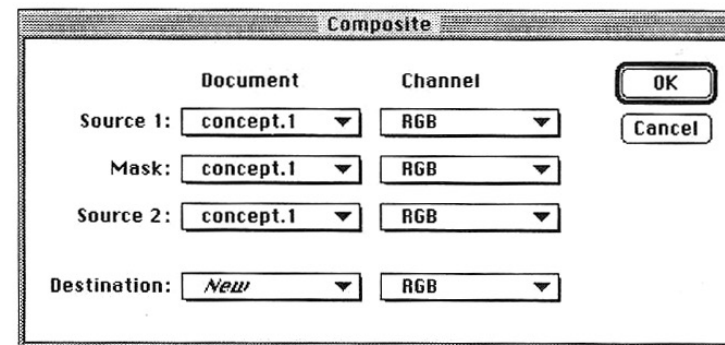
http://www.interaction-design.org/encyclopedia/gestalt_principles_of_form_perception.html
<http://graphicdesign.spokanefalls.edu/tutorials/process/gestaltprinciples/gestaltprinc.htm>

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 title in bold. To the right of the sections are "OK" and "Cancel" buttons.



A dialog box titled "Composite" with a tabular layout. It has two columns: "Document" and "Channel". The rows are: "Source 1" (concept.1, RGB), "Mask" (concept.1, RGB), "Source 2" (concept.1, RGB), and "Destination" (New, RGB). The "Destination" row is the only one with "New" as an option. To the right of the table are "OK" and "Cancel" buttons.

Hierarhcy

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

The image shows a software dialog box titled "Pizza: Pizza Pie Properties". It is organized into two main sections: "BOTTOM STUFF" and "TOPPING STUFF".

BOTTOM STUFF

- Style:** Two buttons labeled "Thin" and "Thick" followed by the text "crust".
- Sauce:** Three buttons labeled "Regular", "Spicy", and "Pesto".

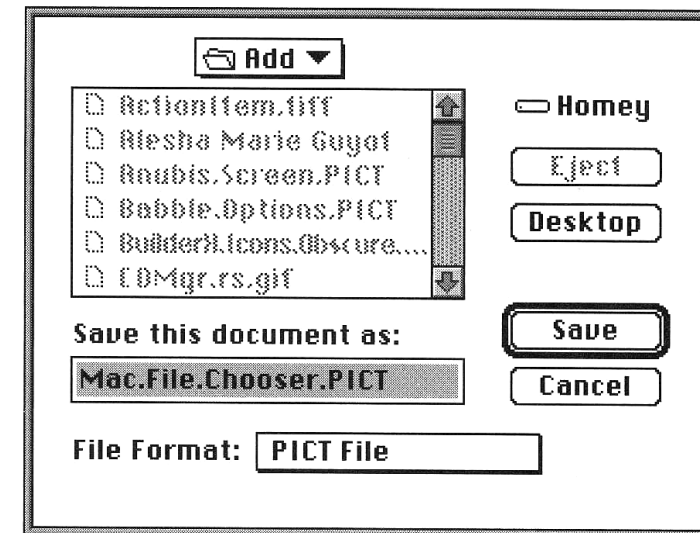
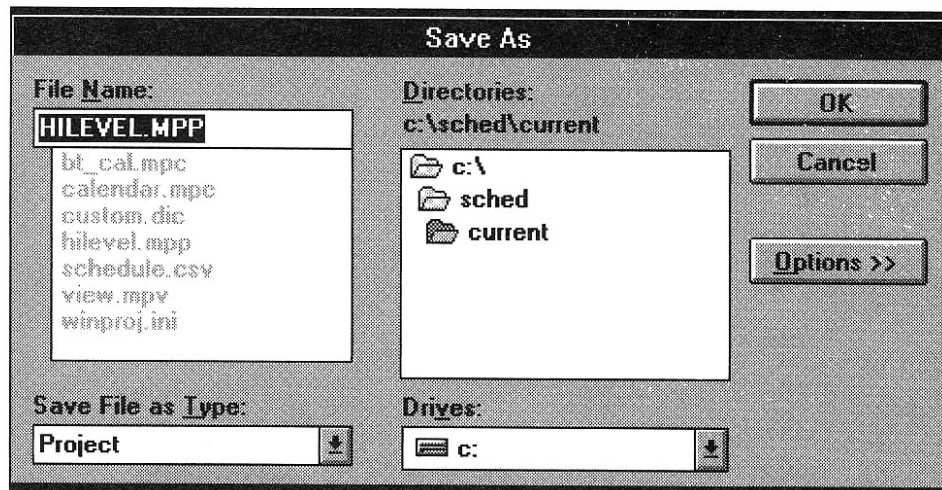
TOPPING STUFF

