

# Visualization in HCI

05 - 499 / 05 - 899 Section C



# Perception

February 13, 2017

# **Perception**

Identification and interpretation of sensory information

From the physical stimulus to recognizing information

Shaped by learning, memory, expectation

# **Cognition**

The processing of information, applying knowledge

Hear someone speak: Perception

Understand the language and the words: Cognition

# **Perception vs. Cognition**

## **Perception**

Eye, optical nerve, visual cortex

Basic perception

First processing  
(edges, planes)

Not conscious

Reflexes

## **Cognition**

Recognizing objects

Relations between objects

Conclusion drawing

Problem solving

Learning, ...

**RED**

**GREEN**

**BLUE**

**YELLOW**

**PINK**

**ORANGE**

**BLUE**

**GREEN**

**BLUE**

**WHITE**

**GREEN**

**YELLOW**

**ORANGE**

**BLUE**

**WHITE**

**BROWN**

**RED**

**BLUE**

**YELLOW**

**GREEN**

**PINK**

**YELLOW**

**GREEN**

**BLUE**

**RED**

# Looking vs. Seeing



Emergence Images. perceptual hysteresis



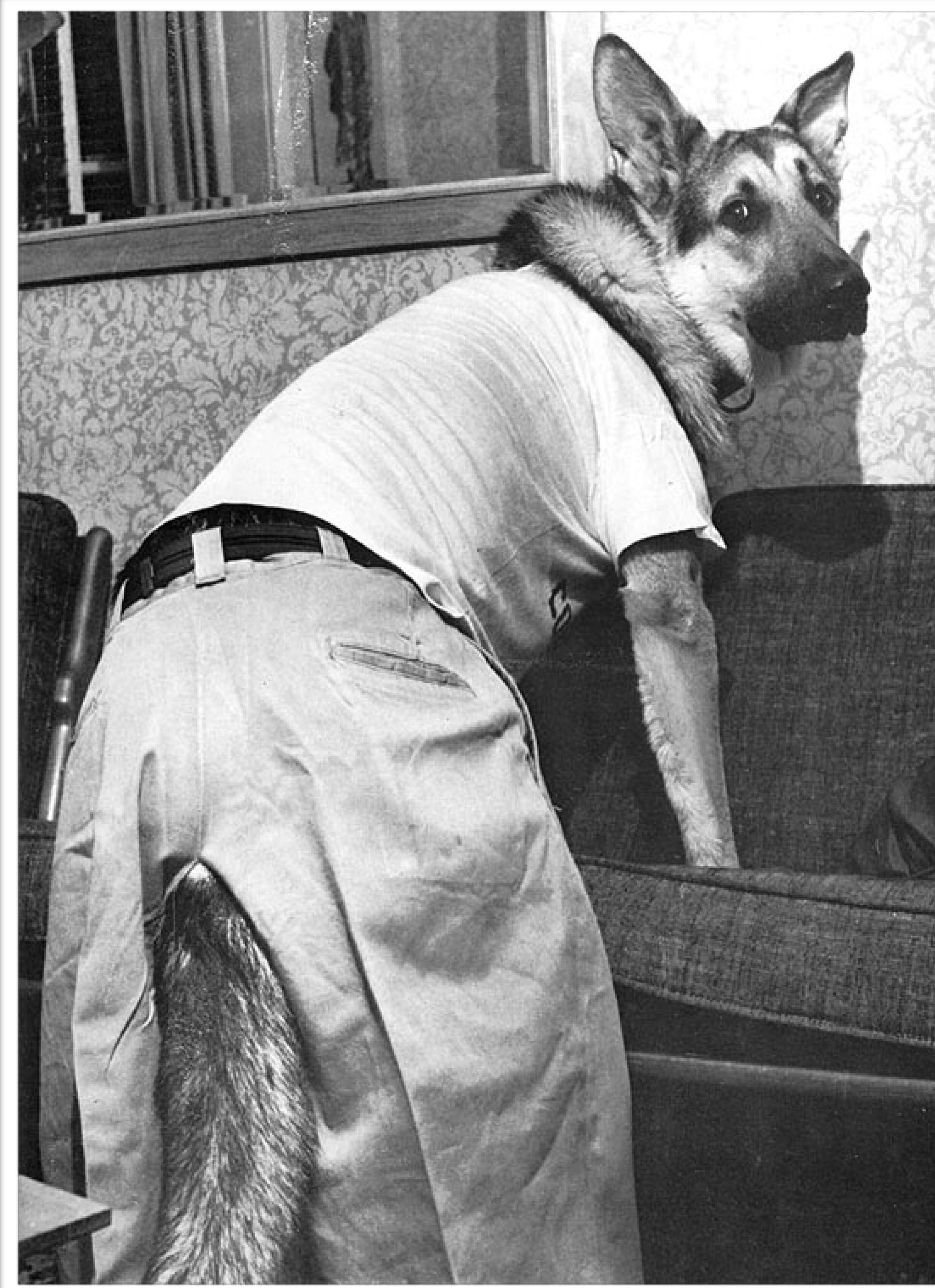
**Looking only at patches doesn't work**

[http://graphics.stanford.edu/~niloy/research/emergence/emergence\\_image\\_siga\\_09.html](http://graphics.stanford.edu/~niloy/research/emergence/emergence_image_siga_09.html)





we rely on priors



# Pareidolia



**Faces in Things** @FacesPics · Mar 9

These chairs have seen some terrible things [pic.twitter.com/GjlC9wuP47](https://pic.twitter.com/GjlC9wuP47)



**Faces in Things** @FacesPics · Mar 22

Hey little guy! [pic.twitter.com/nt2BgwZeTR](https://pic.twitter.com/nt2BgwZeTR)



**Faces in Things** @FacesPics · Mar 10

A terrified pickle [pic.twitter.com/Ffph1wzTyv](https://pic.twitter.com/Ffph1wzTyv)



**Faces in Things** @FacesPics · Feb 14

Deep in thought Deep Fryer [pic.twitter.com/1Qyqjmslka](https://pic.twitter.com/1Qyqjmslka)



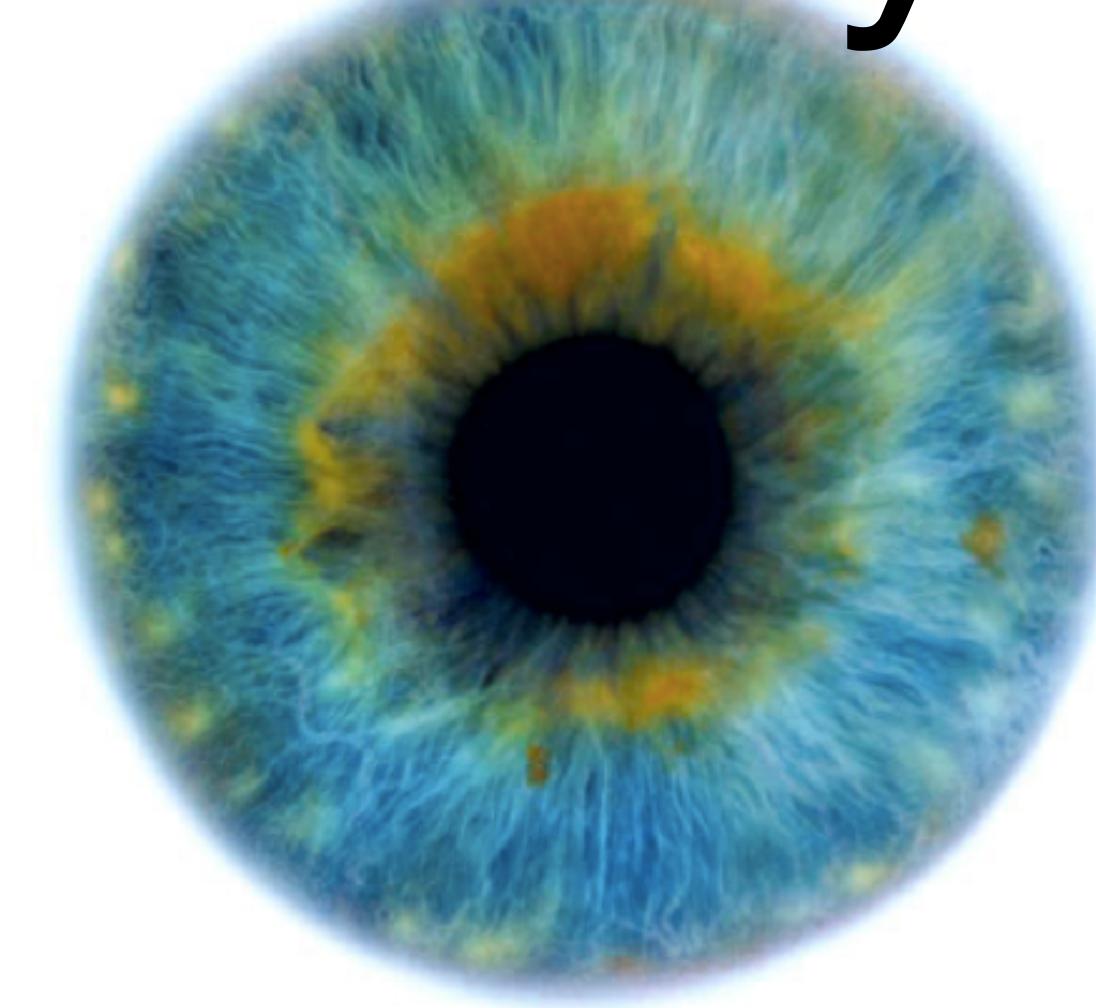
# Take Home Point

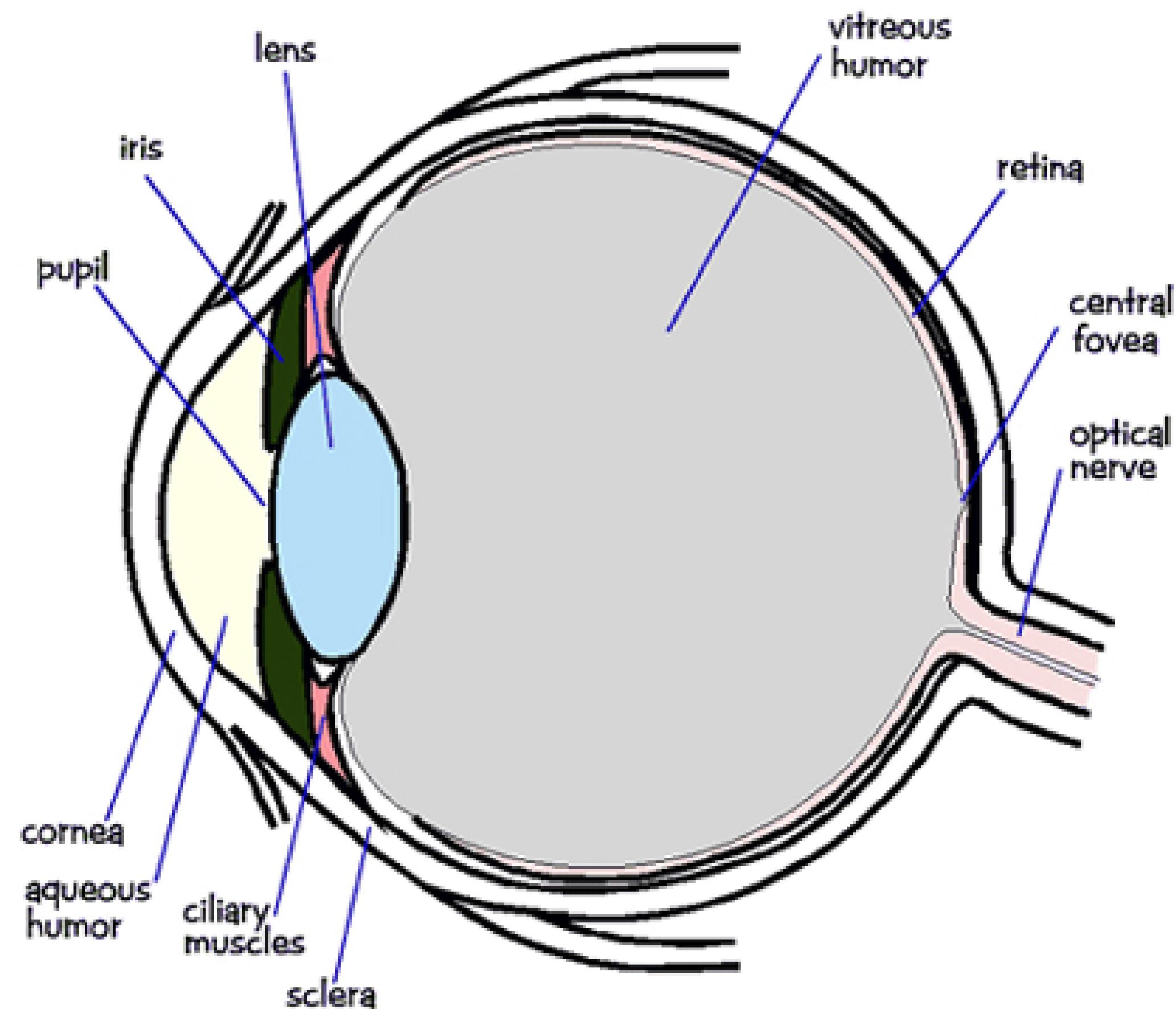
Vision is “constructed” top down from the input

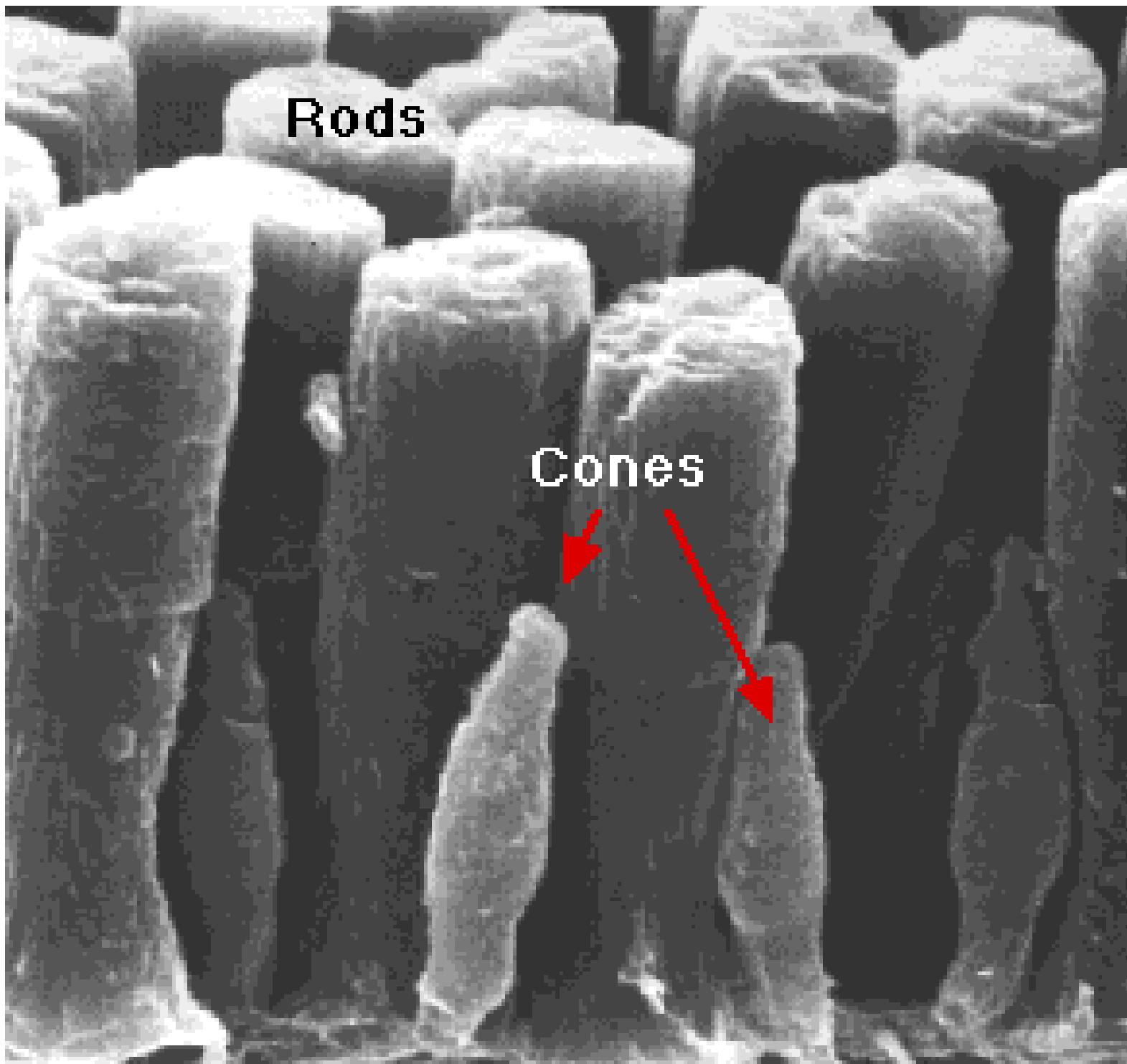
*“What you see when you see a thing depends on what the thing is. What you see the thing as depends on what you know about what you are seeing.”*

Zenon W. Pylyshyn  
Canadian Cognitive Scientist  
and Philosopher

# The Eye







~120 million rods

~5-6 million cones

Category	Count	Percentage	Avg. Value	Total Value
Entertainment	10,000	20.0%	10.00	100,000
Food	8,000	16.0%	8.00	64,000
Healthcare	7,000	14.0%	7.00	49,000
Transportation	6,000	12.0%	6.00	36,000
Utilities	5,000	10.0%	5.00	25,000
Business	4,000	8.0%	4.00	16,000
Residential	3,000	6.0%	3.00	9,000
Commercial	2,000	4.0%	2.00	4,000
Industrial	1,000	2.0%	1.00	1,000
Total	50,000	100.0%	5.00	250,000

# Human Visual System

## VIDEO!

Vision works as sequence of **fixations** and **saccades**

fixations: maintaining gaze on single location (200-600 ms)

saccades: moving between different locations (20-100 ms)

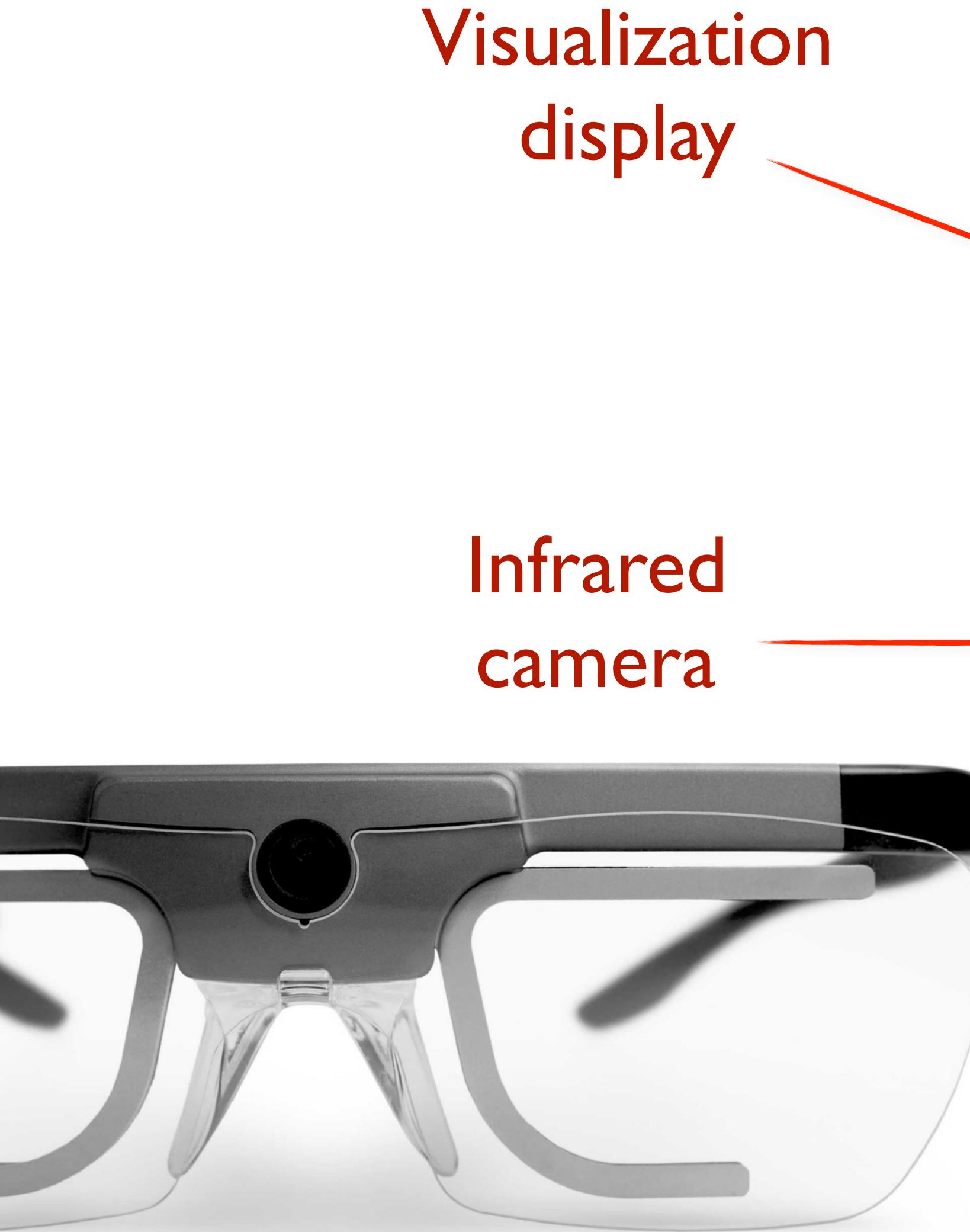
Vision not similar to a camera

More similar to a dynamic and ongoing construction project

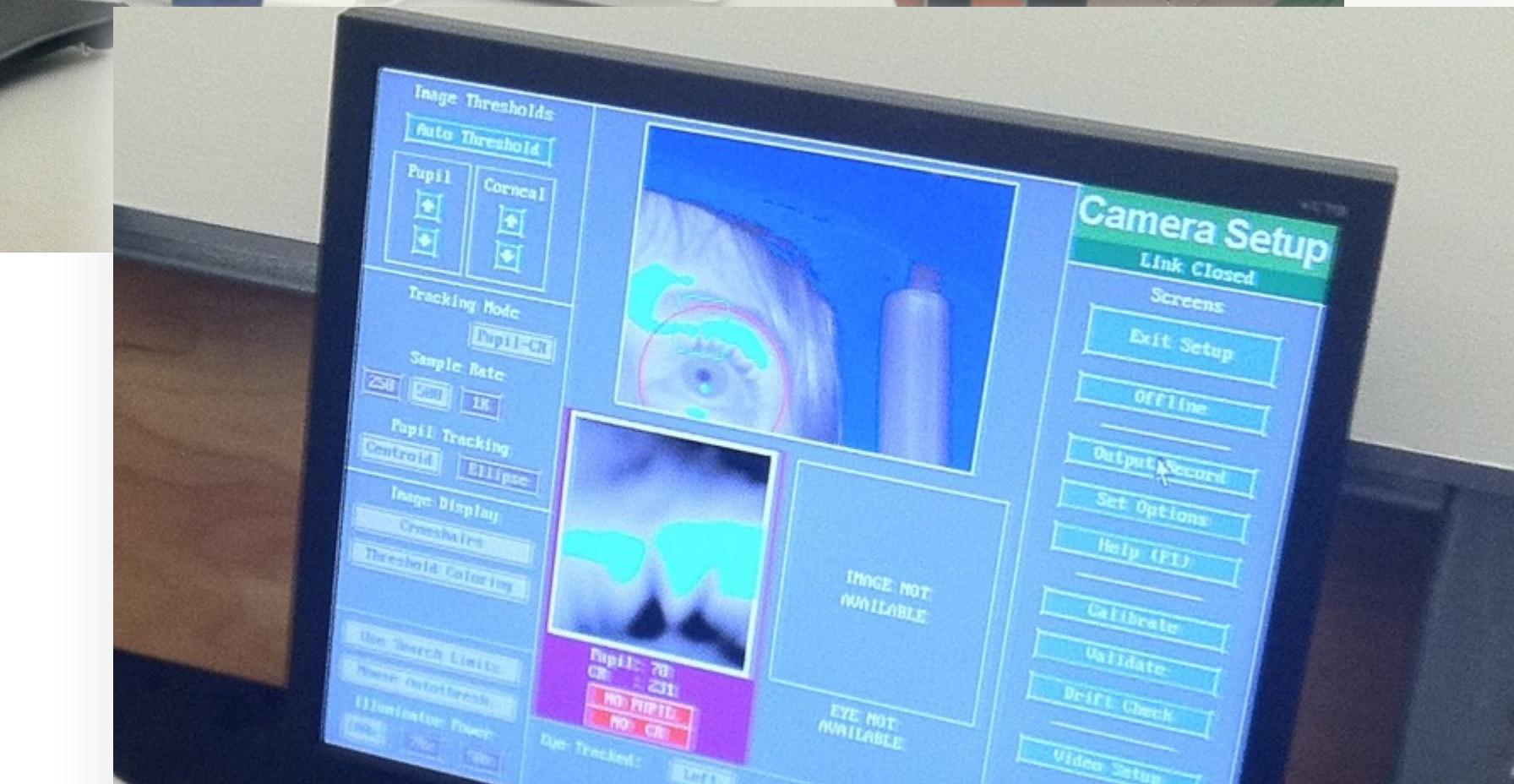




# Eye-Tracking Experiment



Visualization  
display



Video!