- Toppings:** A grid of buttons organized by category:
 - Meat:** Ham, Bacon, Sausage
 - Veggies:** Olive, Pepper, Onion
 - Other:** Cheese, Pesto, Anchovy
- Options:** Two checkboxes: "Red Peppers" (checked) and "Extra Cheese" (unchecked).

At the bottom of the dialog are two buttons: "Apply" and "Reset".

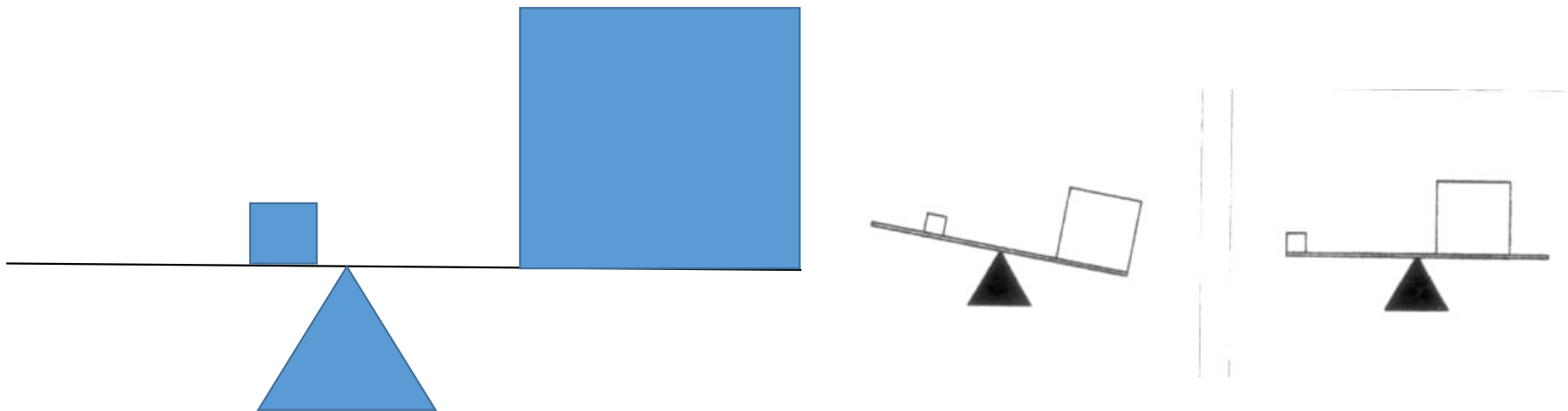
Relationship

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



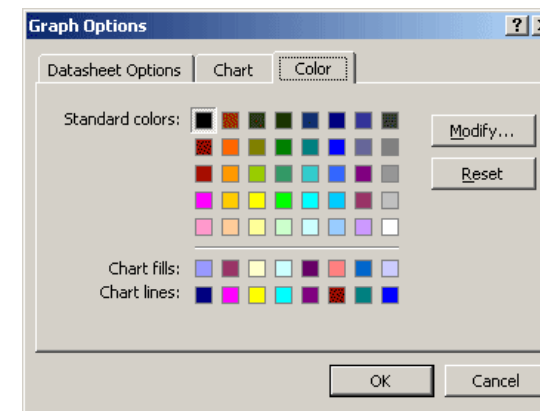
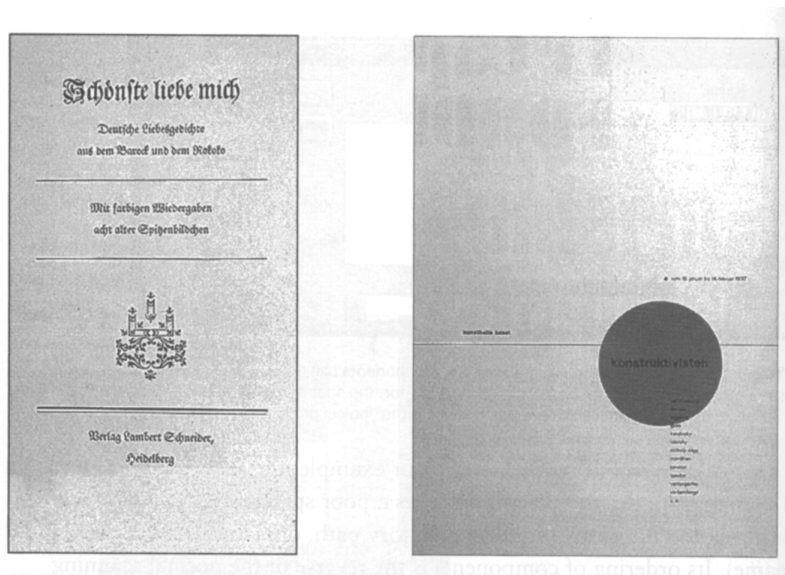
Balance

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



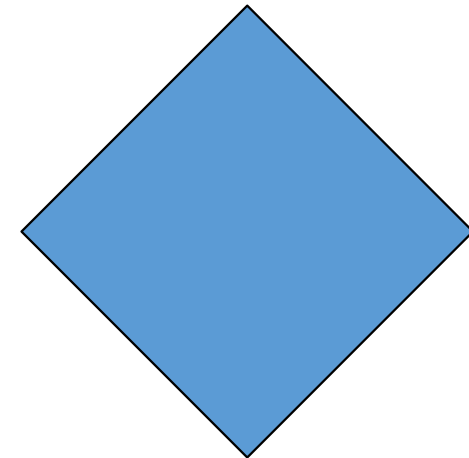
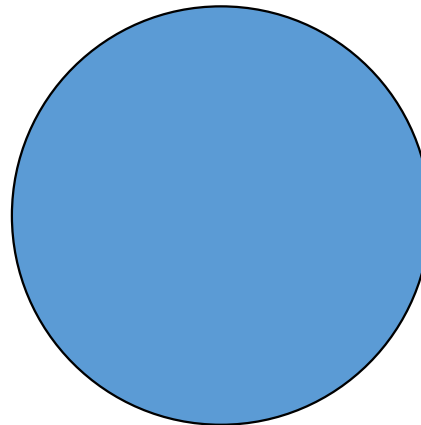
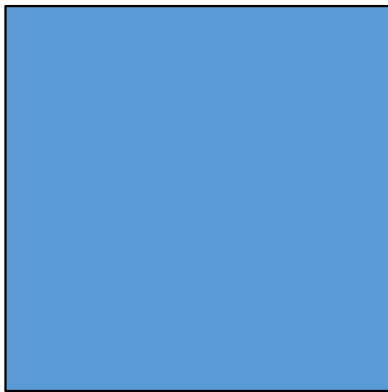
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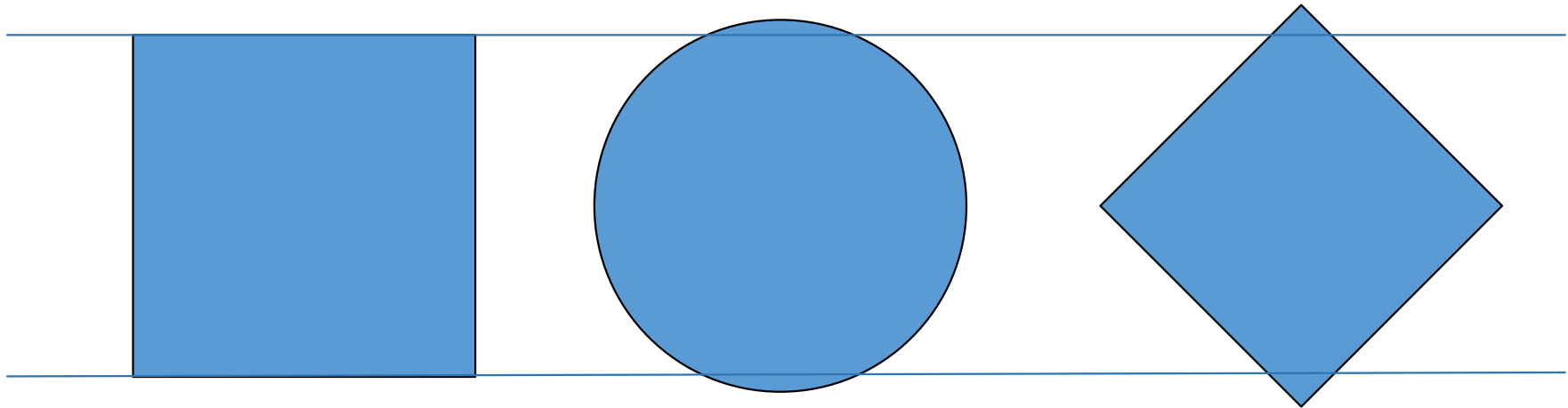
Human Size Perception