**SensoMotoric Instruments presents**

**Karaoke**

**Gaze Tracking and User Observation**

# Human Visual System

## VIDEO!

No general purpose vision

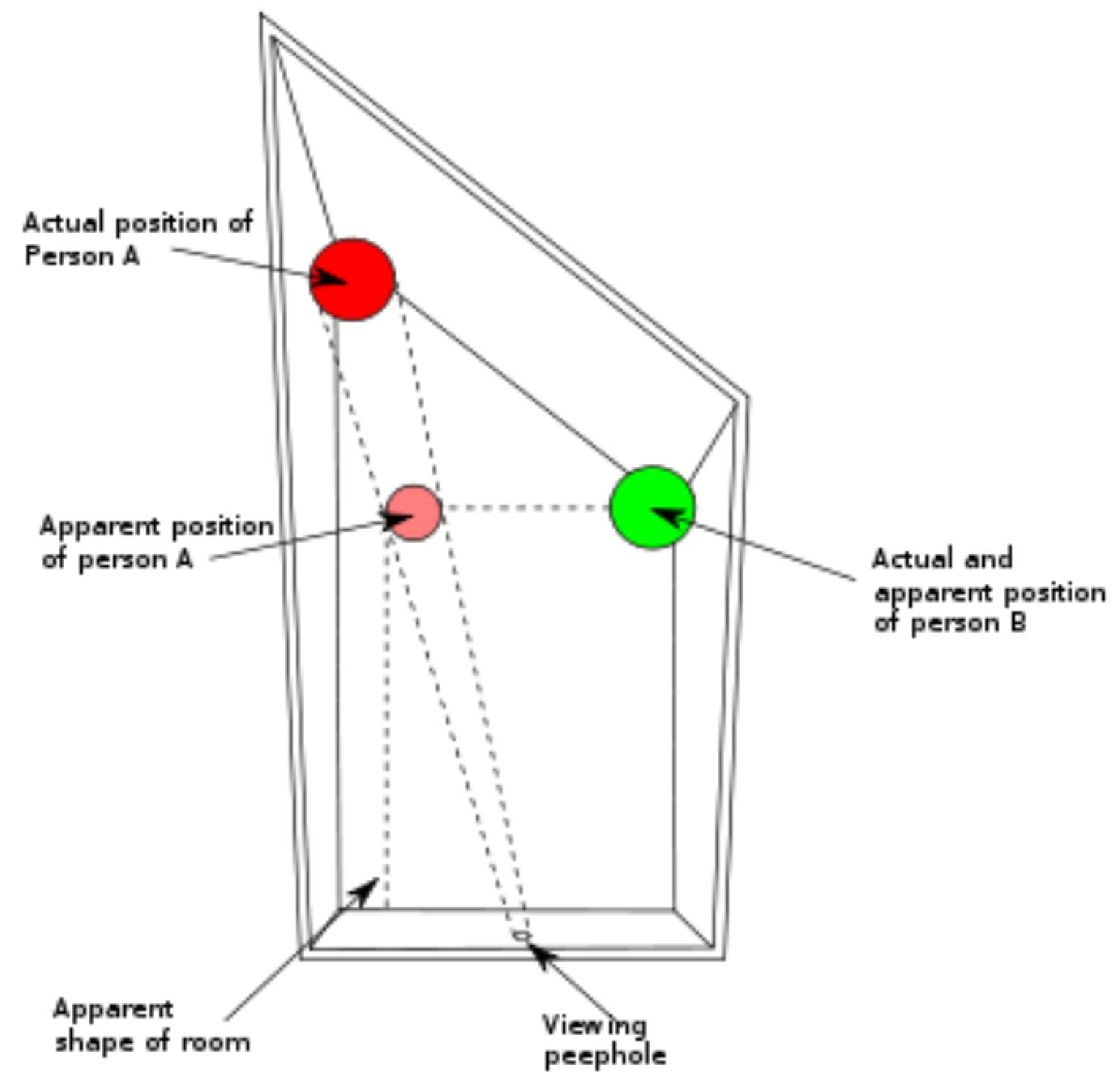
What we see depends on our goals and expectations

Relative judgments: strong

Absolute judgments: weak



Ames Room

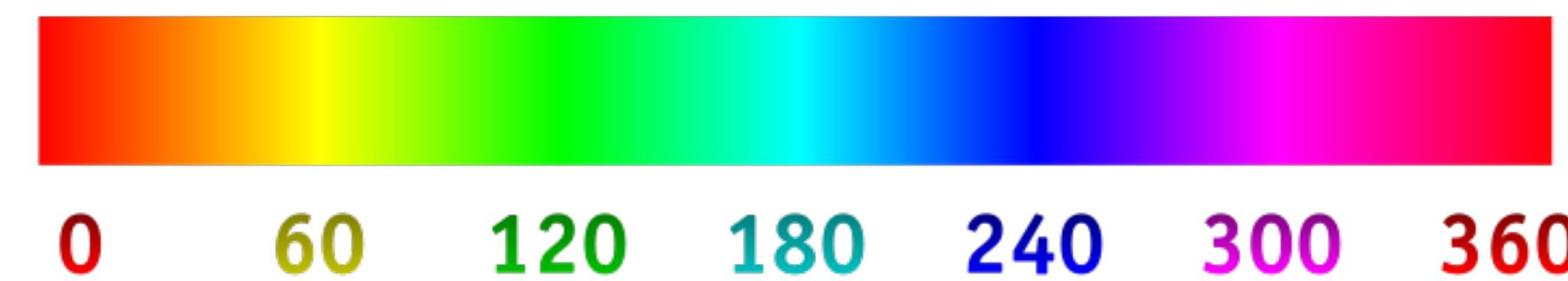




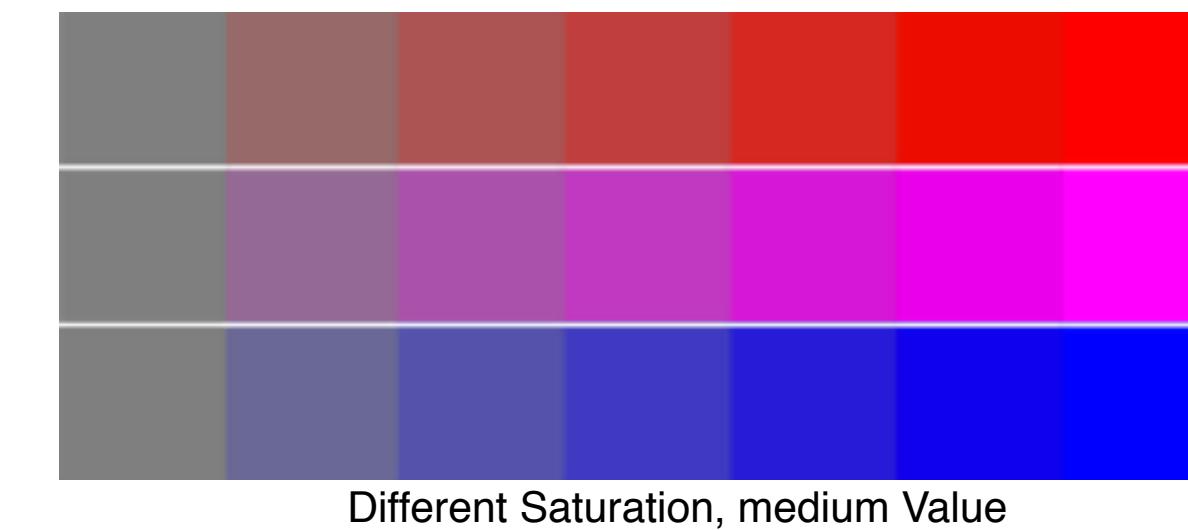
# Color

# Dimensions of Color

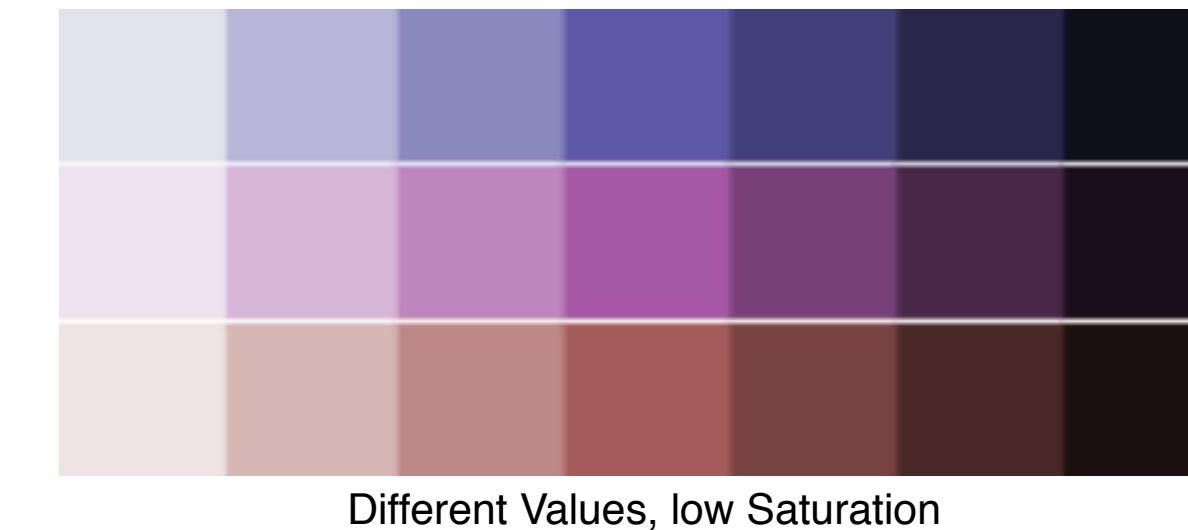
Hue



Saturation



Luminance

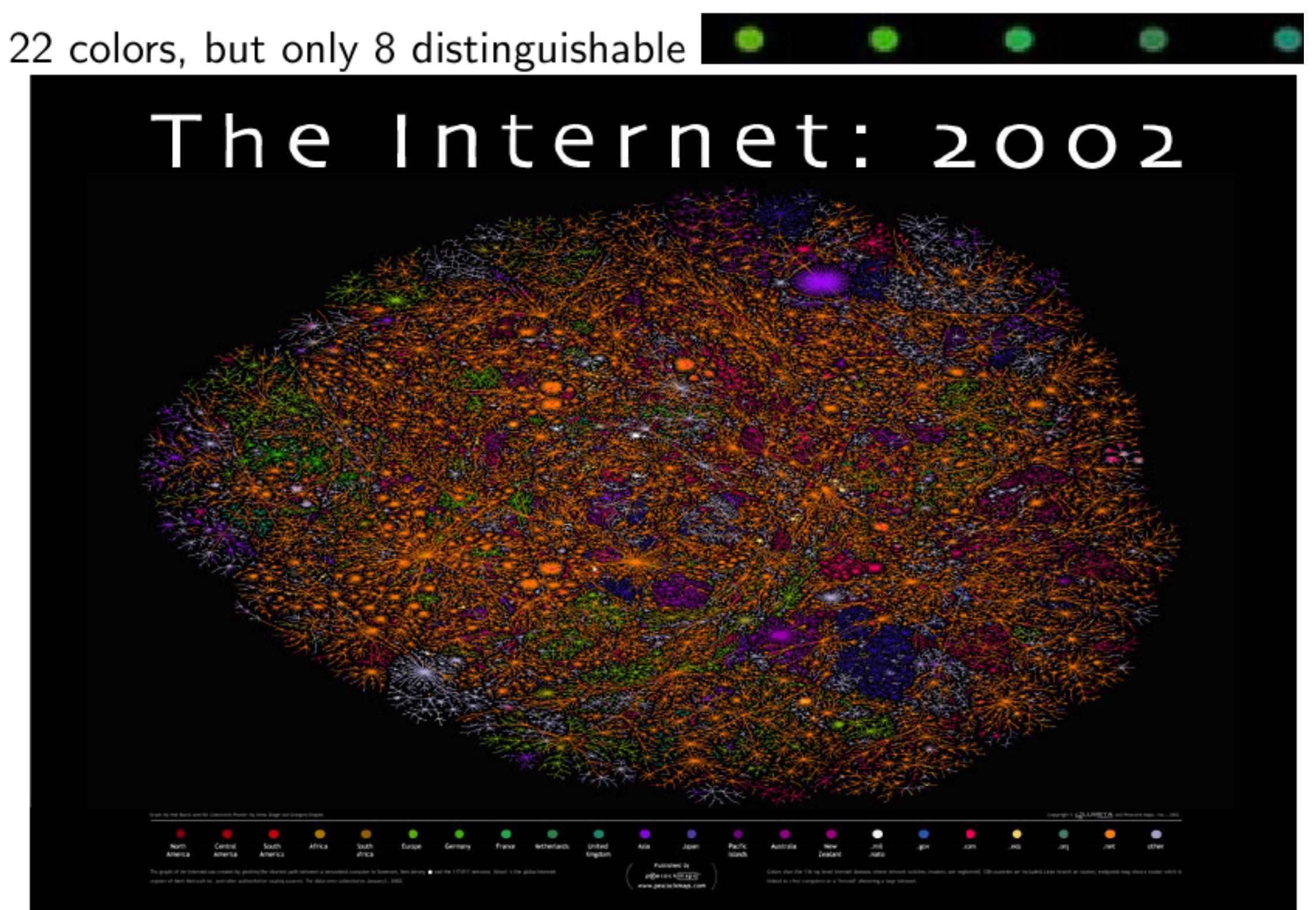


# Qualitative Data Vis

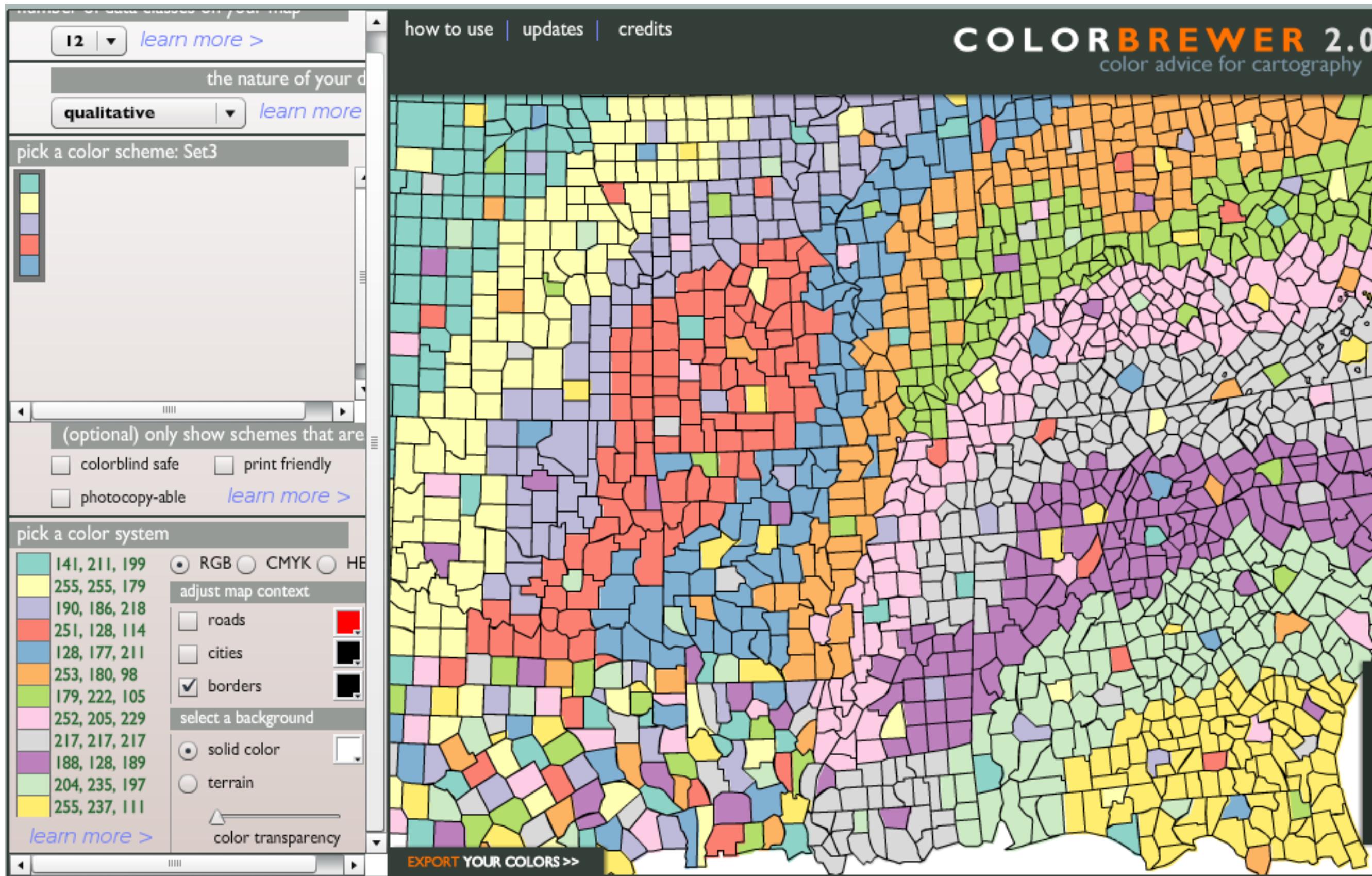
# Color labeling (nominal information coding)

recommended: about 6, no more than 10

22 colors, but only 8 distinguishable



# Application: Labeling



Carefully designed color scheme for 12 colors [colorbrewer]

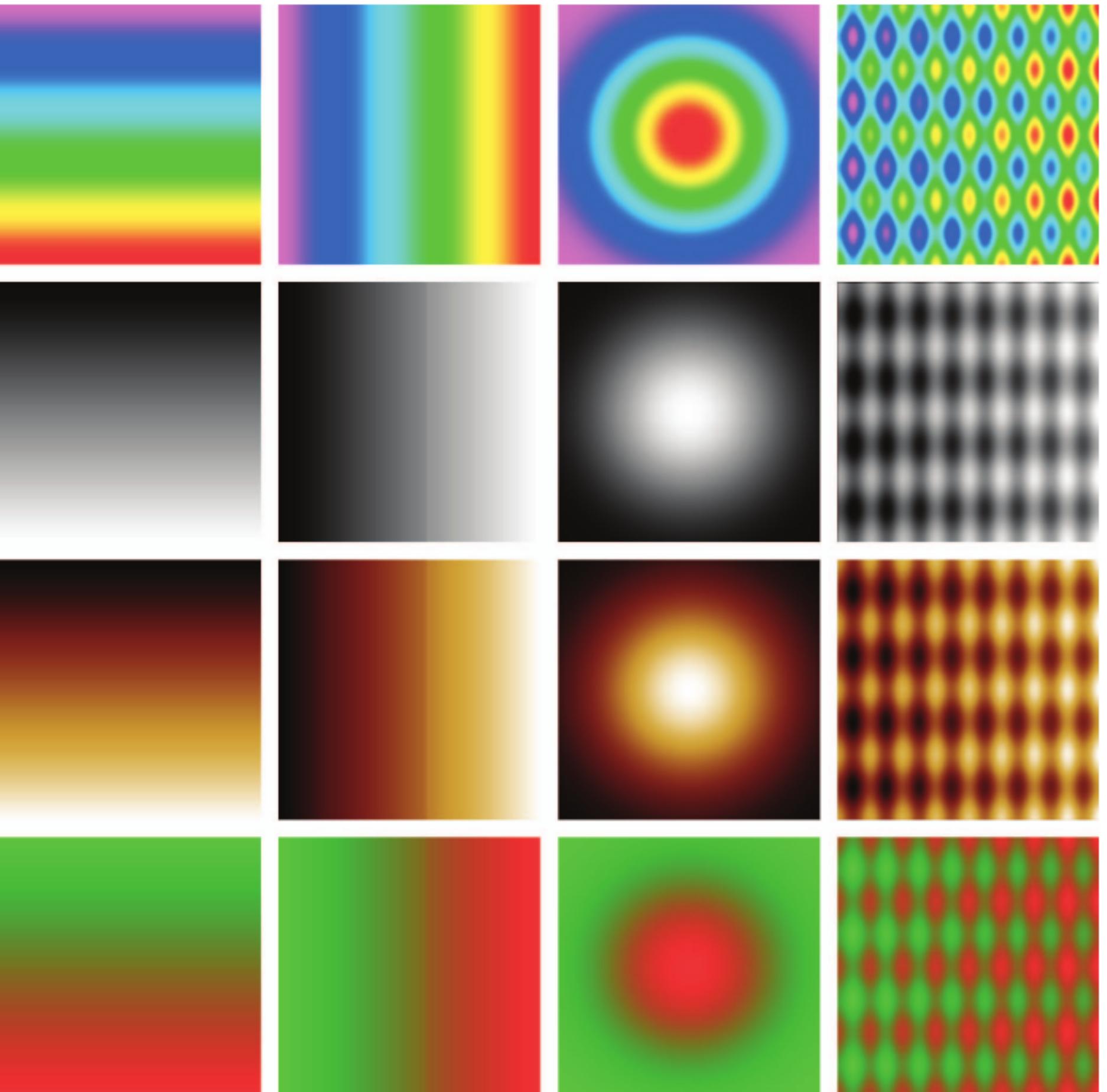
# Quantitative Data Vis

use value

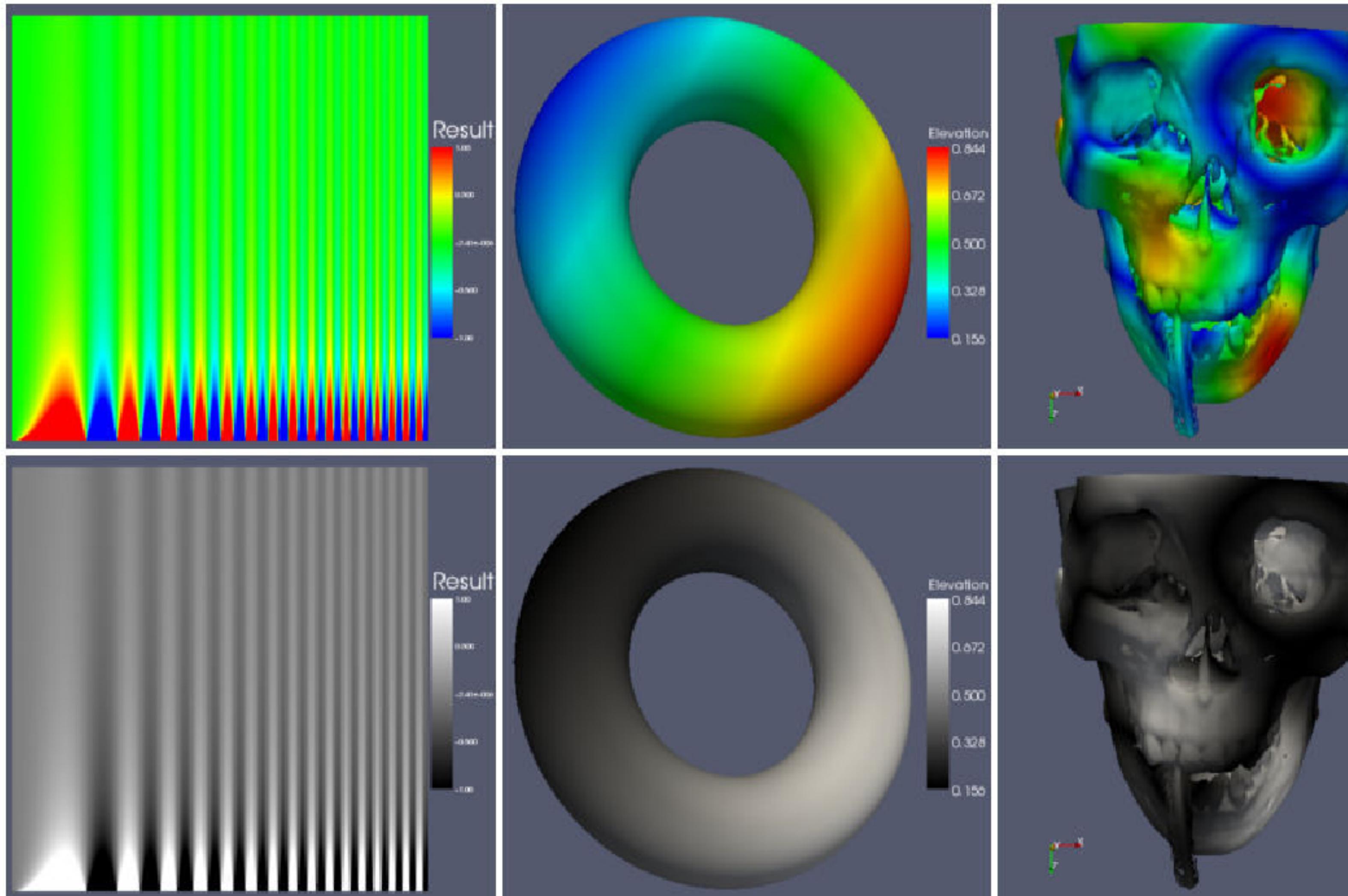
saturation works but not as good

don't use hue!

Danger: rainbow color map



# Rainbow vs. Value Color map



# Design Critique

# Four Ways to Slice Obama's 2013 Budget Proposal

Explore every nook and cranny of President Obama's federal budget proposal.

All Spending    Types of Spending    Changes    Department Totals

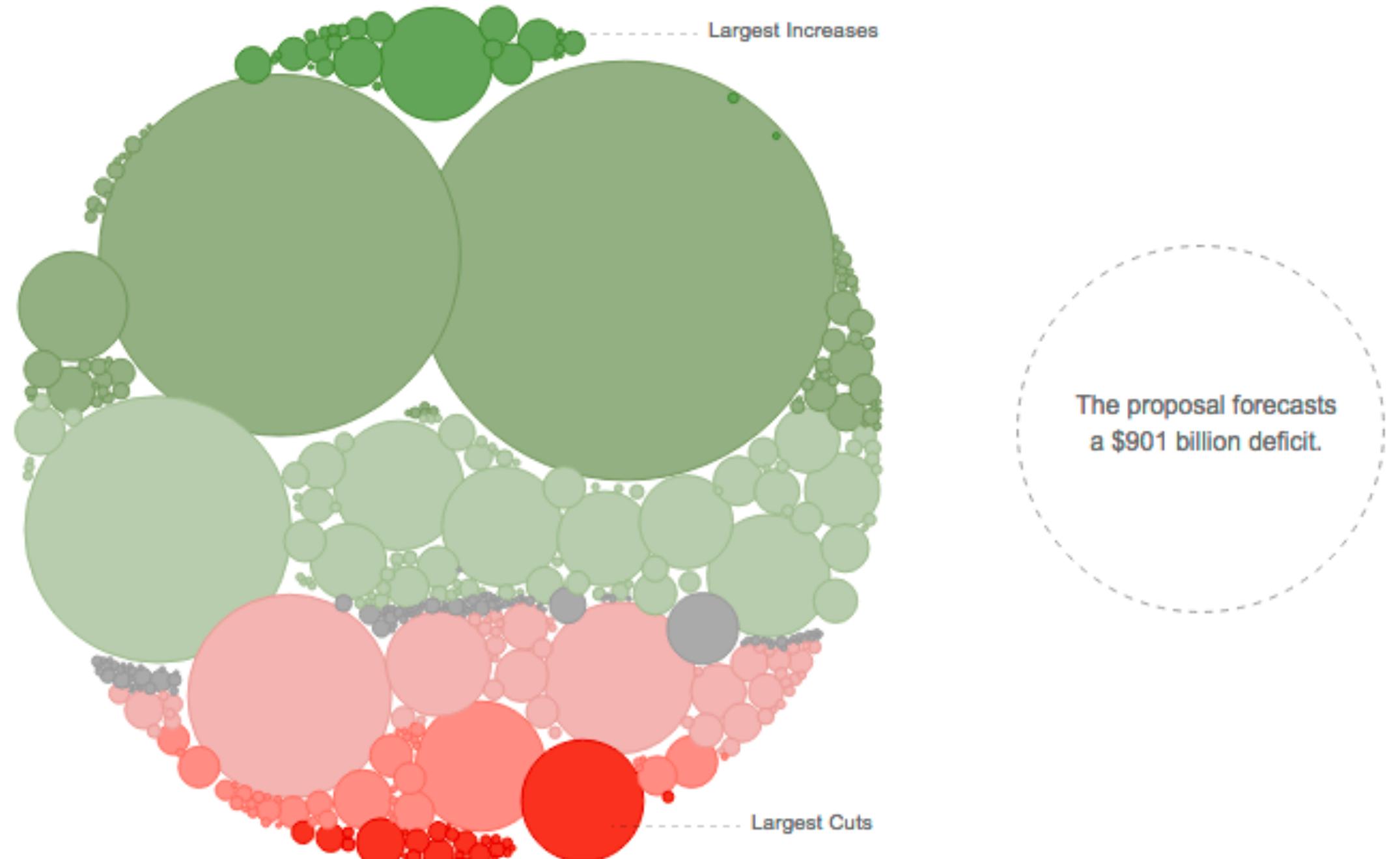
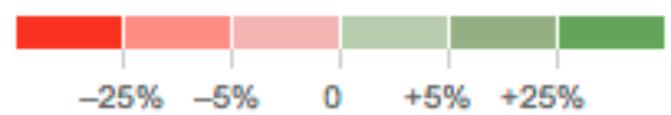
## How \$3.7 Trillion Is Spent

Mr. Obama's budget proposal includes \$3.7 trillion in spending in 2013, and forecasts a \$901 billion deficit.

Circles are sized according to the proposed spending.



Color shows amount of cut or increase from 2012.

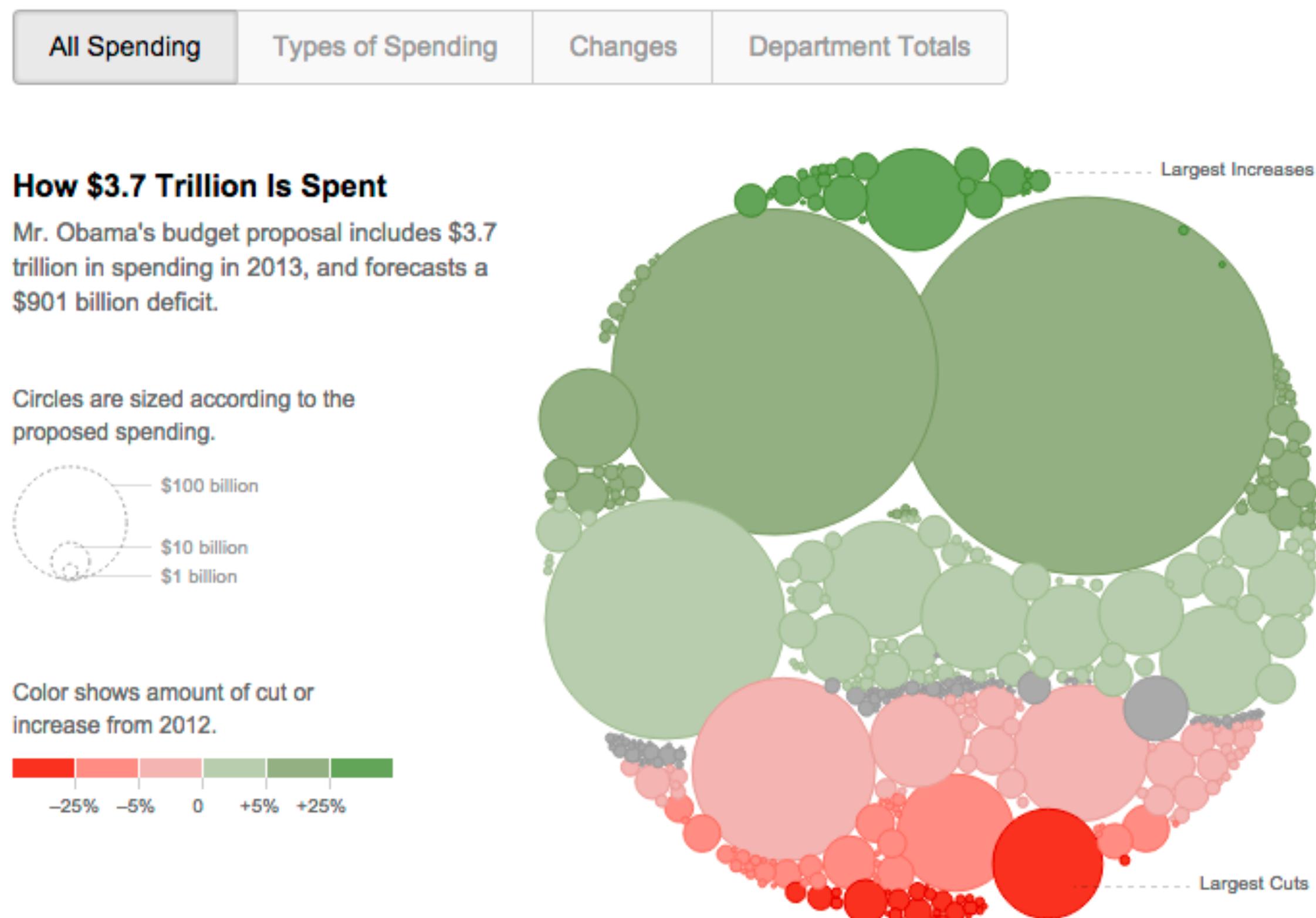


Source: <http://bit.ly/feb13-source>

In your discussion group please answer the following questions:

## Four Ways to Slice Obama's 2013 Budget Proposal

Explore every nook and cranny of President Obama's federal budget proposal.



- What is the primary visual encoding in panel 1? Is there a redundant encoding? Are these good choices?
- What tasks do you think the creators had in mind?
- How is position used in panel 1? How is position used (both in x and y) in panel 3 (changes)?
- What do you think about the use of animation?
- What do you think about the vis in panel 4 (Departmental Totals)?
- Is the visualization easy to understand?
- Can you read the data from the visualization?
- Why do you like / dislike this visualization?
- Can you suggest any improvements? How would you redesign it?

**Source:** <http://bit.ly/feb13-source>

# Color Blindness

10% of males, 1% of females (probably due to X-chromosomal recessive inheritance)

Most common: red-green weakness / blindness

Reason: lack of medium or long wavelength receptors, or altered spectral sensitivity (most common: green shift)

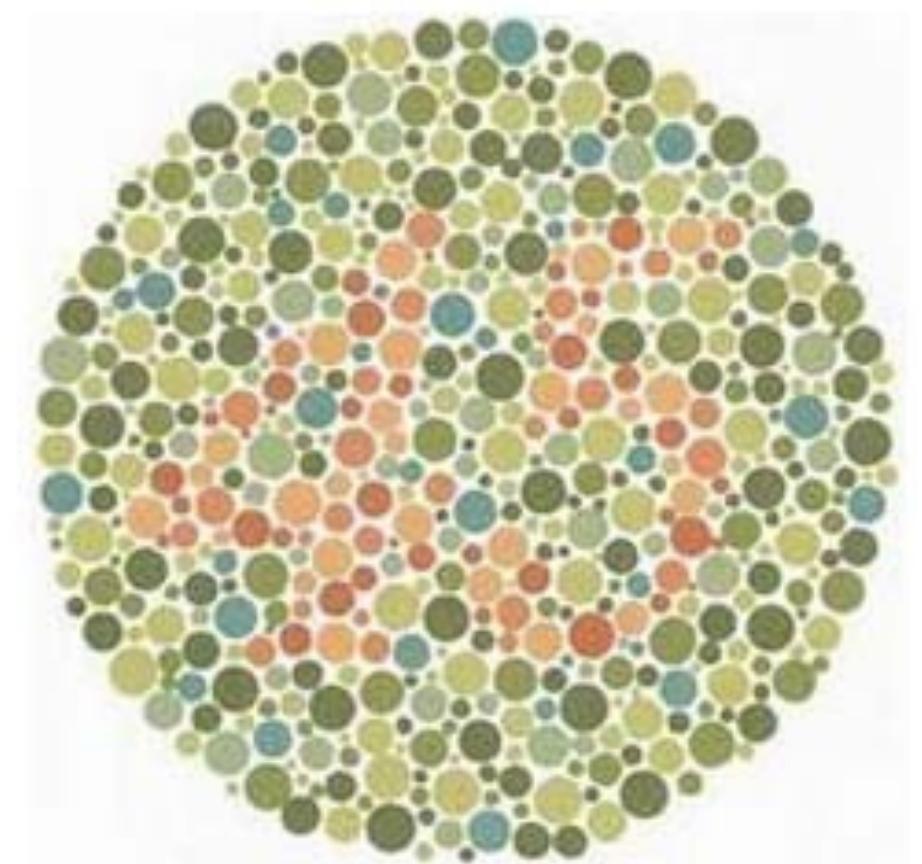
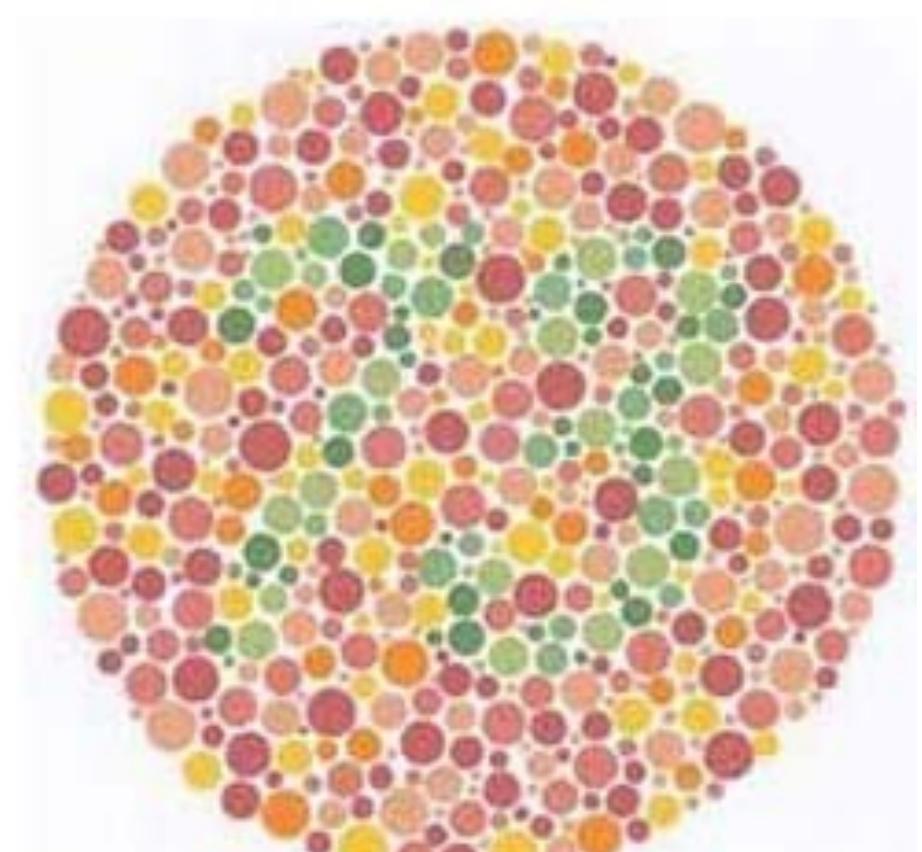
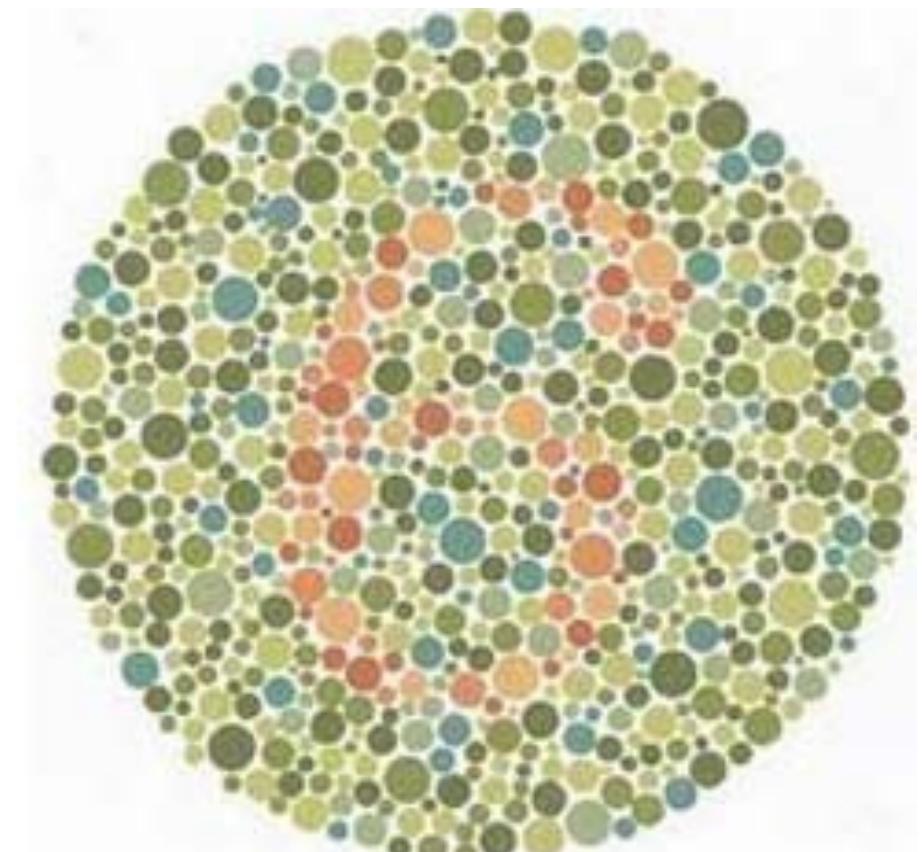
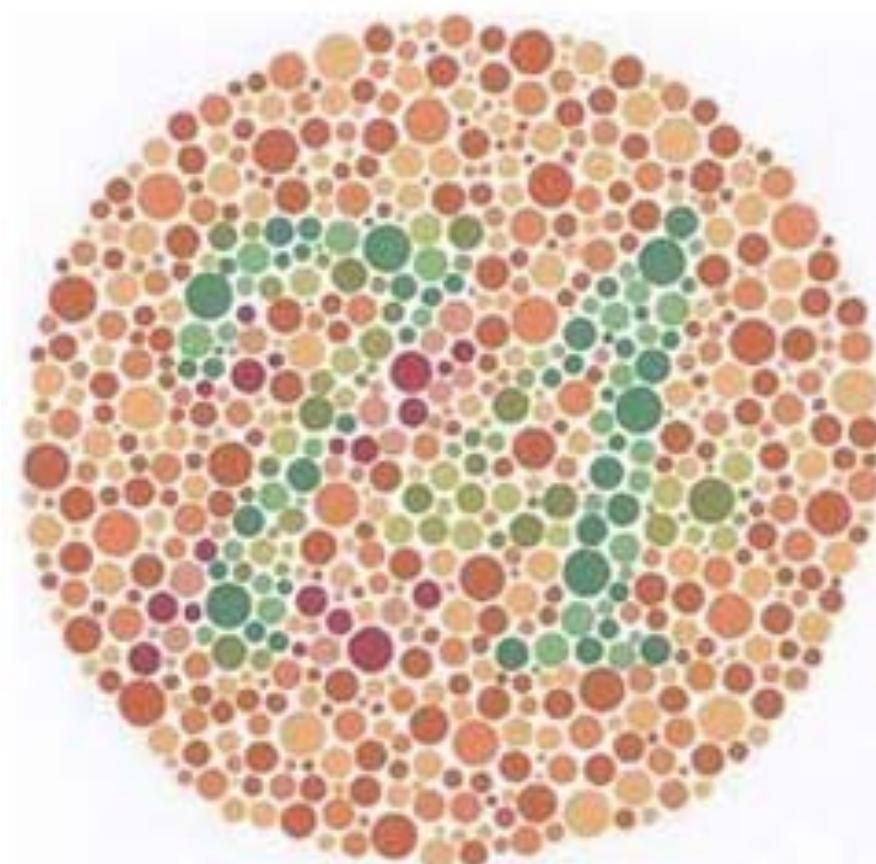
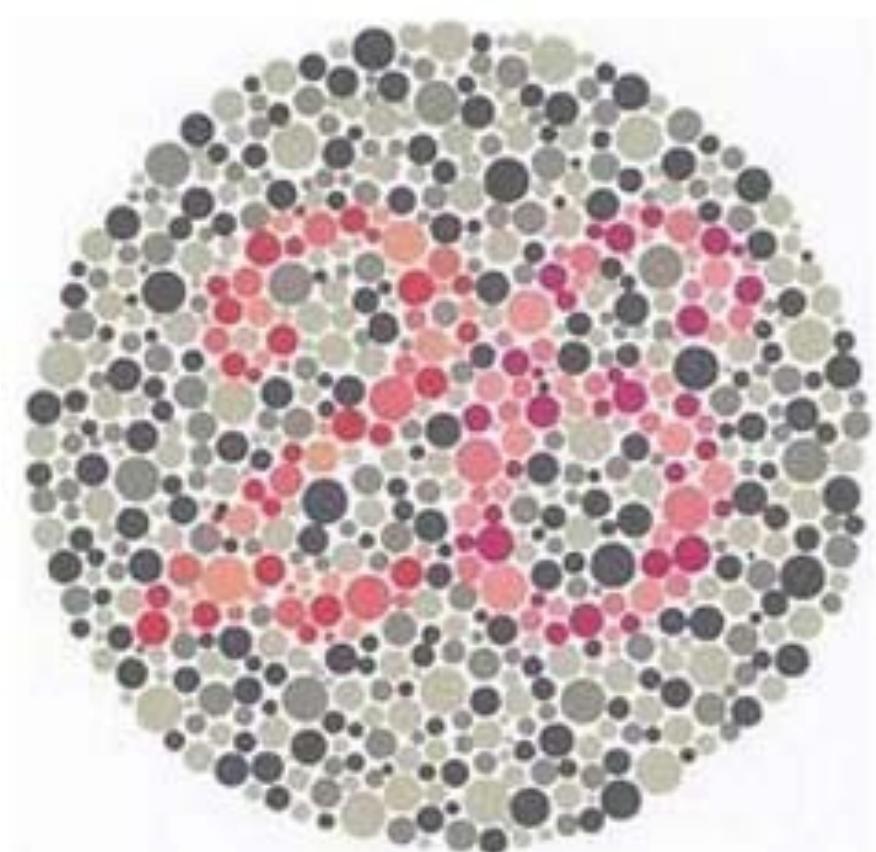
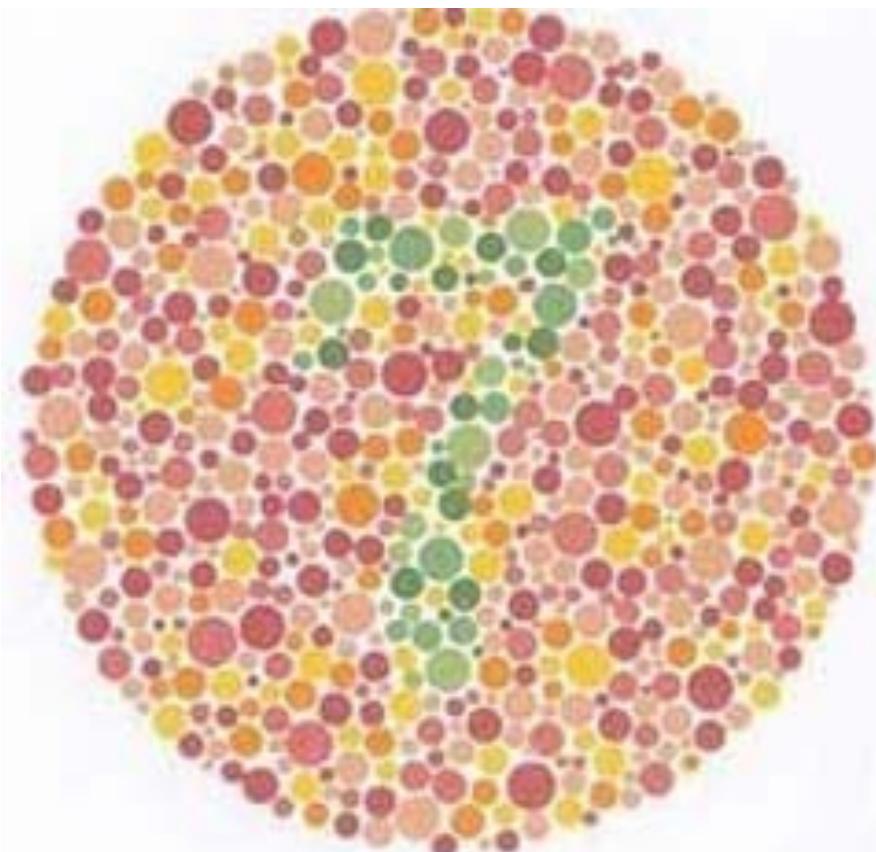
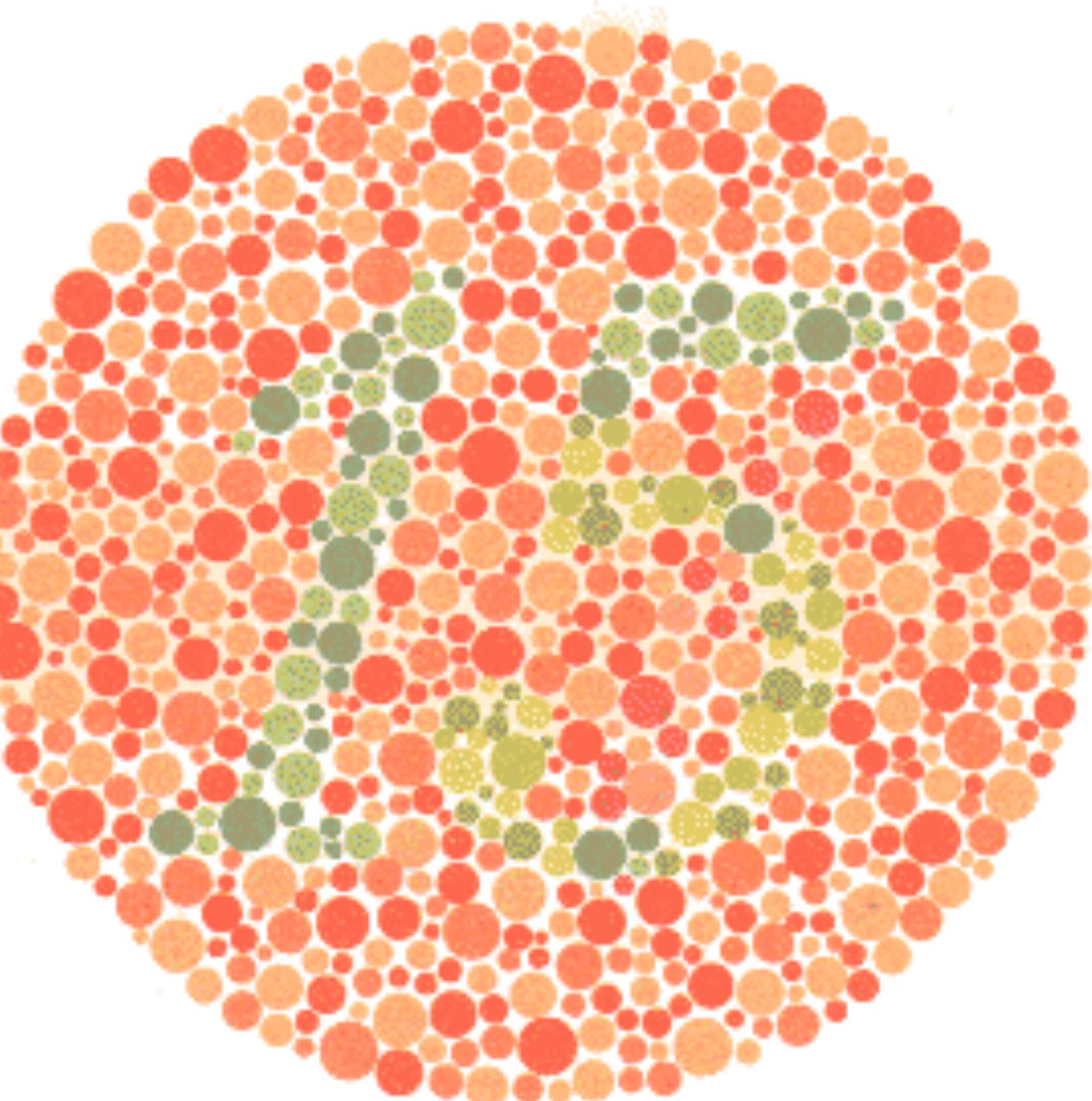
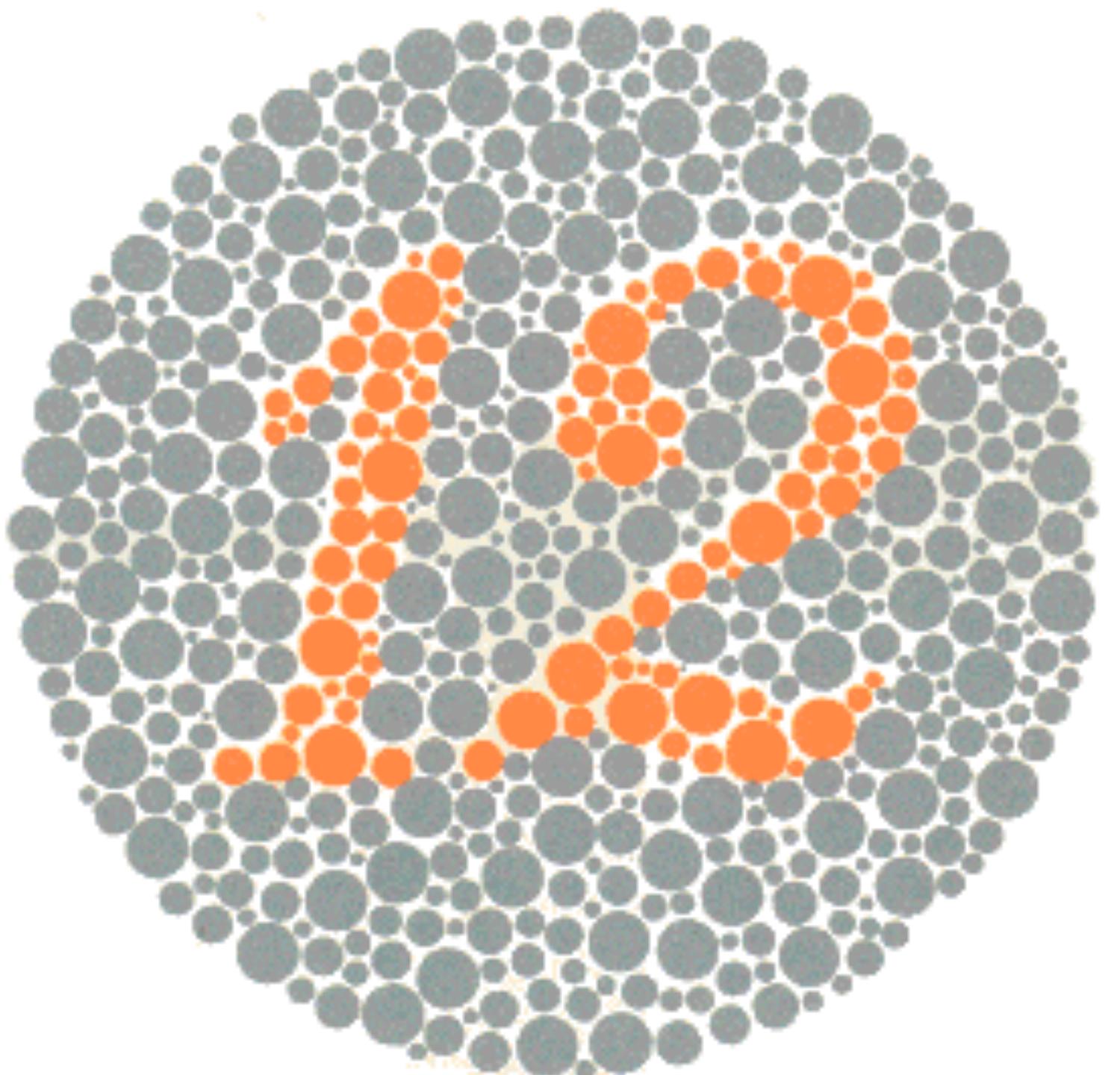