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



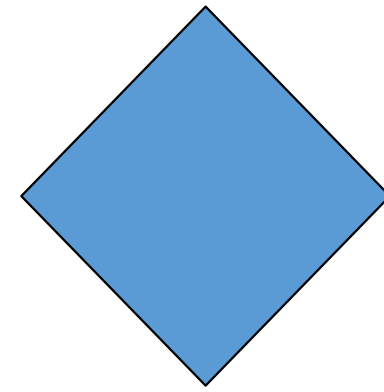
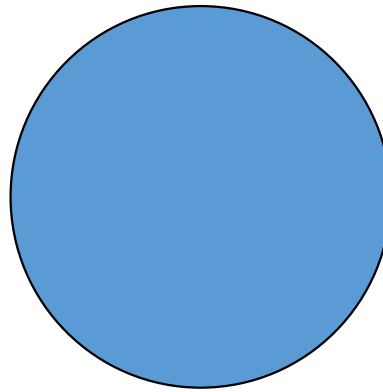
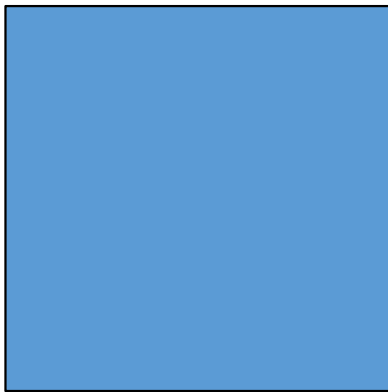
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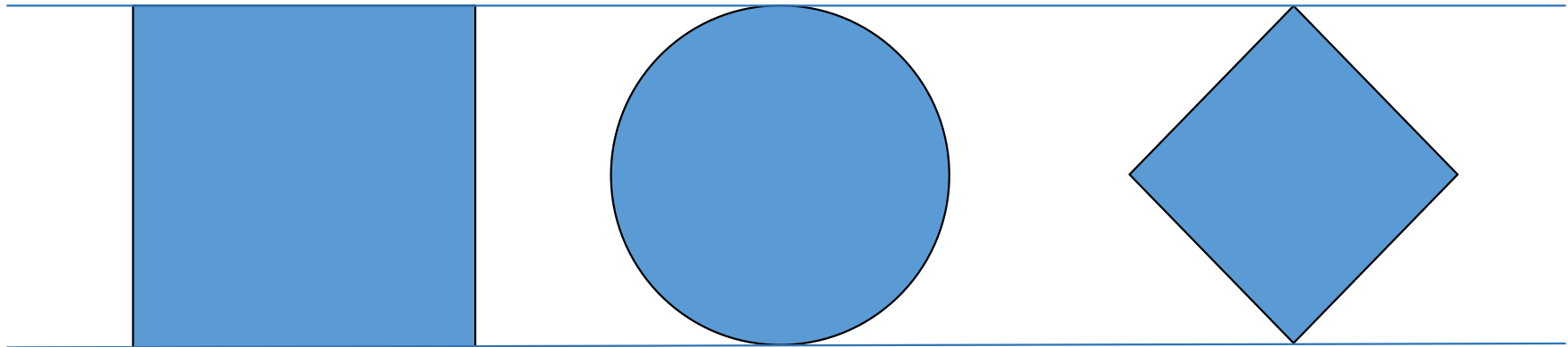
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Human Size Perception

- Straight edges appear larger than curved edges
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- Optical adjustment



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

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, inattentional blindness, attentional blink

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

Postattentive Amnesia

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

- traditional search vs. postattentive search

GREEN VERTICAL

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

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)

Traditional Search



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

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Traditional Search



**GREEN
VERTICAL**



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Postattentive Search



**WHITE
TILTED**



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

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)