Normal Color Perception

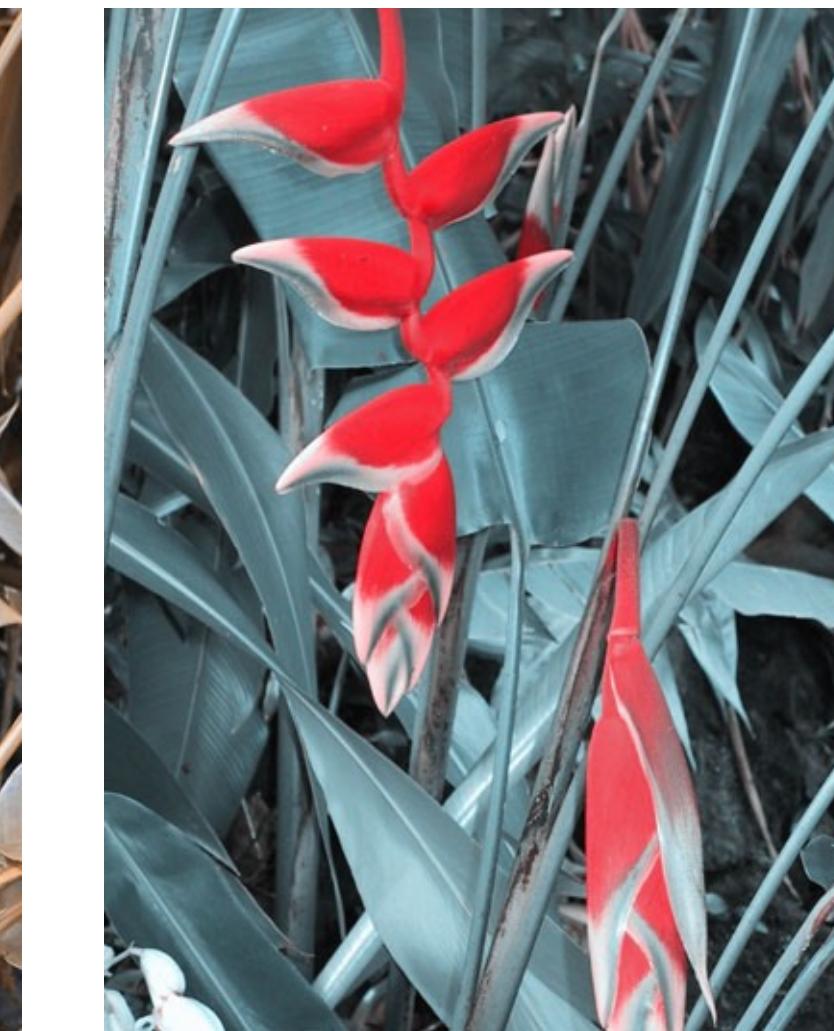
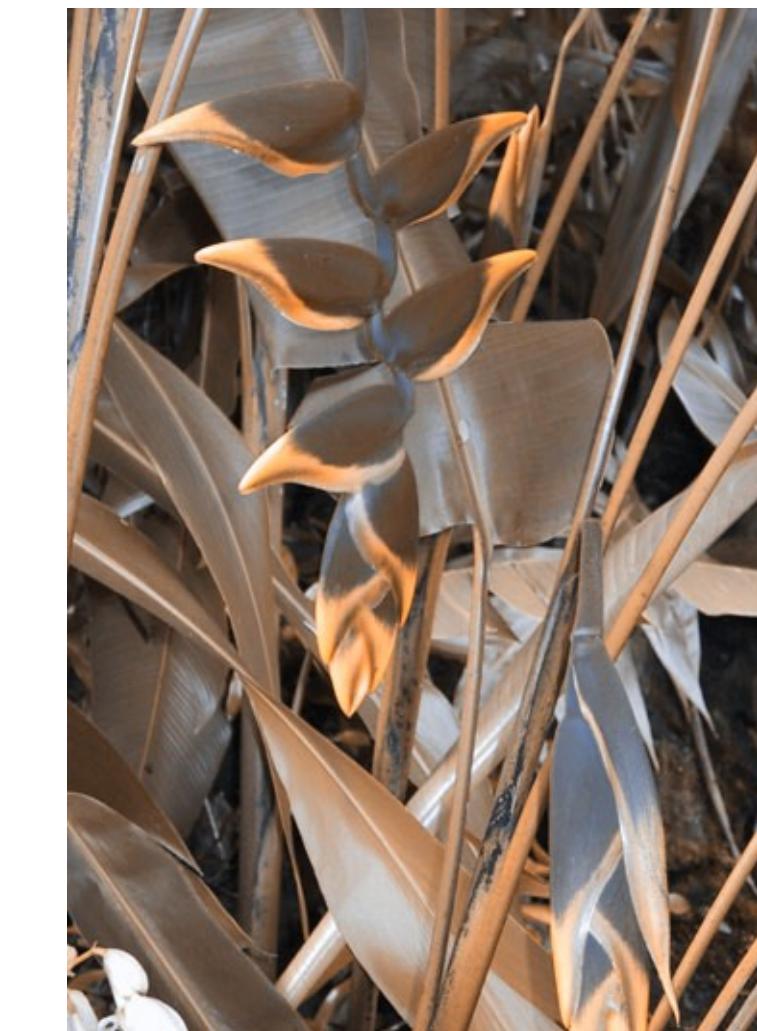
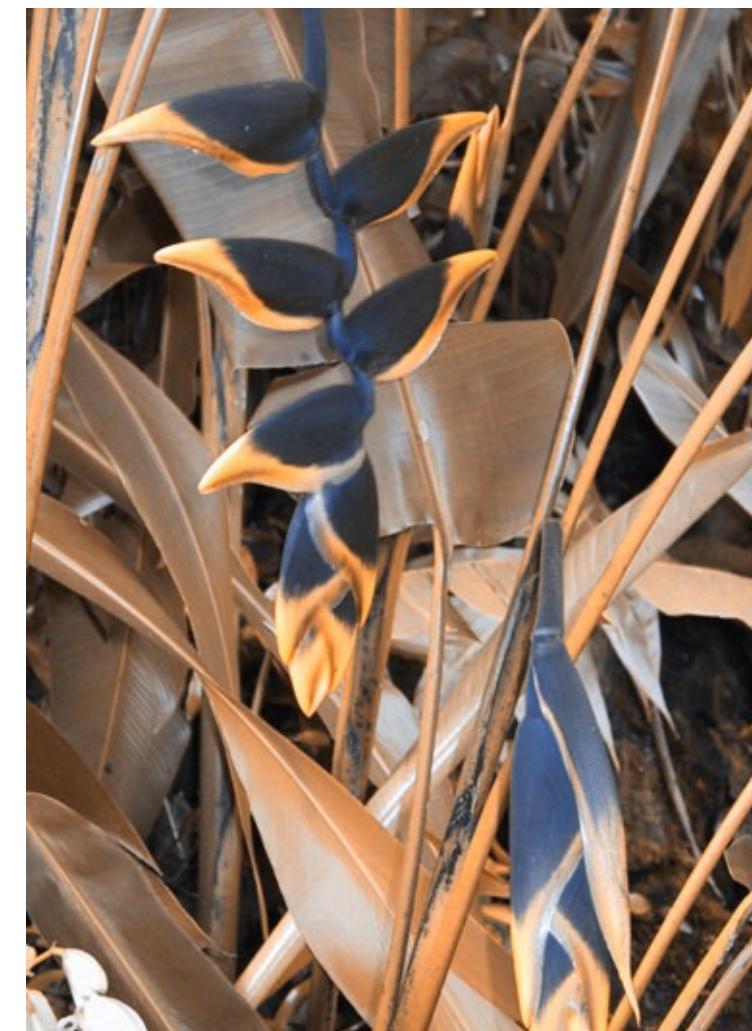
Deuteranopia (no green receptors)

Protanopia (no red receptors)

# Color Blindness Tes



# Color Blindness



Protanope

No L cones

Red / green  
deficiencies

Deuteranope

No M cones

Tritanope

No S cones

Blue / Yellow  
deficiency

All Spending Types of Spending Changes Department Totals

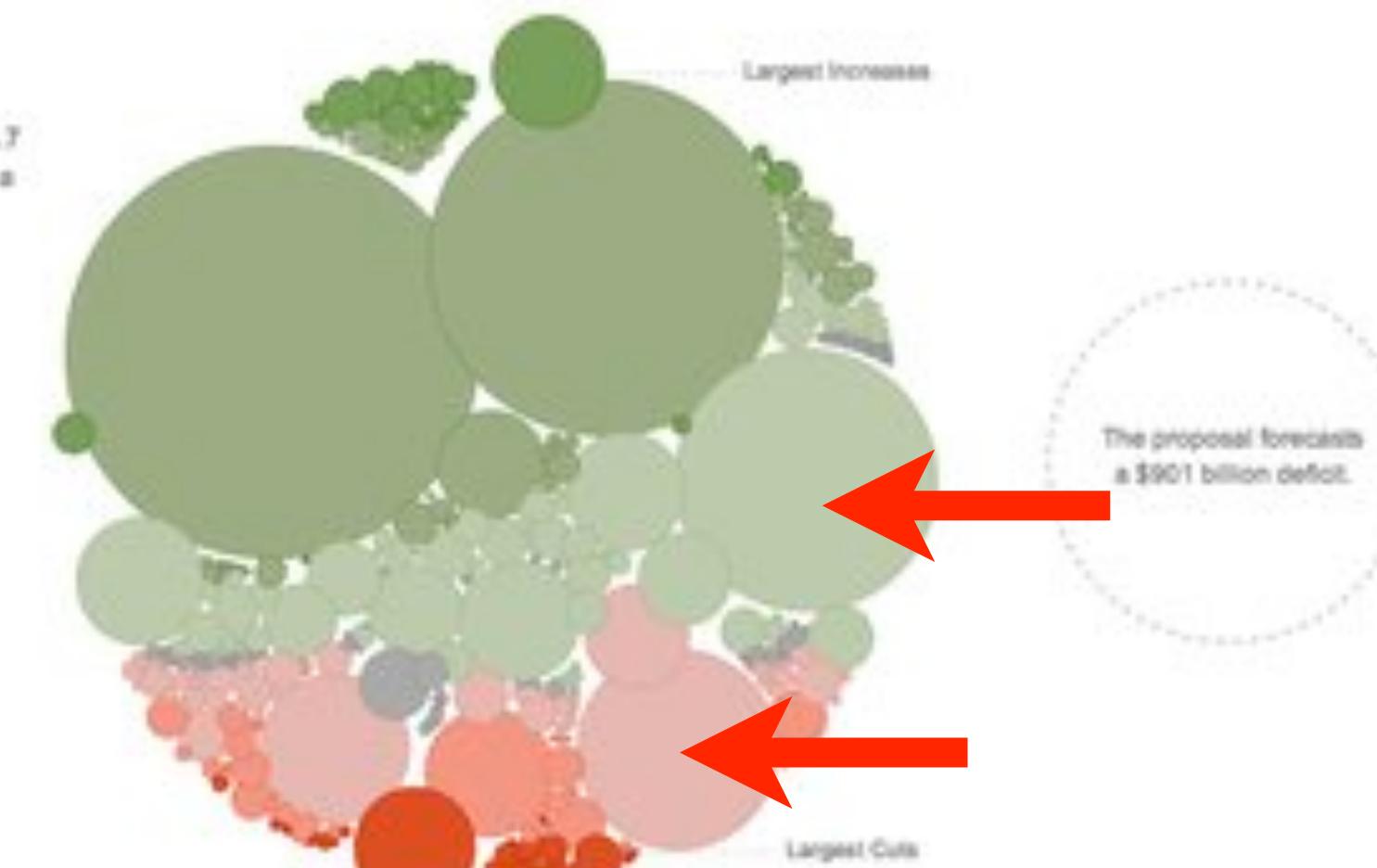
### How \$3.7 Trillion Is Spent

Mr. Obama's budget proposal includes \$3.7 trillion in spending in 2013, and forecasts a \$901 billion deficit.

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All Spending Types of Spending Changes Department Totals

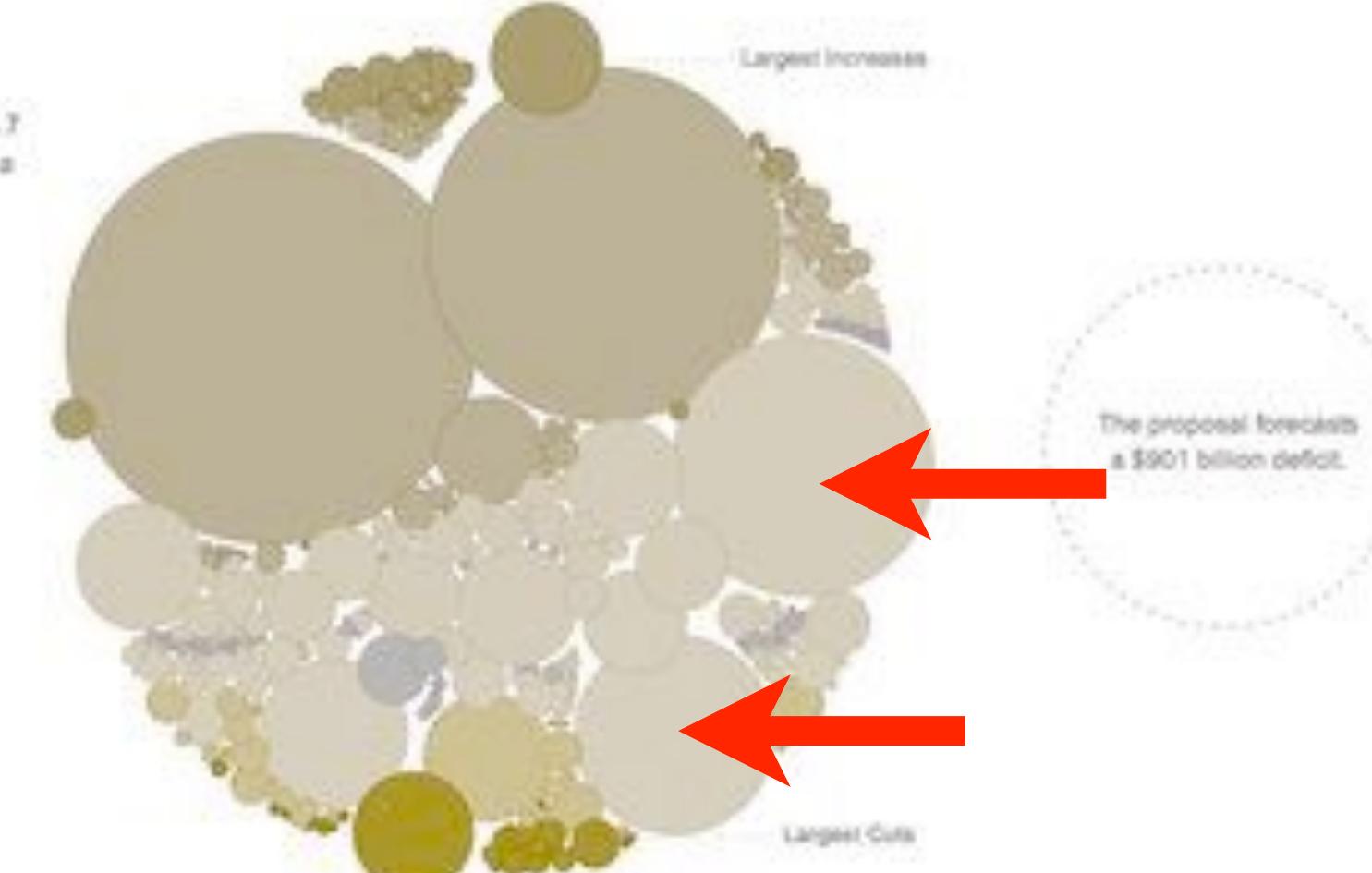
### How \$3.7 Trillion Is Spent

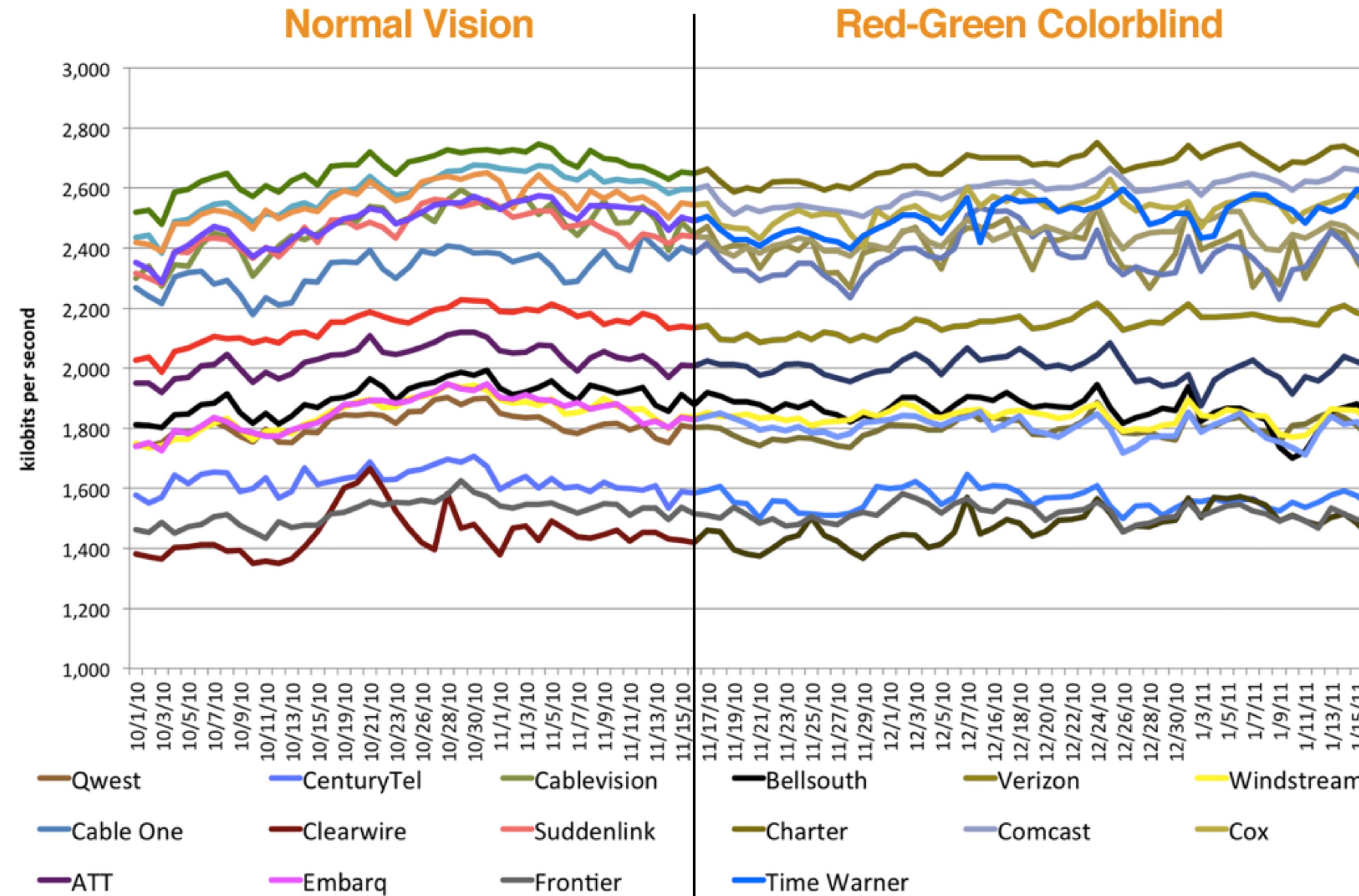
Mr. Obama's budget proposal includes \$3.7 trillion in spending in 2013, and forecasts a \$901 billion deficit.