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

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

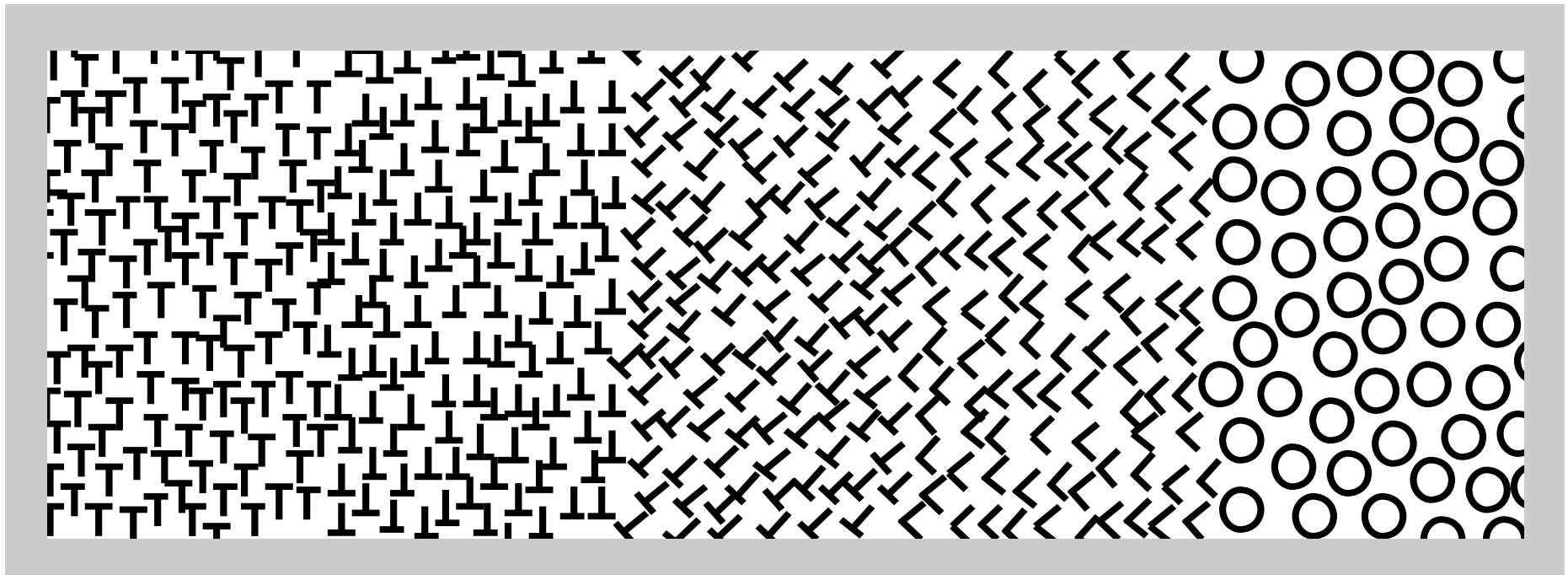
How many sevens?

2398419309213985874506209348952034809502
3984210293841909238740129384610329849238
4265293845013945594858601239480234958728
4596394058640598239485802394895029348658
4561024596234851604569828309458673049561
3045916459086130495298646658956405196809
5866304598683049561835601830459680345907
6283486510465183560241620945613045618304
5968230459630459860395620349568204385362

Color Makes Them Pop Out

2398419309213985874506209348952034809502
3984210293841909238740129384610329849238
4265293845013945594858601239480234958728
4596394058640598239485802394895029348658
4561024596234851604569828309458673049561
3045916459086130495298646658956405196809
5866304598683049561835601830459680345907
6283486510465183560241620945613045618304
5968230459630459860395620349568204385362