Circles are sized according to the proposed spending.



Color shows amount of cut or increase from 2012.





Andy Baio

# Simulate Color Vision Deficiencies

<http://www.color-blindness.com/coblis-color-blindness-simulator/>  
<http://www.vischeck.com/>

 Colblindor

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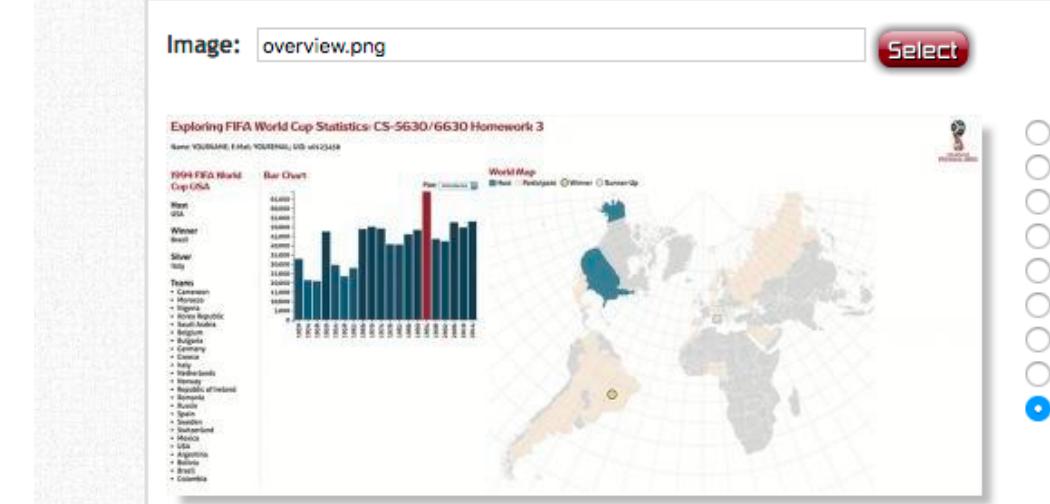


**Coblis — Color Blindness Simulator**

If you are not suffering from a color vision deficiency it is very hard to imagine how it looks like to be colorblind. The Color BLIndness Simulator can close this gap for you. Just play around with the sample picture or upload your own images. Please make sure that you just use JPG, GIF or PNG images with a size below 600kB.

**CVD Simulator**

Image:



Normal Color Vision  
 Red-Blind/Protanopia  
 Green-Blind/Deutanopia  
 Blue-Blind/Tritanopia  
 Red-Weak/Protanomaly  
 Green-Weak/Deutanomaly  
 Blue-Weak/Tritanomaly  
 Monochromacy/Achromatopsia  
 Blue Cone Monochromacy

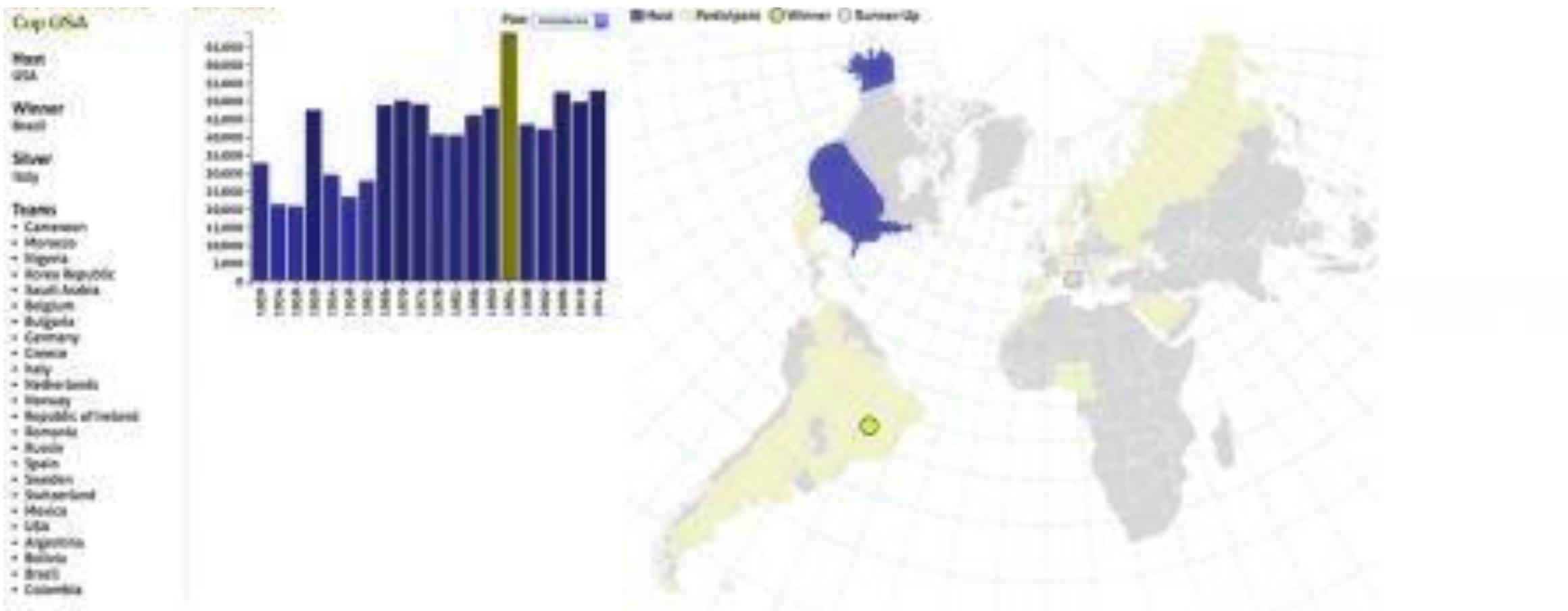
**FREE Color Blind Check**

New kind of color blindness test! Try [Color Blind Check](#) and test type and severity of your color vision deficiency. Easy and fun! Info at [www.colorblindcheck.com](http://www.colorblindcheck.com)



ANDROID APP ON Google play

**CVD Cateories**



# Red-Blind



# Blue Blind



# Monochromacy

# Luminance, Brightness, Lightness

## Luminance

measured amount of light (luminous intensity per area)

## Brightness

perceived amount of light

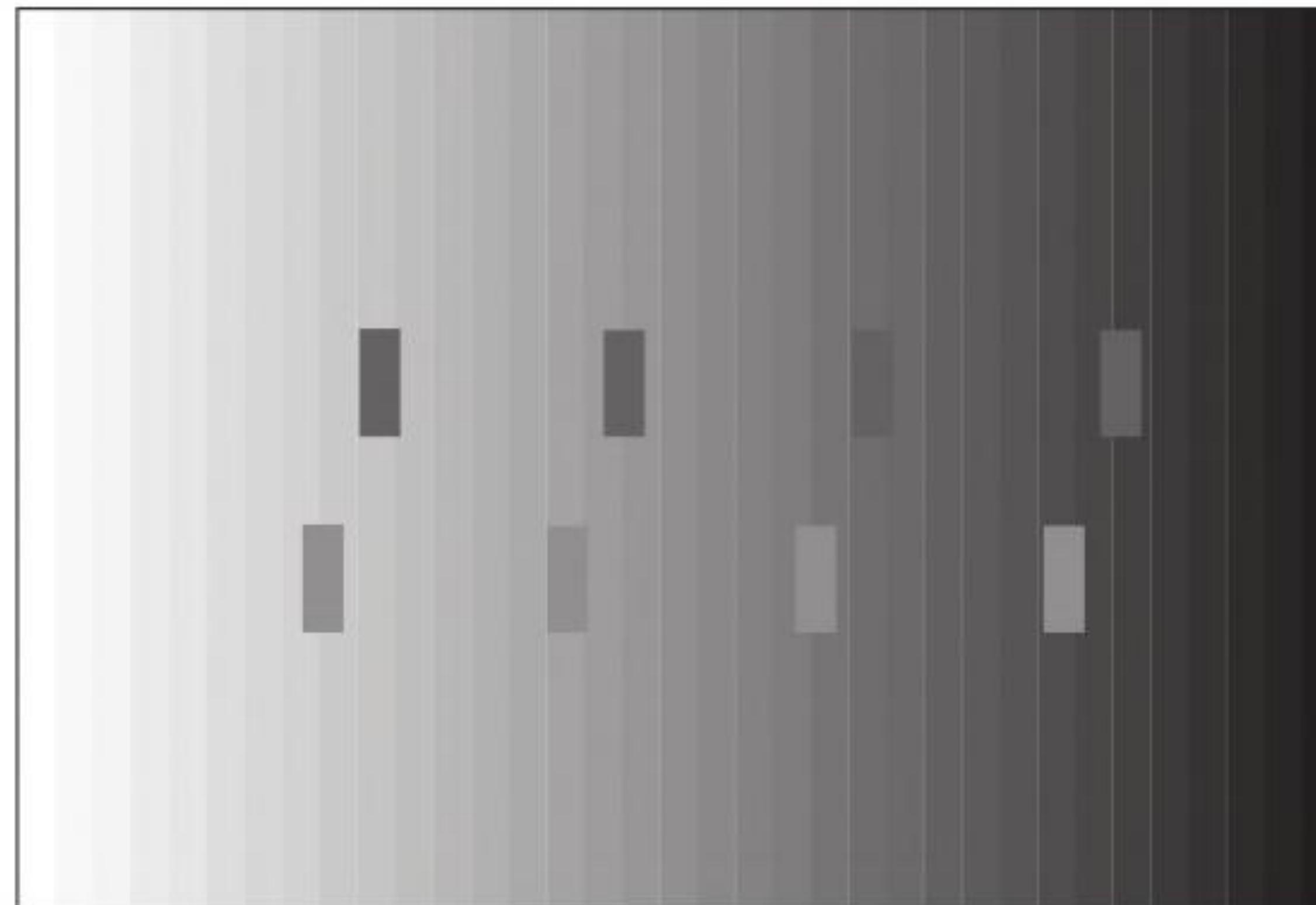
## Lightness

perceived reflectance of a surface

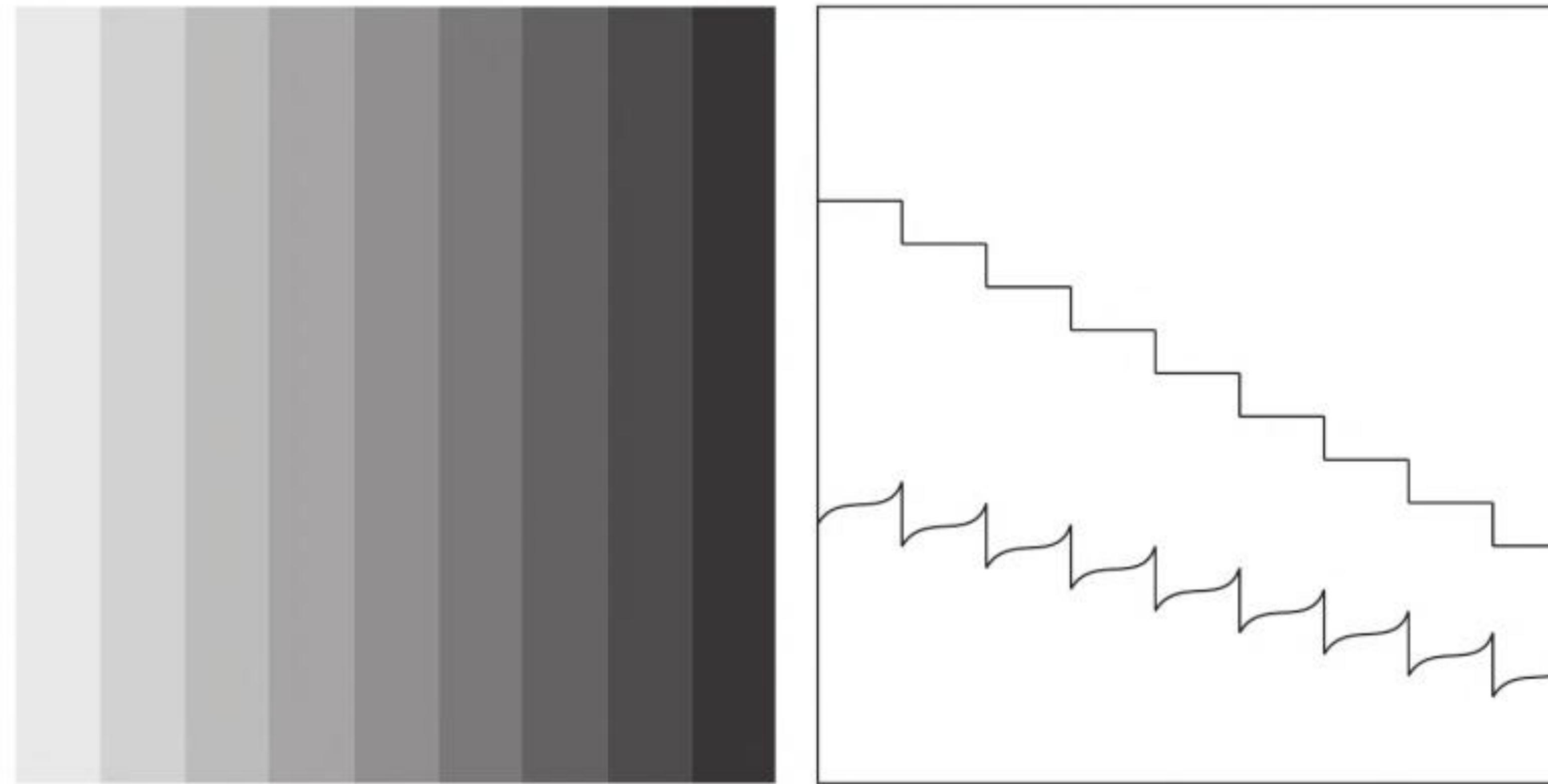
lightness of a color

# Simultaneous Brightness Contrast

The perceived brightness of an object is relative to its background



# Chevreul Illusion



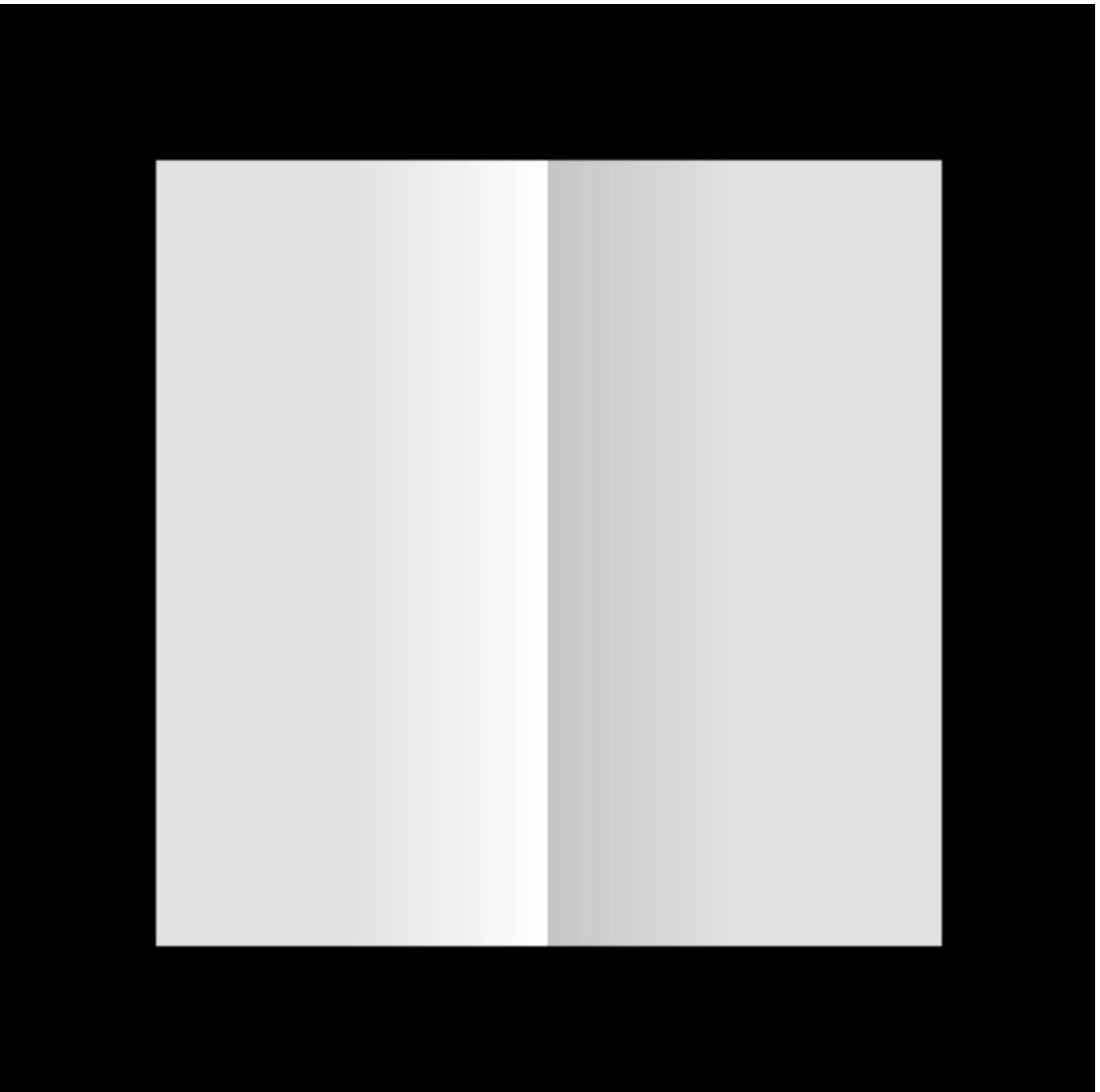
# Edge Enhancement

Cornsweet effect

Make objects more distinct



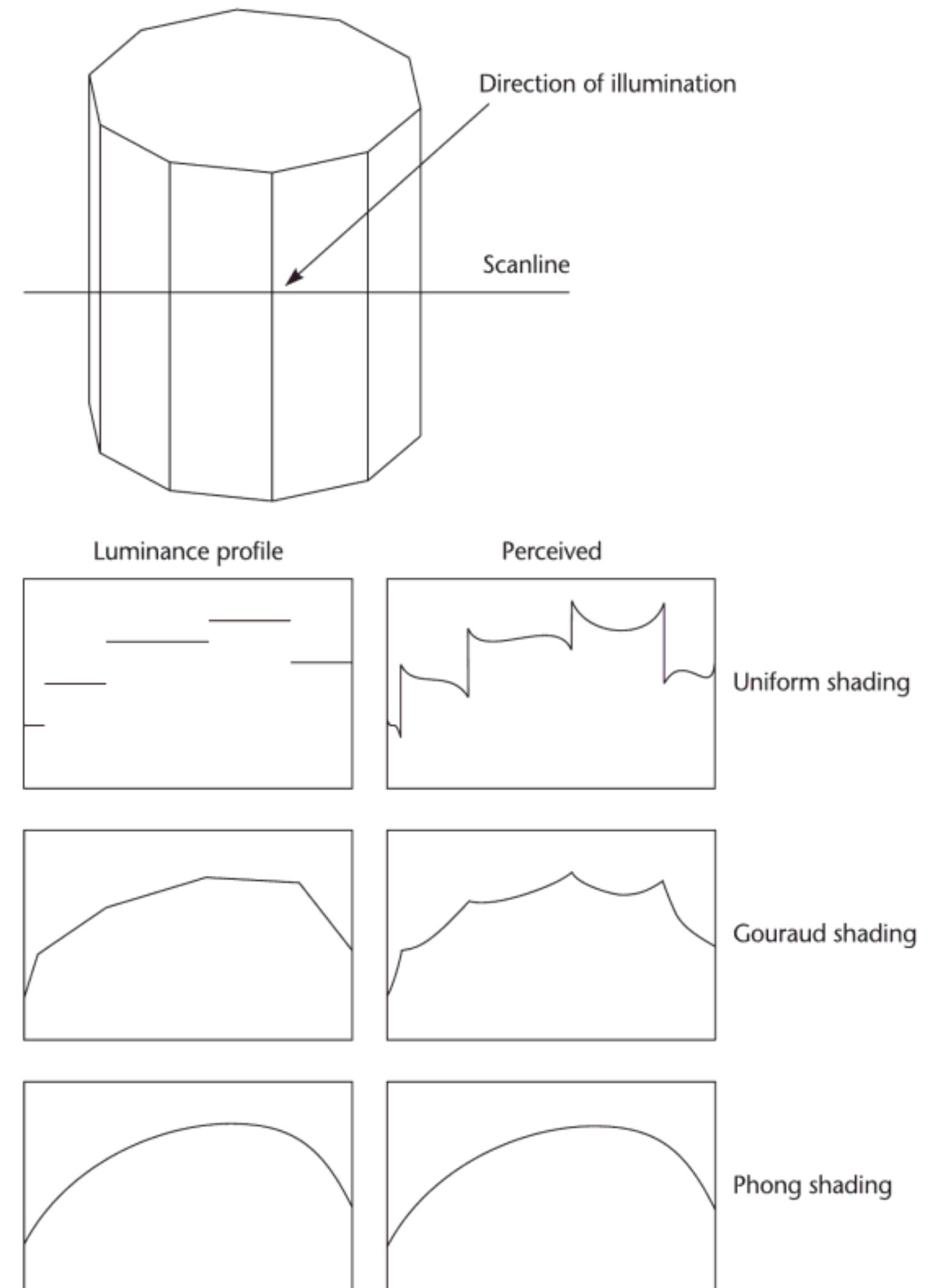
Seurat's Bathers



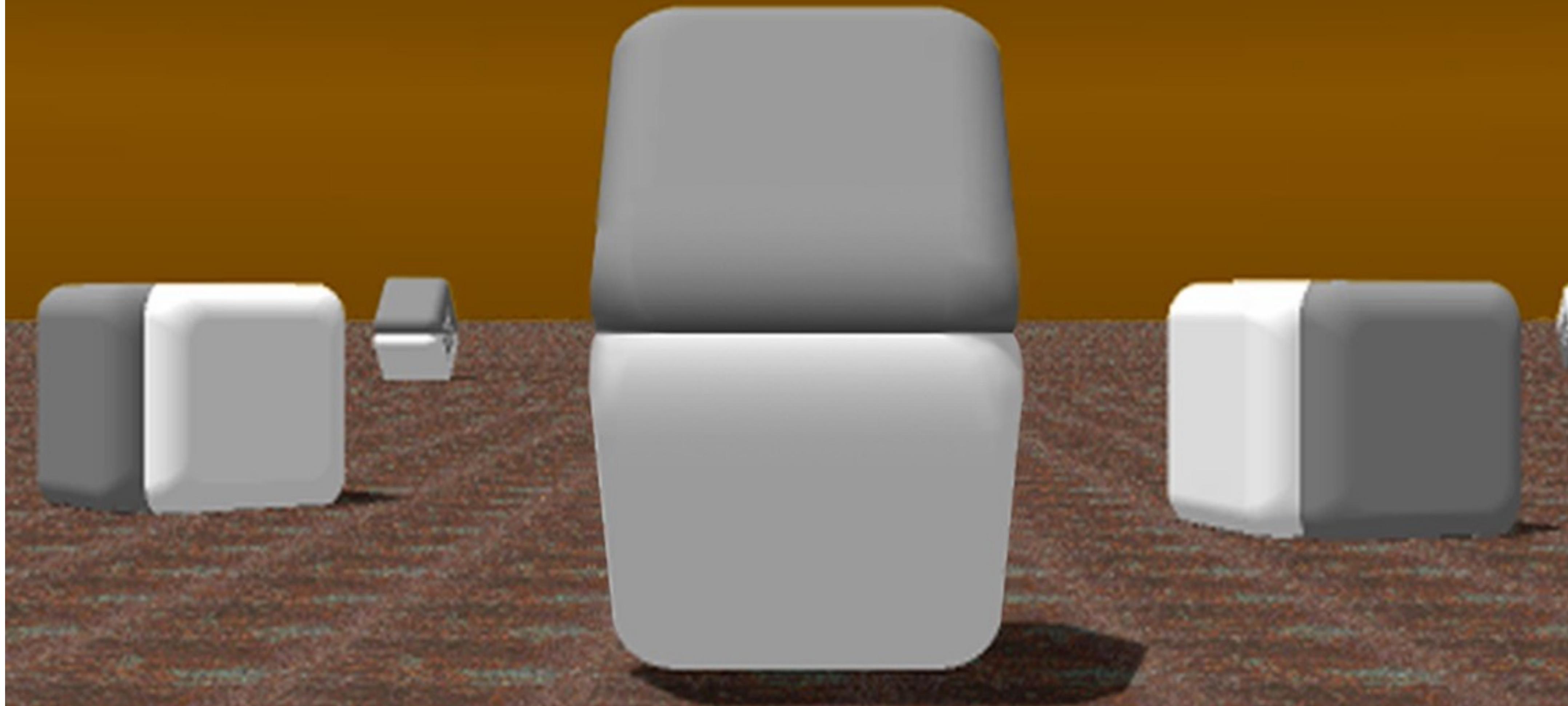
# Why is this an issue?

Can result in large errors of judgment

Amplifies artifacts in computer graphics shading



# Cornsweet Illusion



# Cornsweet Illusion



# Demo

<http://purveslab.net/see-for-yourself/>

**purves-lab**

Laboratory of Dale Purves, M.D. Center for Cognitive Neuroscience Duke University

MAIN NEWS PEOPLE RESEARCH PUBLICATIONS RESOURCES [SEE FOR YOURSELF](#) CONTACT

Lightness/Brightness	Color	Lines and Angles	Motion	Sound and Music

**Brightness contrast: standard**

In viewing this stimulus, people invariably perceive the square on the brighter surround (left) to be darker than the square on the darker surround (right). Click on the "Play" button to convince yourself that the squares are equiluminant or click on the "Move mask" button to manually position the mask over the squares.

[» Read the empirical explanation](#)  
[» Download high resolution images](#)

# Preattentive Processing

# Preattentive Processing

Properties detected by the low-level visual system

very rapid - 200-250 milliseconds

very accurate

processed in parallel

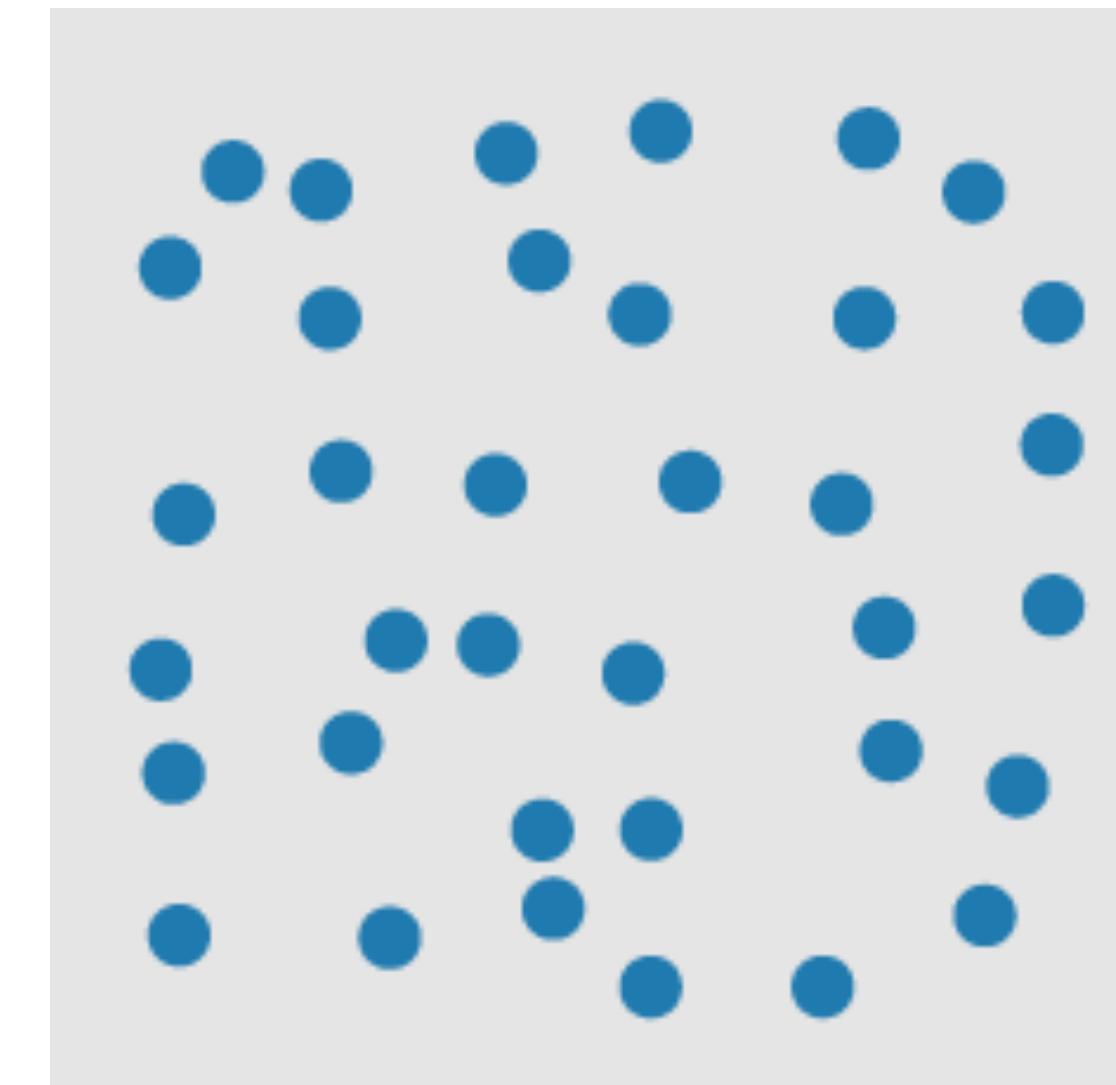
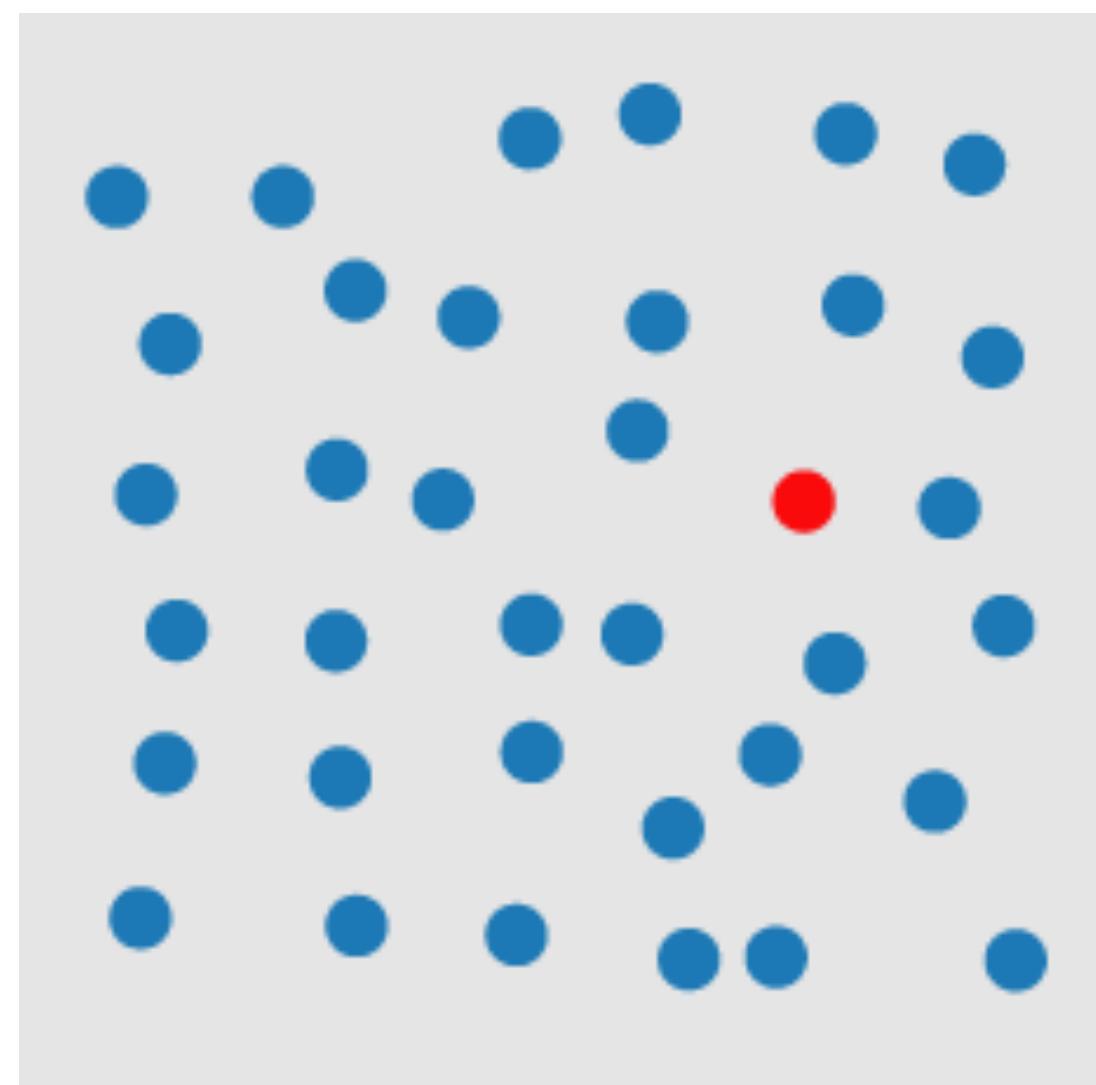
happens before focused attention -> “pre”-attentive

attention is very important for cognition

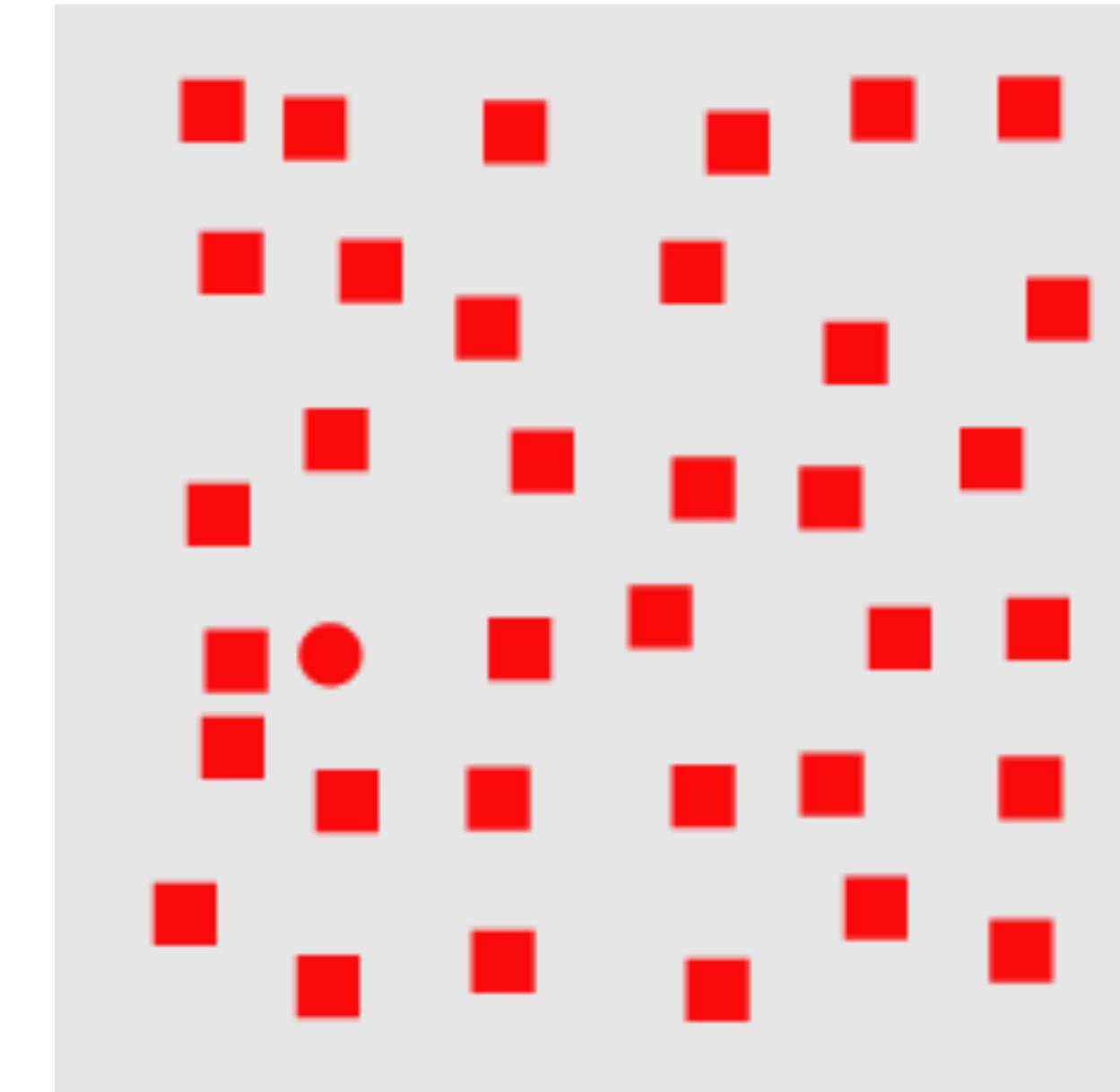
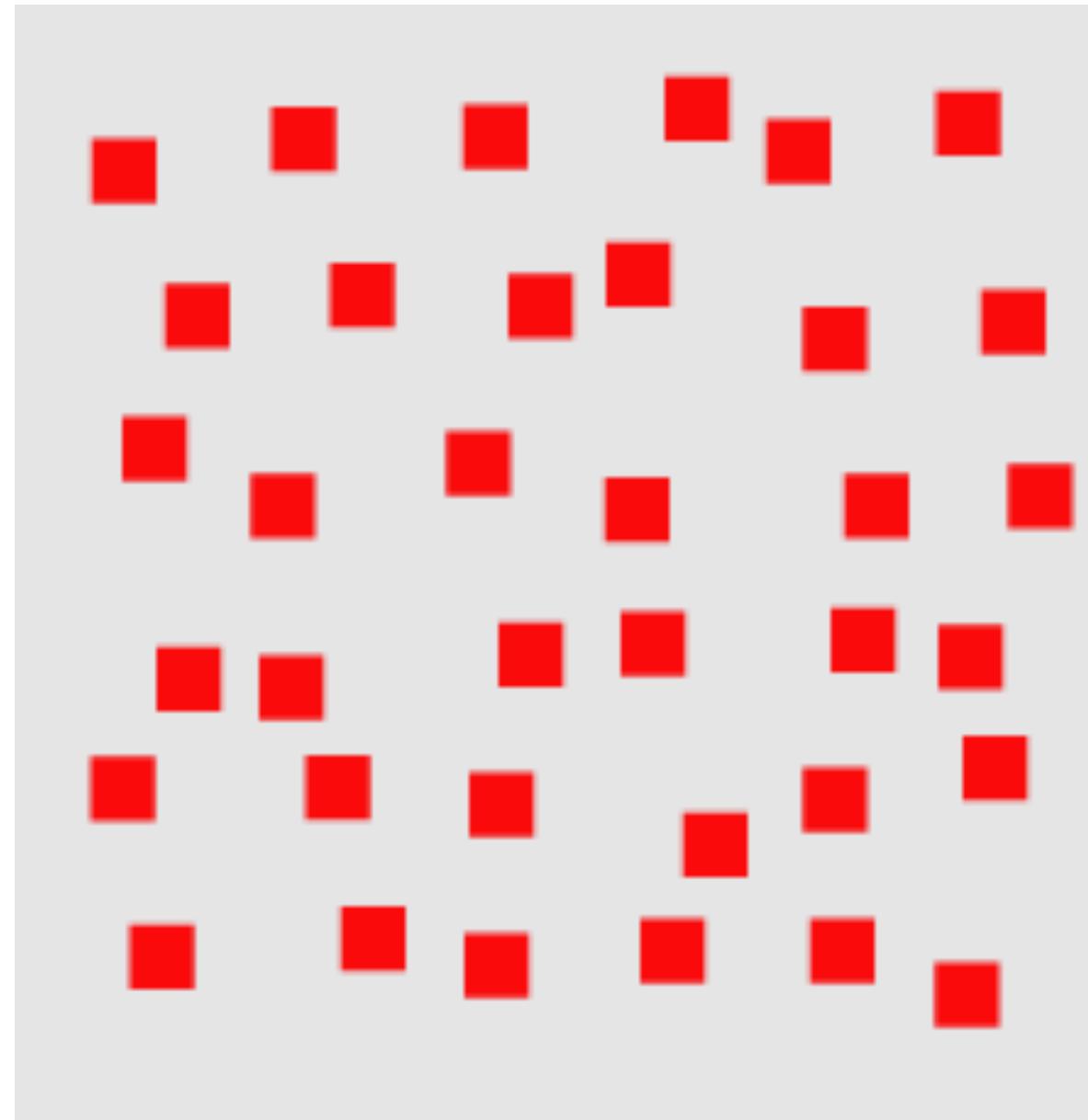
Independent of the number of distractors!

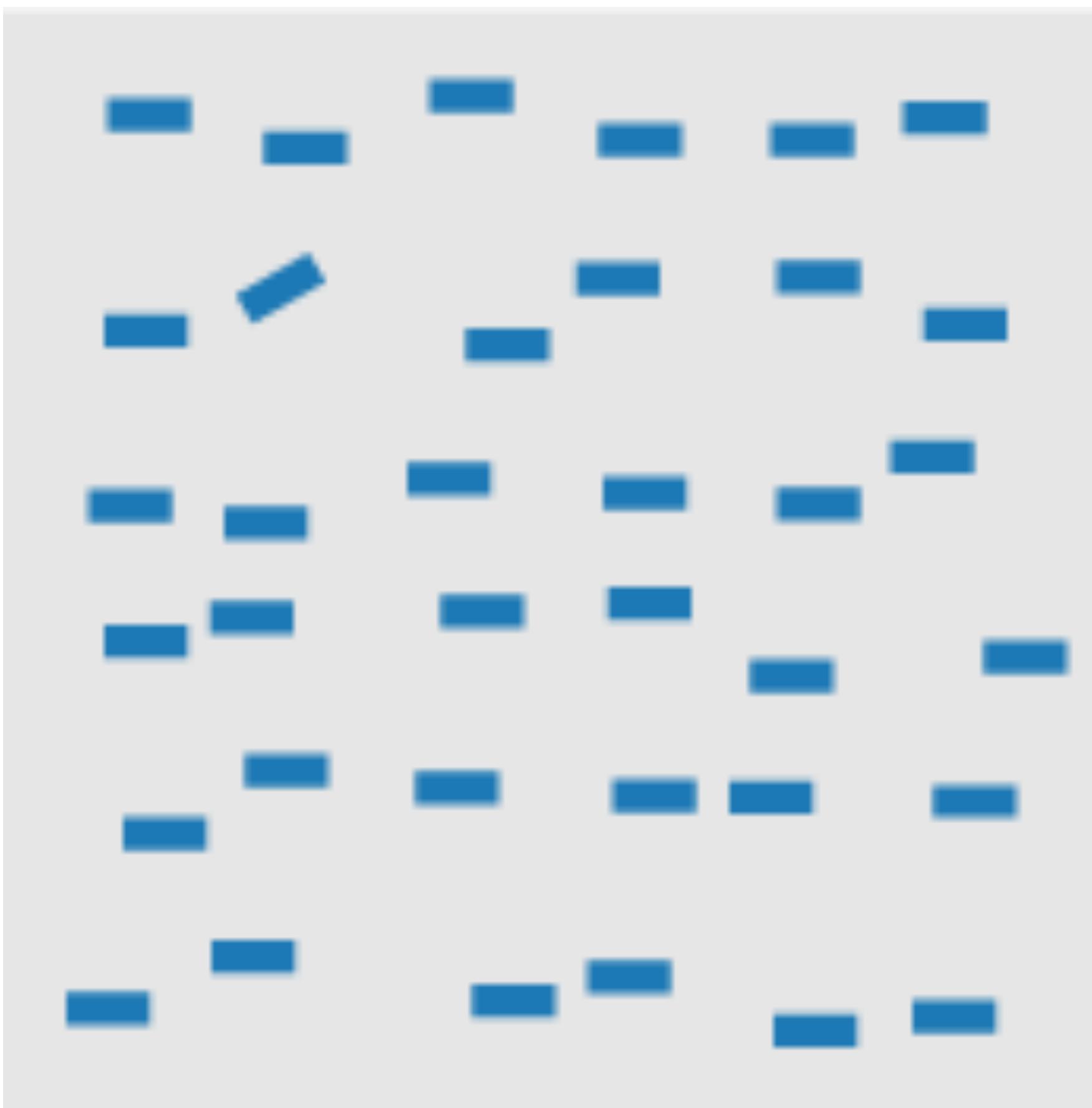
Opposite: sequential search (processed serially)