Segmentation



Slide Idea from Colin Ware

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

Laws of preattentive display

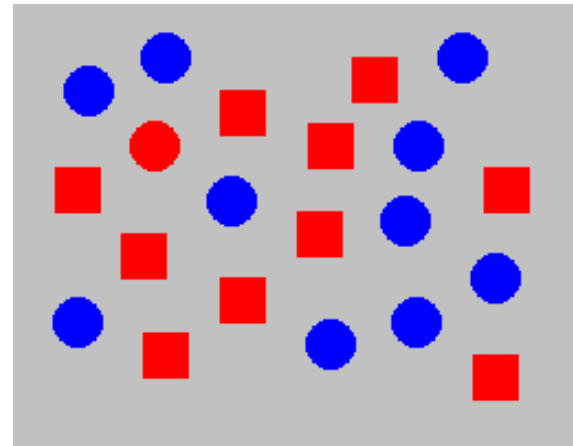
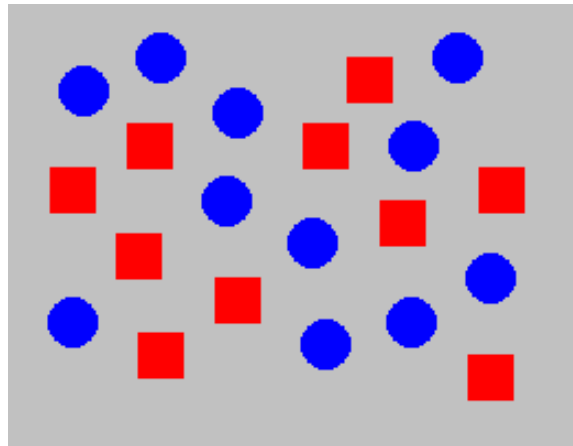
- Must stand out on some simple dimension
 - color,
 - simple shape = orientation, size
 - motion,
 - depth

Color Hue, Simple Shading, Semantic depth of field

- Lessons for highlighting – one of each

Hue and Shape

- Determine if a red circle is present



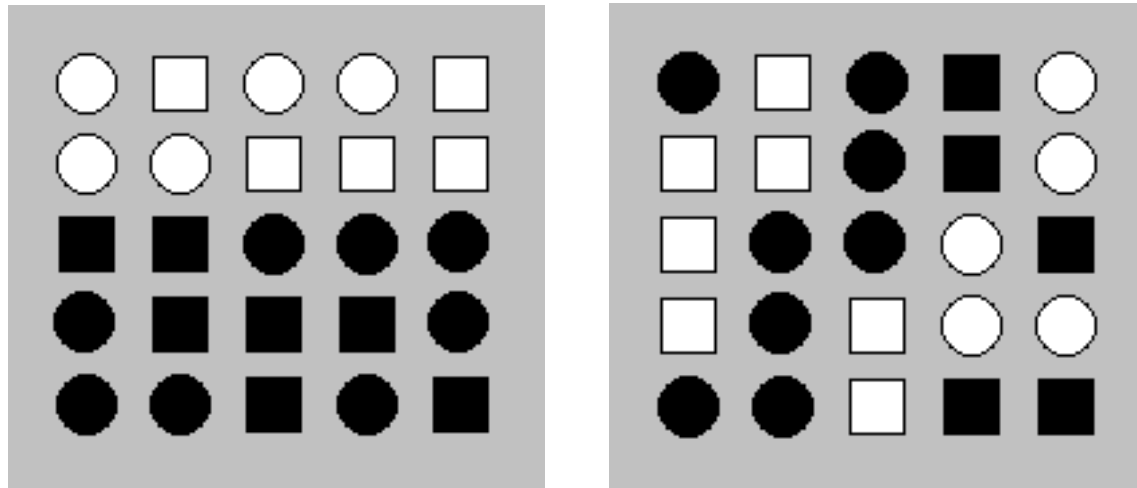
- Cannot be done preattentively
- Must perform a sequential search
- Conjunction of features (shape and hue) causes it

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

John Stasko

Brightness and Shape

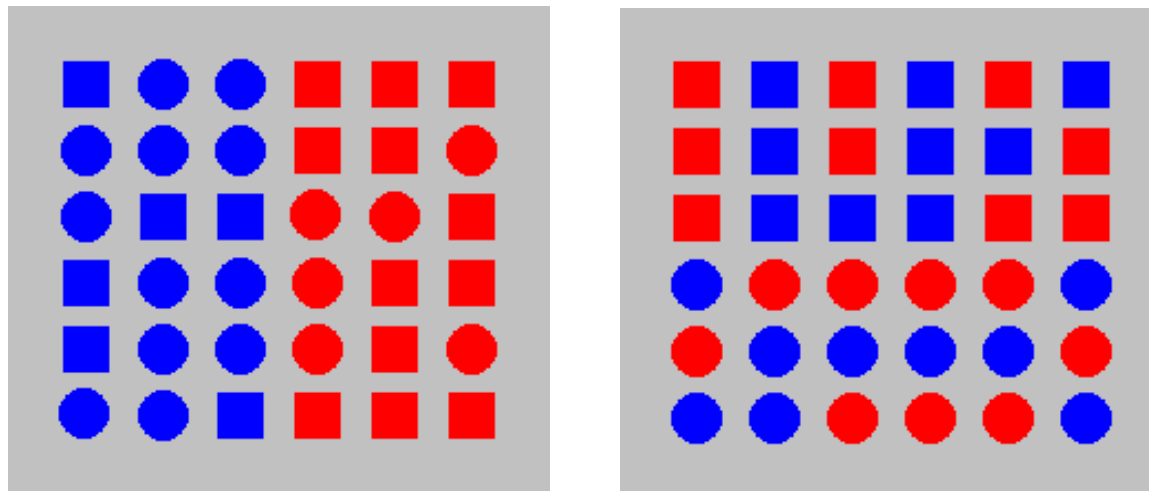
- Is there a boundary?



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

Hue versus Shape

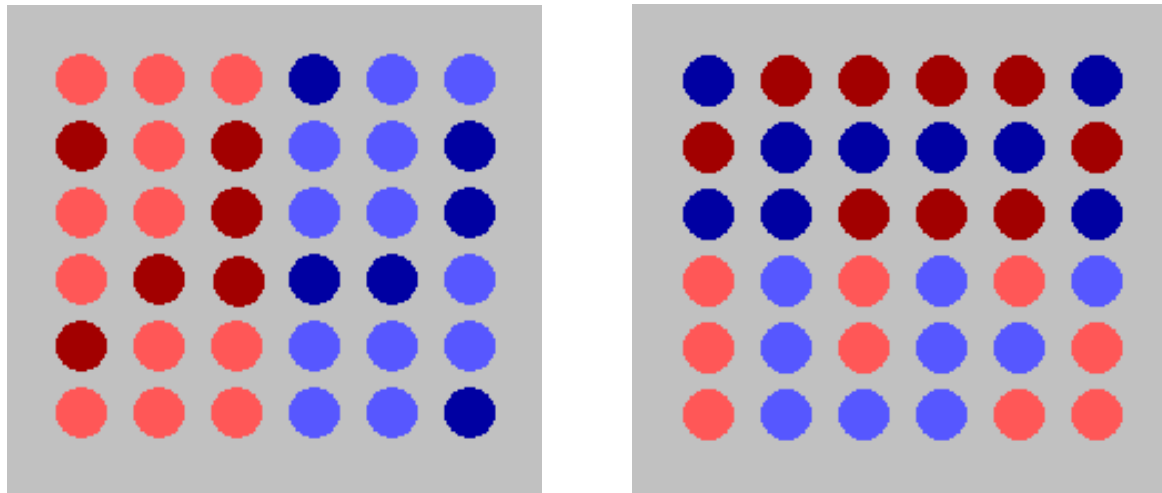
- Is there a boundary?



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

Hue versus brightness

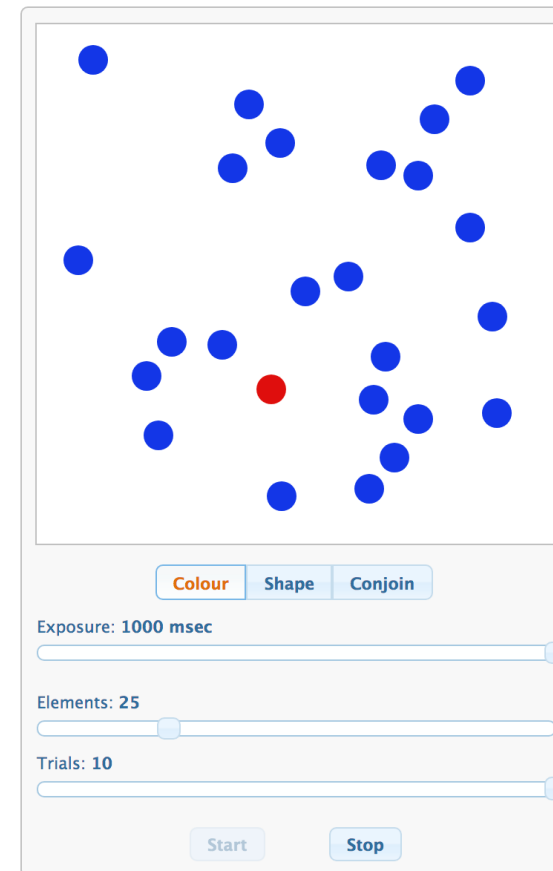
- Is there a boundary?



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

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>