# Difference in Hue

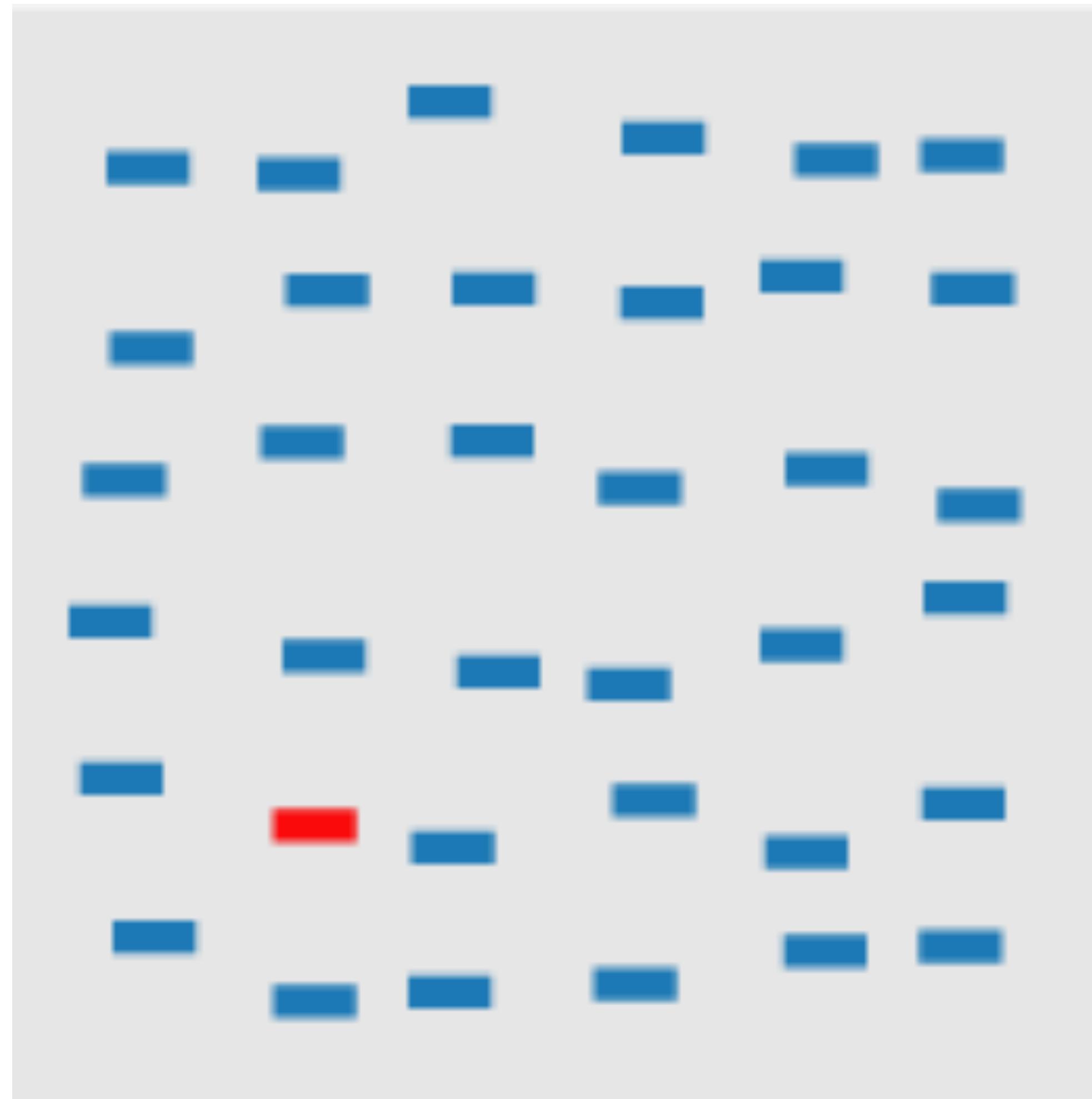


# Difference in Curvature / Form





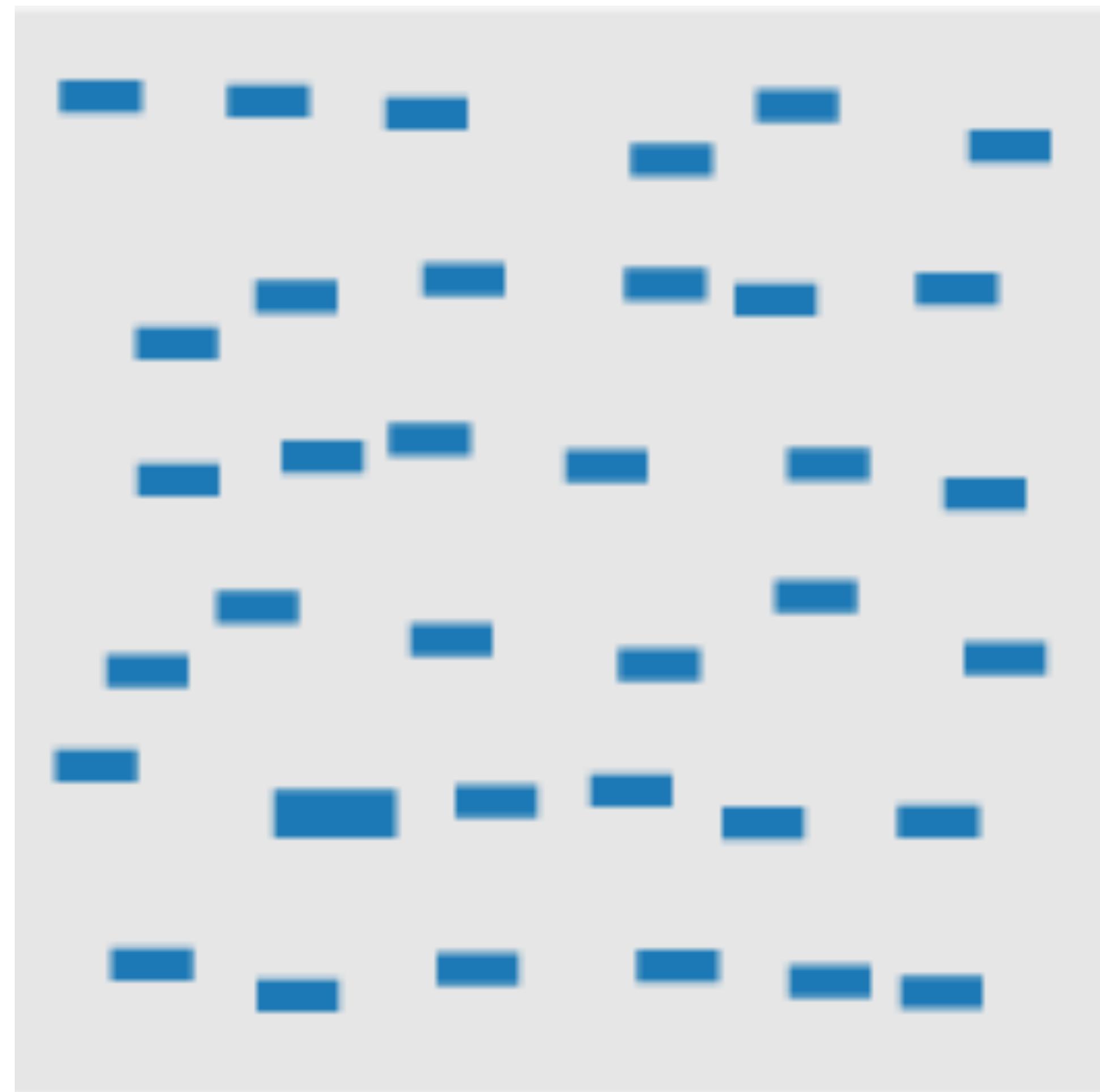
orientation



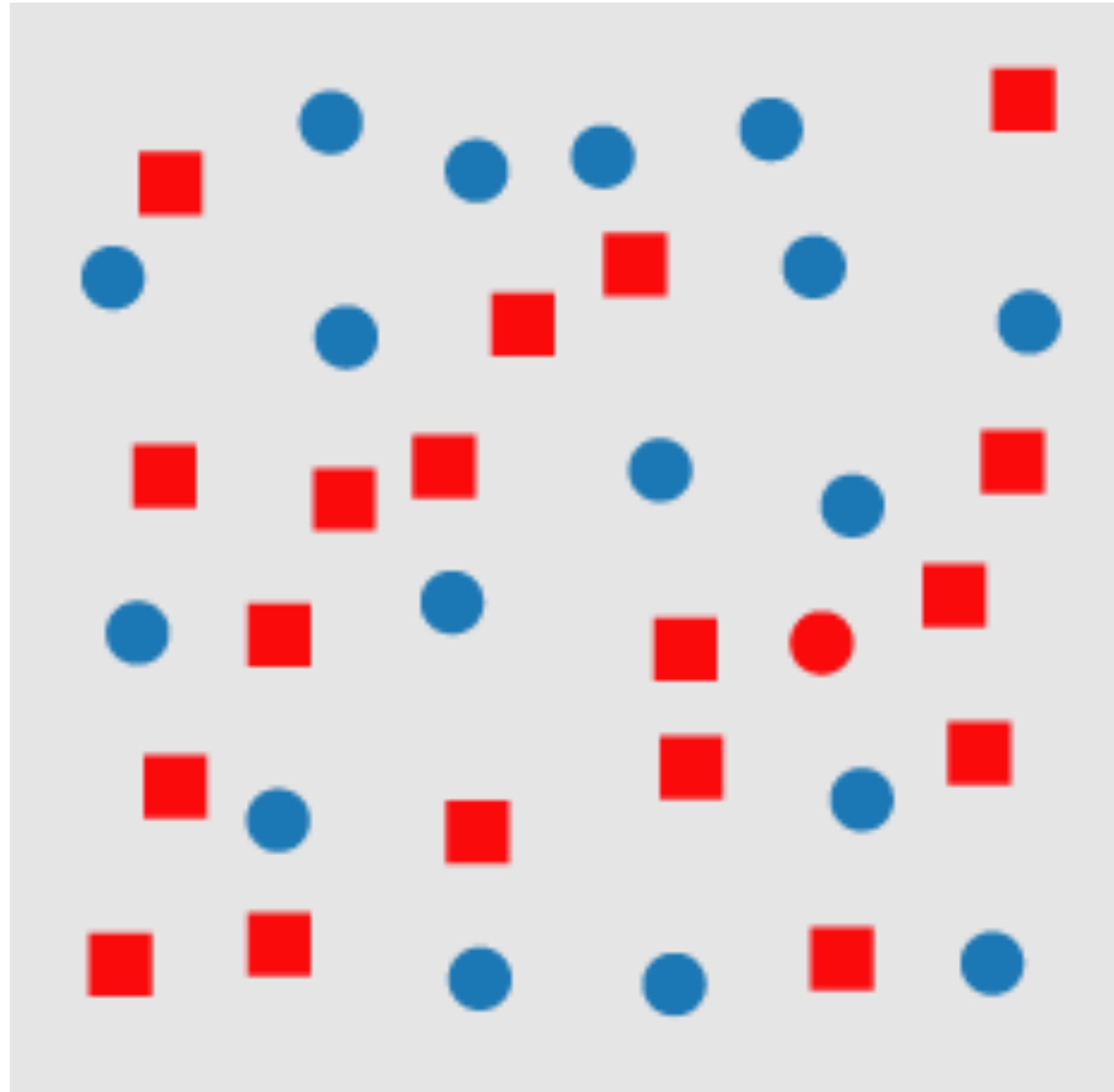
hue



closure

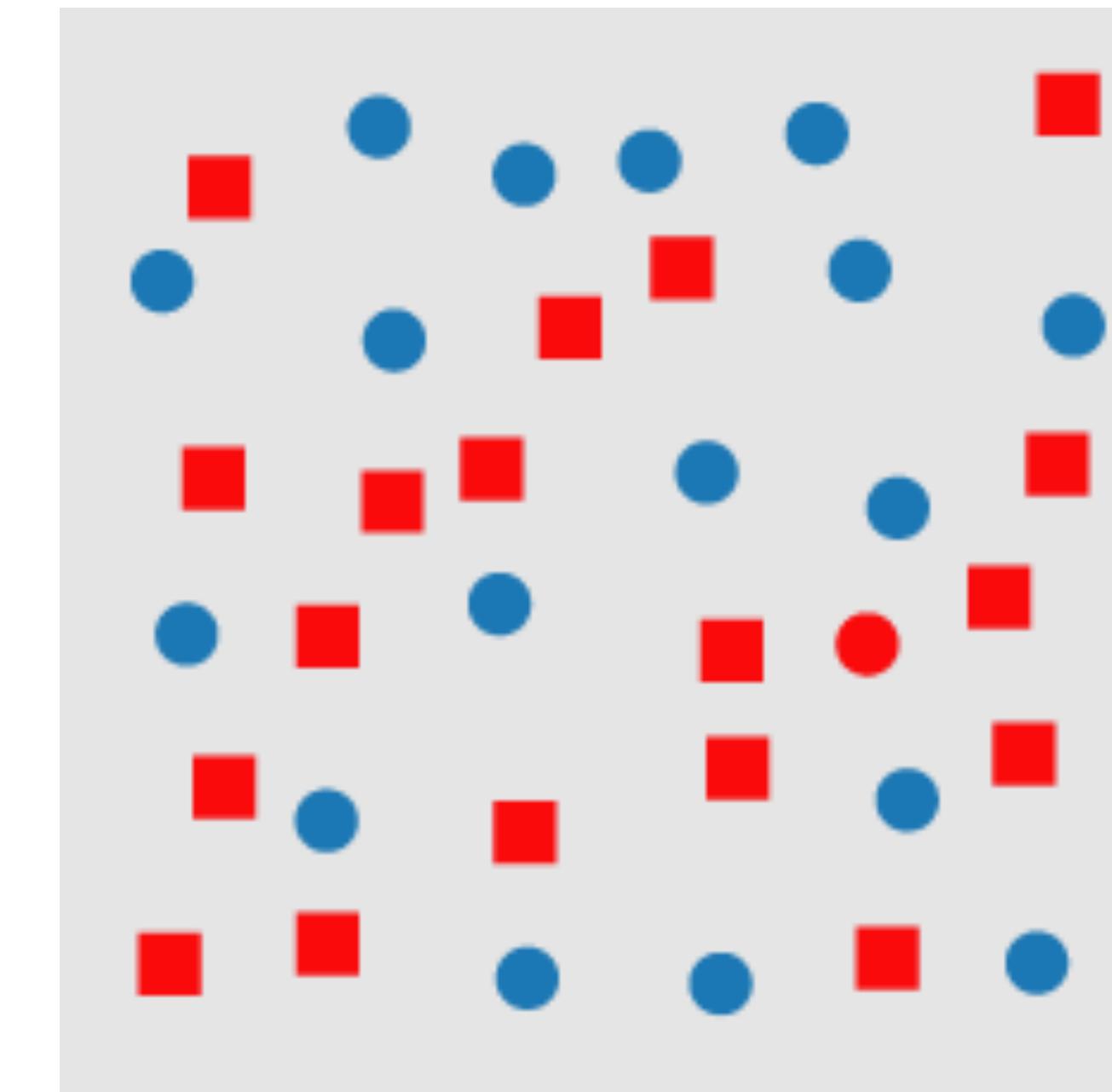
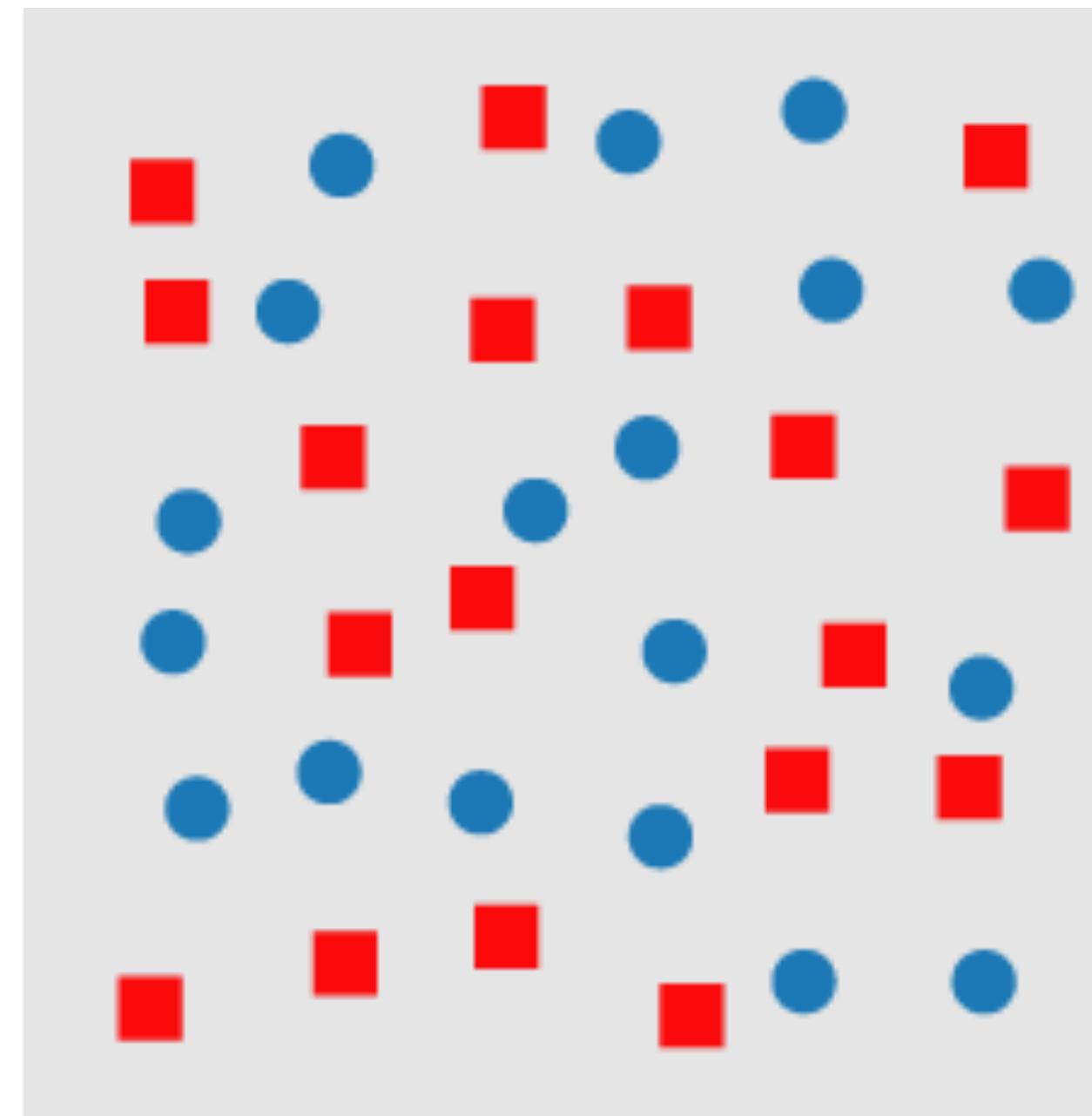


size



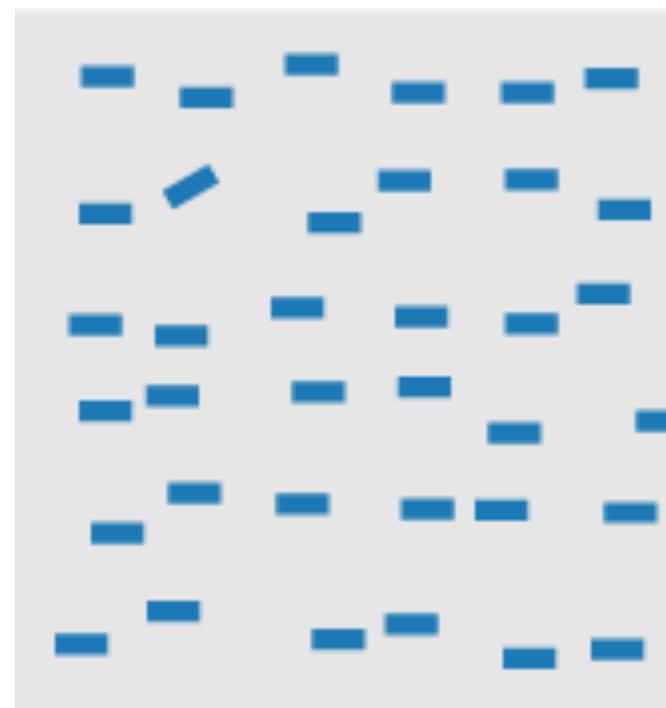
?

# Not Valid for Combinations

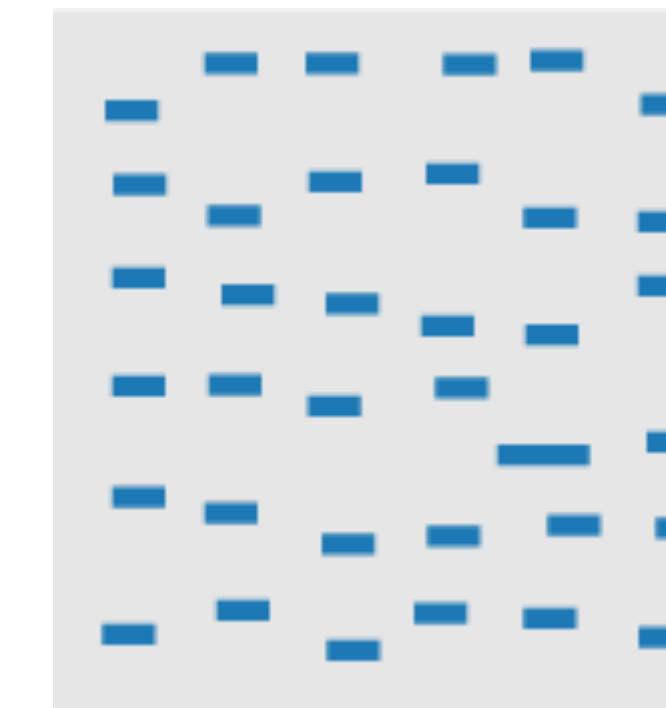


Conjunction Targets – no unique visual property  
target: red, circle  
distractor objects have both properties

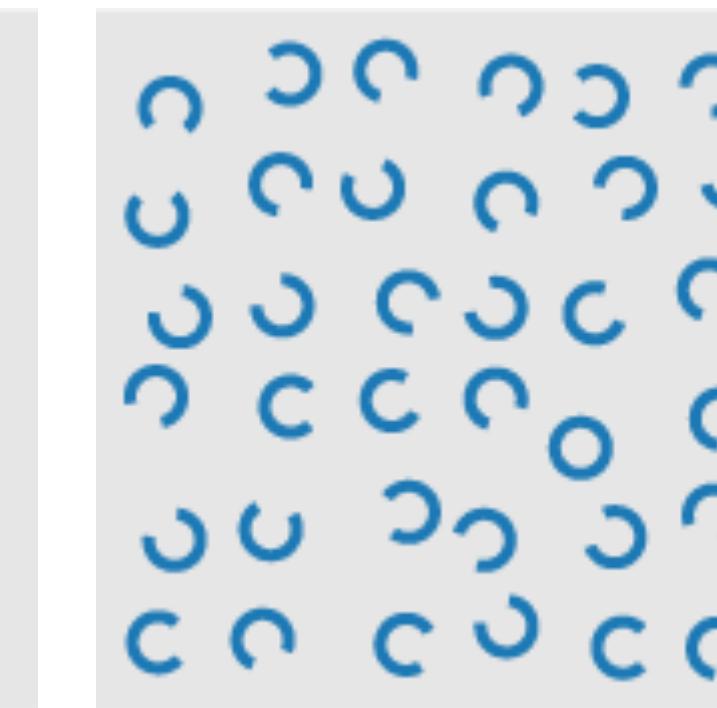
# Some Preattentive Properties



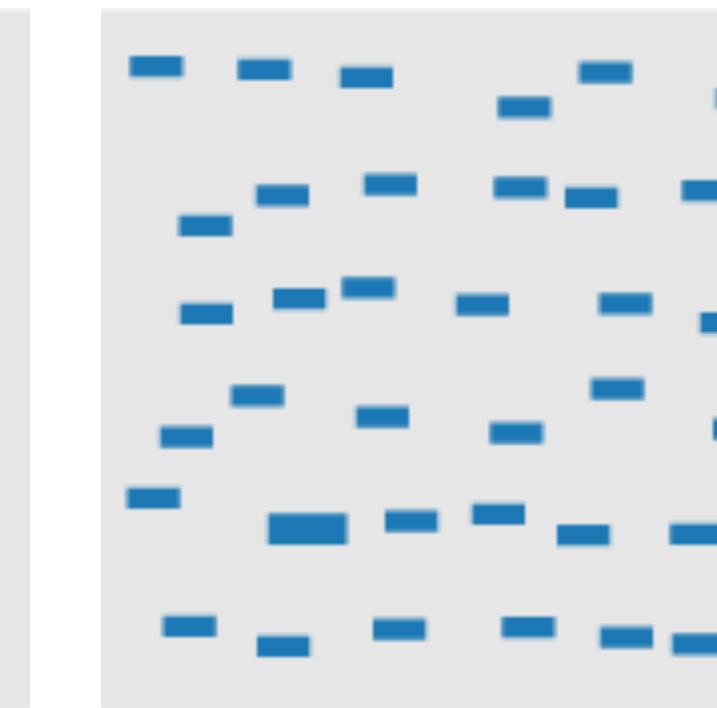
orientation



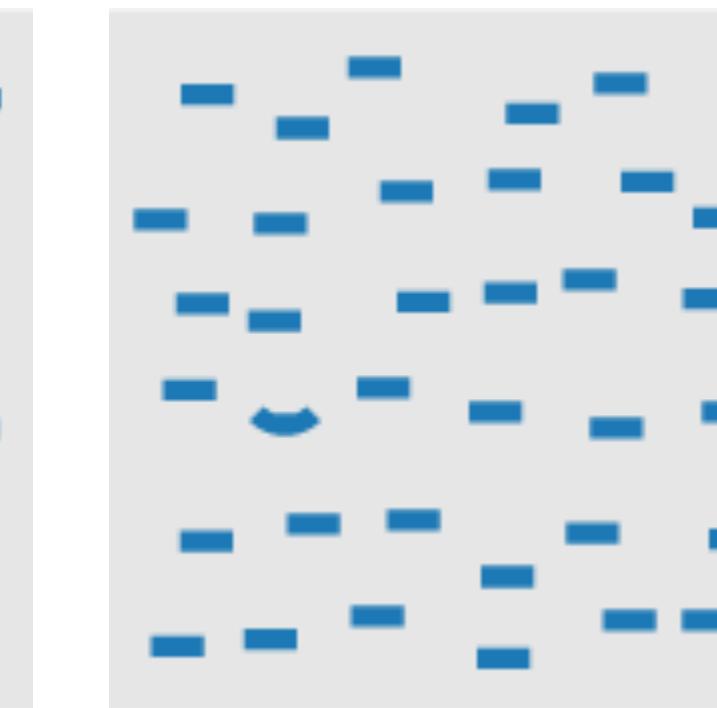
length



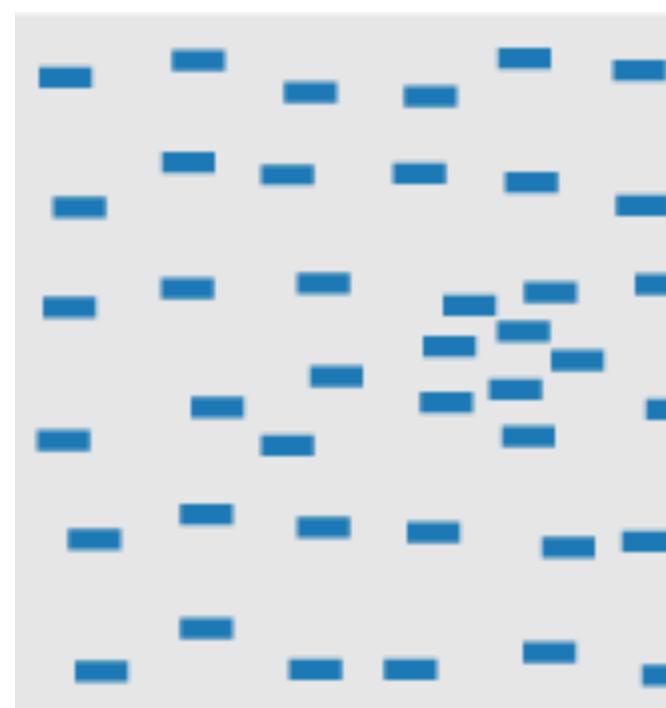
closure



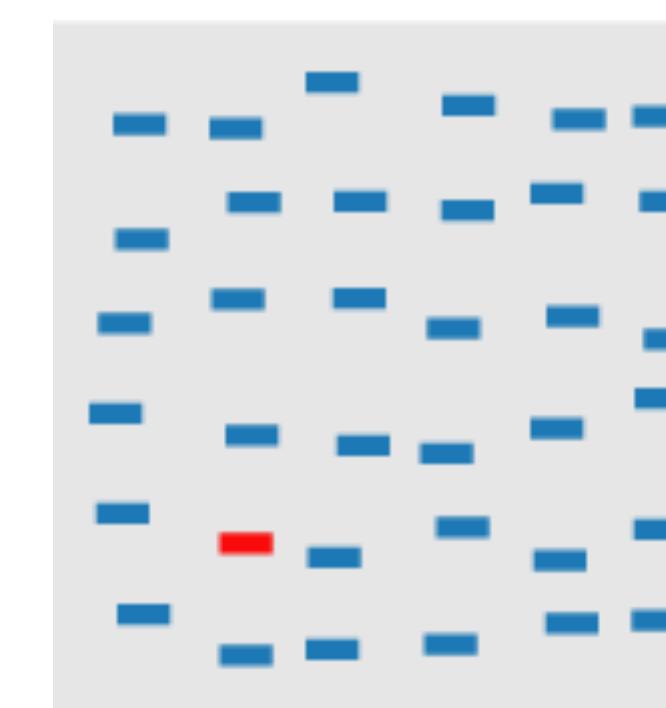
size



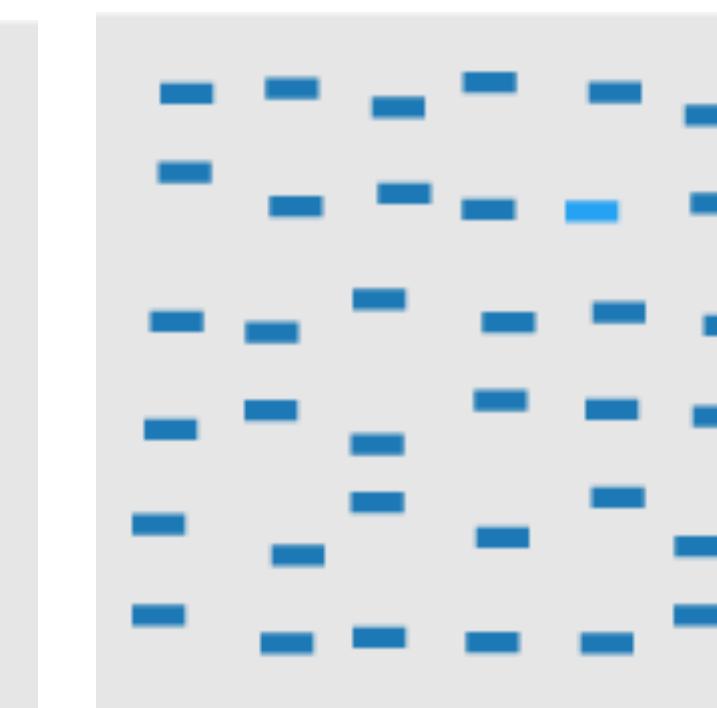
curvature



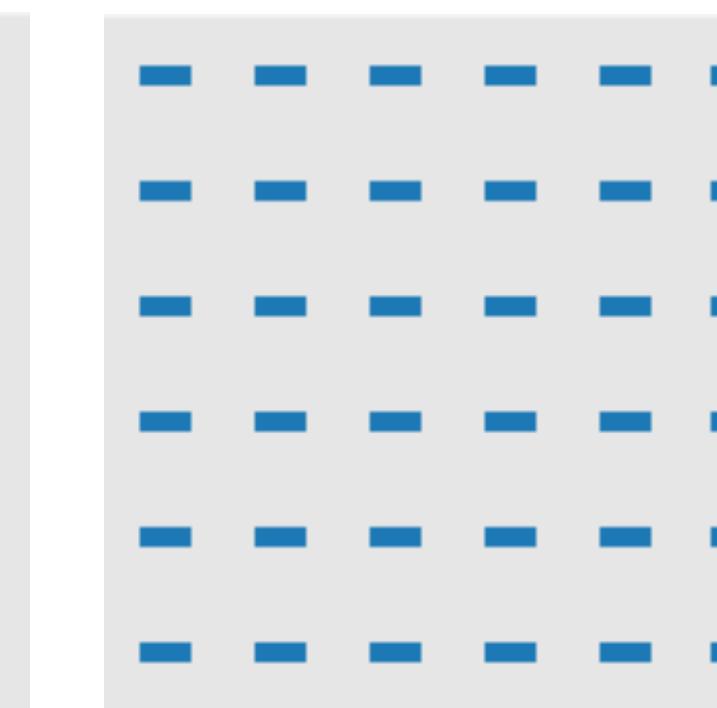
density



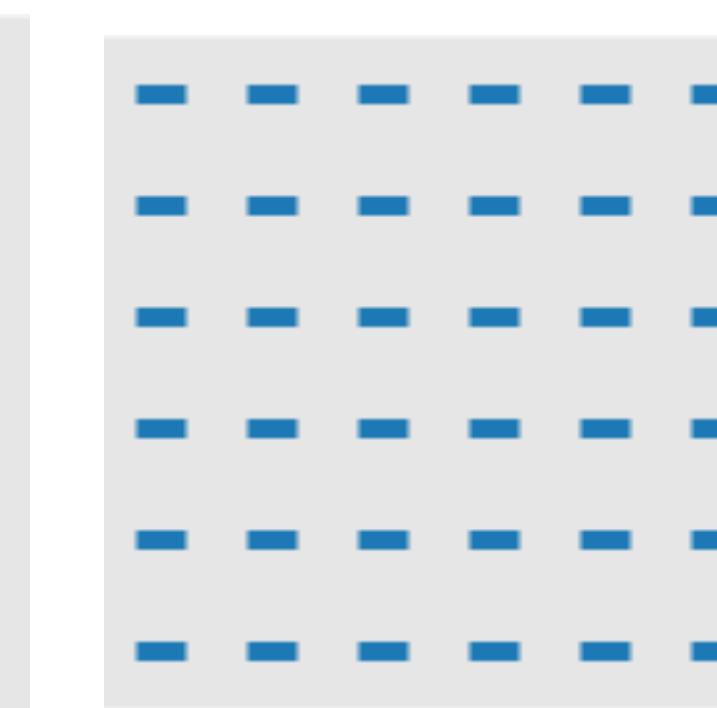
hue



hue



flicker



direction of motion

# Tasks

## target detection

detect the presence or absence of a target

## boundary detection

detect a texture boundary between two groups of elements, where all of the elements in each group have a common visual property

## region tracking

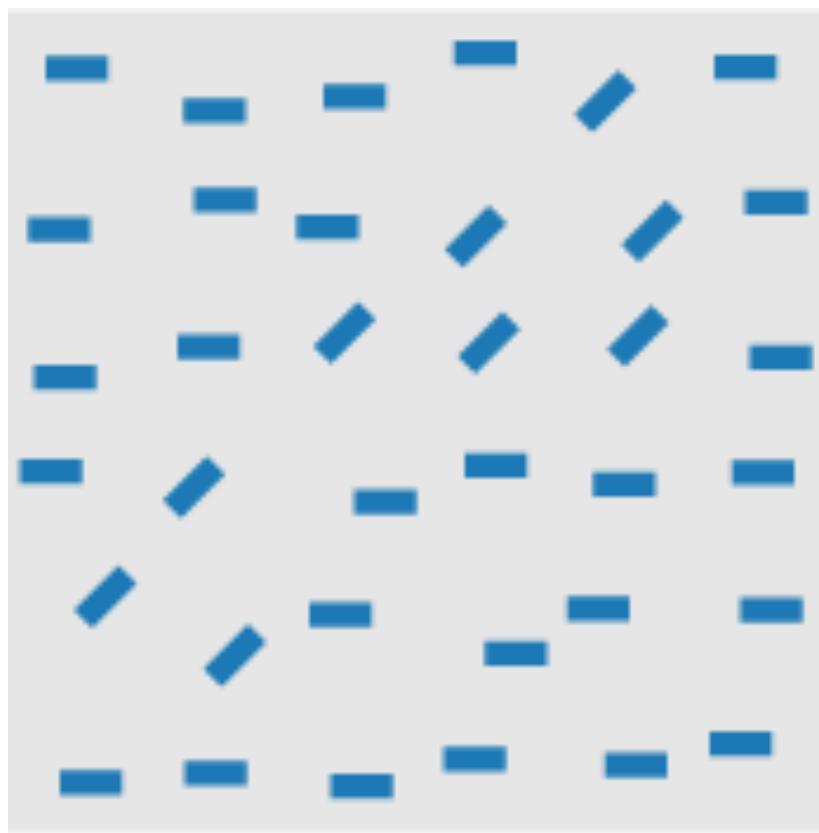
track one or more elements with a unique visual feature as they move in time and space

## counting and estimation

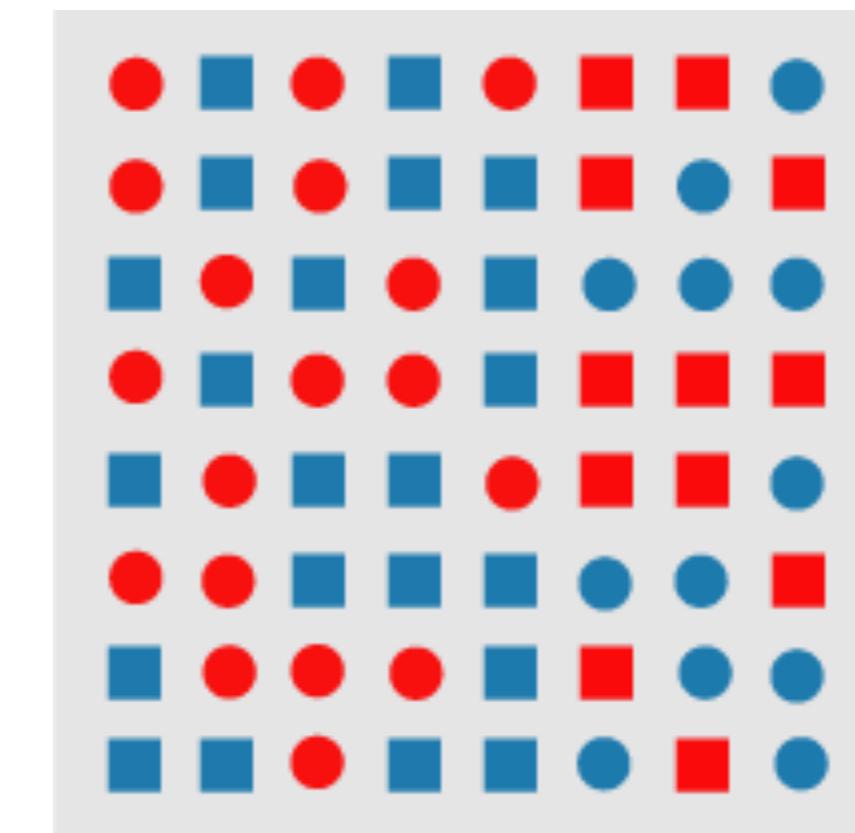
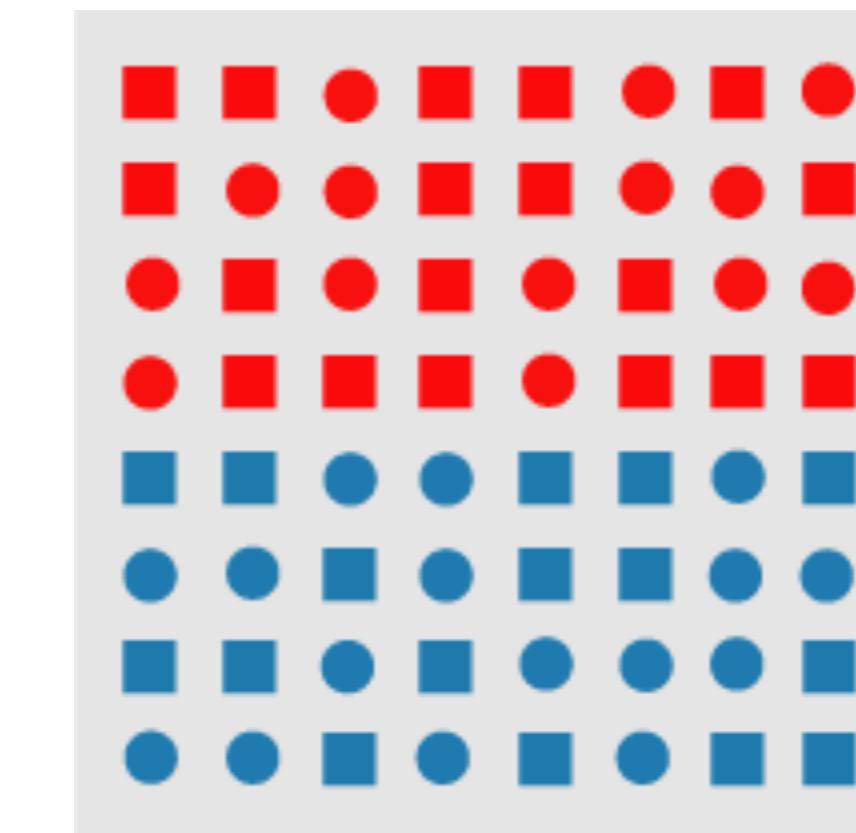
users count or estimate the number of elements with a unique visual feature.

# Tasks

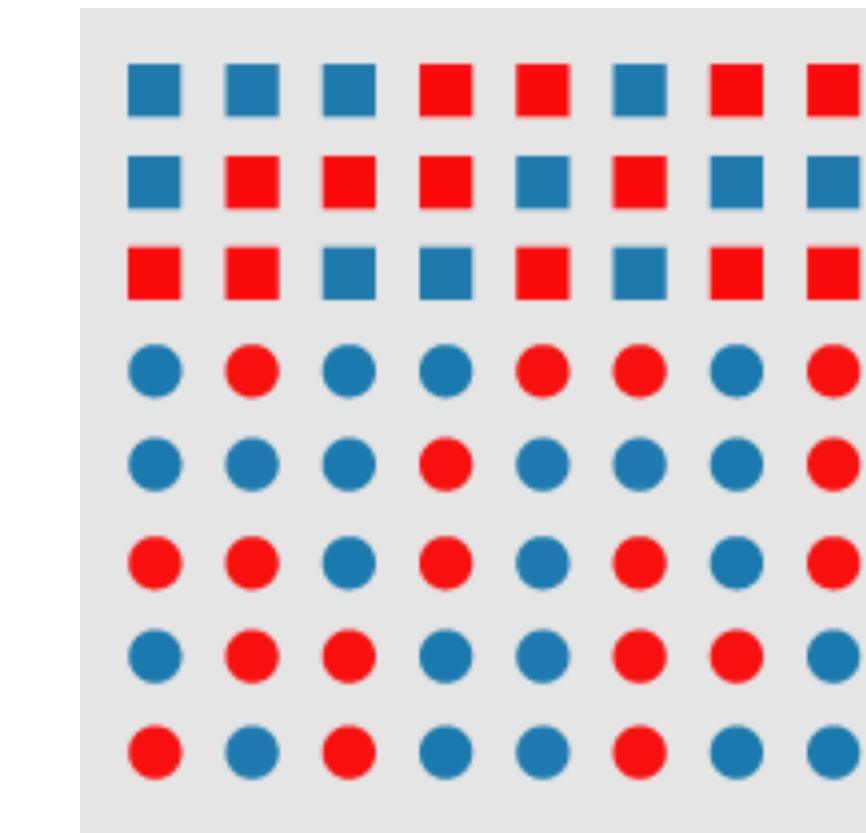
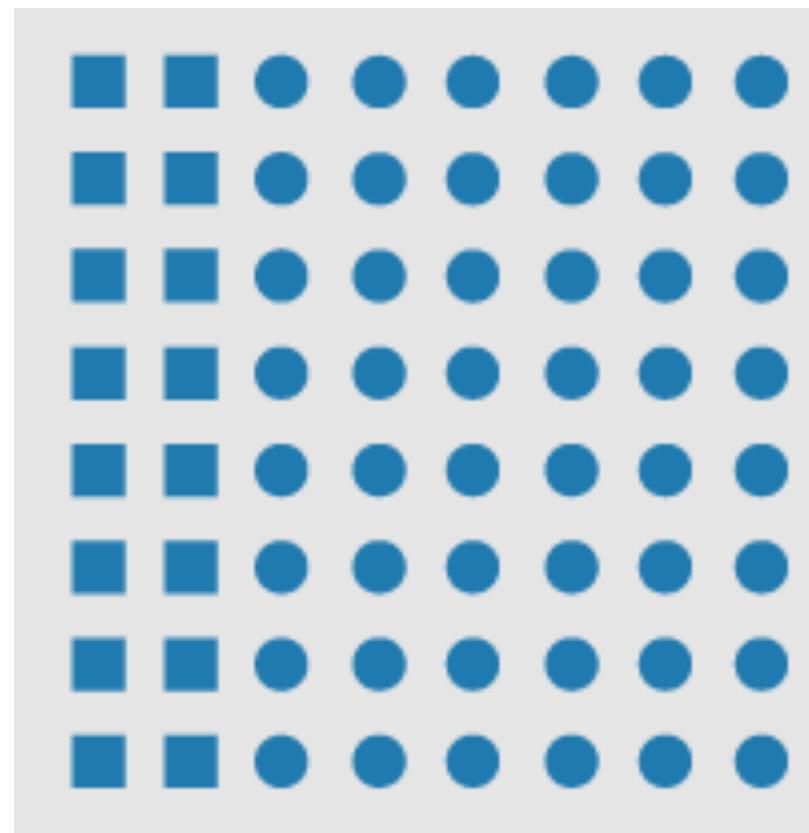
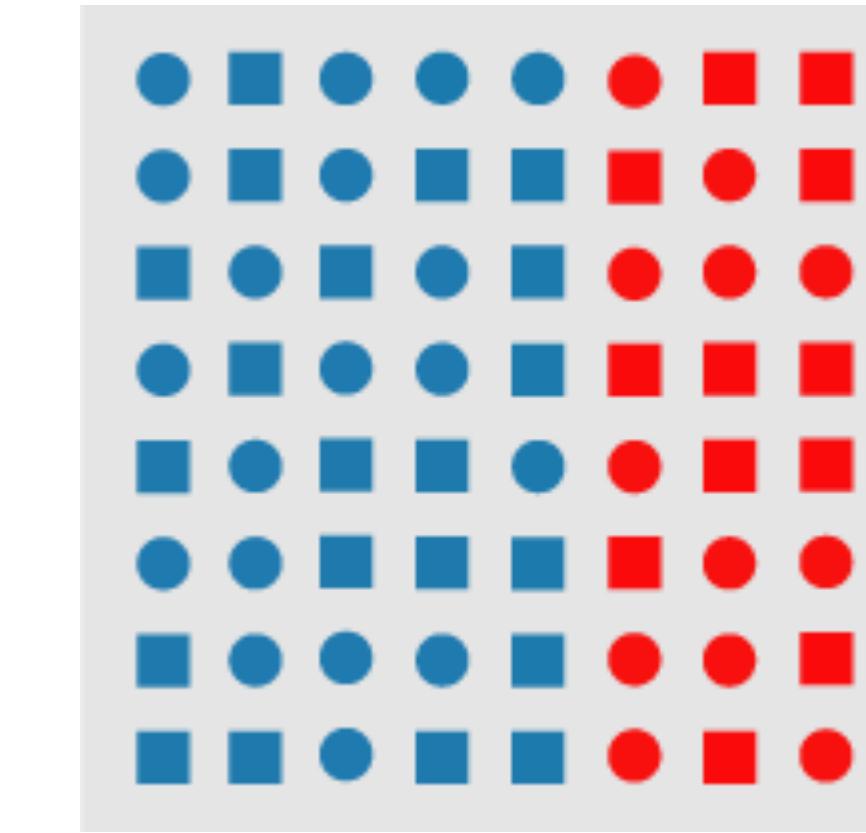
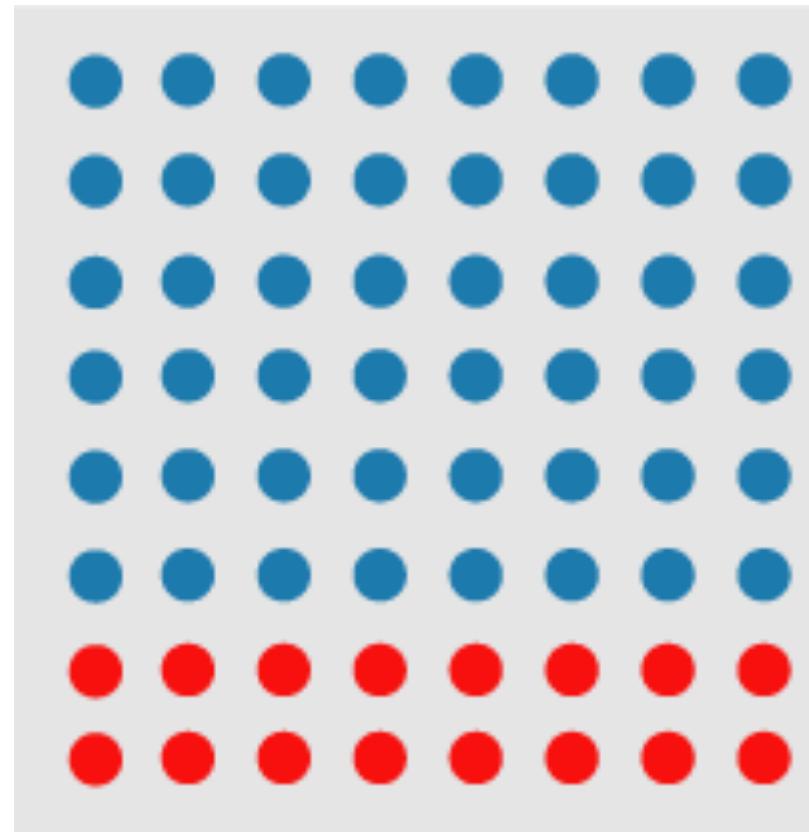
Number Estimation



Boundary Detection



# Hierarchy of Preattentive Features



Examples online!

# Theories of Preattentive Processing

Not known for sure how it works

Several theories:

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

# Preattentive Processing in Vis

Can be used to draw attention to areas of interest

Can be used to express similarity/group memberships

Visual features must be carefully designed

Conjunctions must be avoided

Examples are “Cues” (Focus and Context technique)

# Change Blindness

# Change Blindness

Details of an image cannot be remembered across separate scenes

except in areas with focused attention

Interruption (e.g. a blink, eye saccade or blank screen) amplifies this effect

Not failure of vision system

failure due to inappropriate attentional guidance





Ron Rensink 2002



Ron Rensink 2002



Ron Rensink 2002



Ron Rensink 2002

# Change Blindness

## Various theories about causes

Overwriting: Information that was not abstracted is lost

First Impression: Only initial view is abstracted

Nothing is Stored: Only abstract concepts are committed to memory

Everything is Stored, Nothing is Compared: We compare only when we are forced to

Feature Combination: scenes are combined as long as they make sense

## Influencing factors

attention

expectation (knowing something will change)

semantic importance of changed object

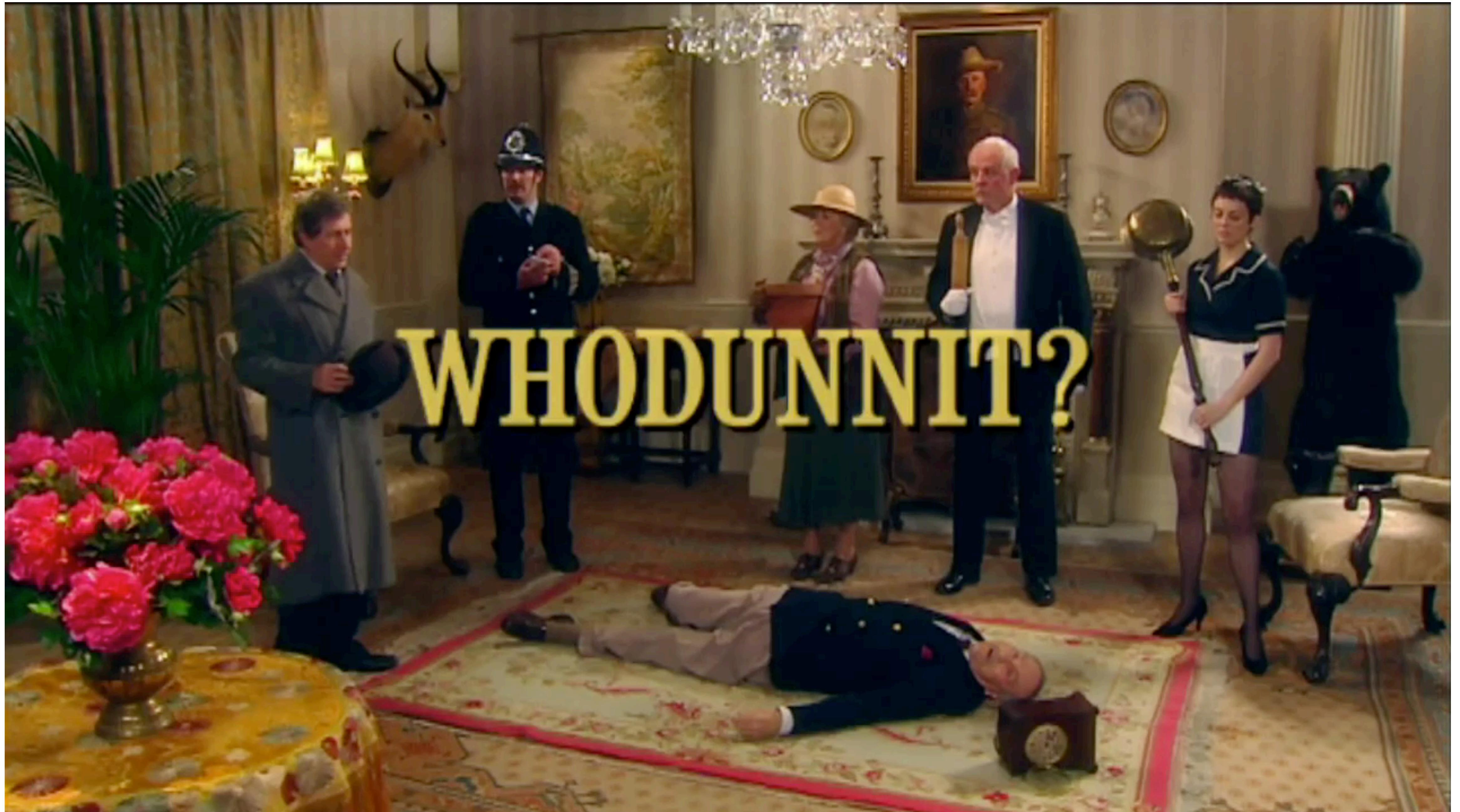
low level object properties overlooked more easily



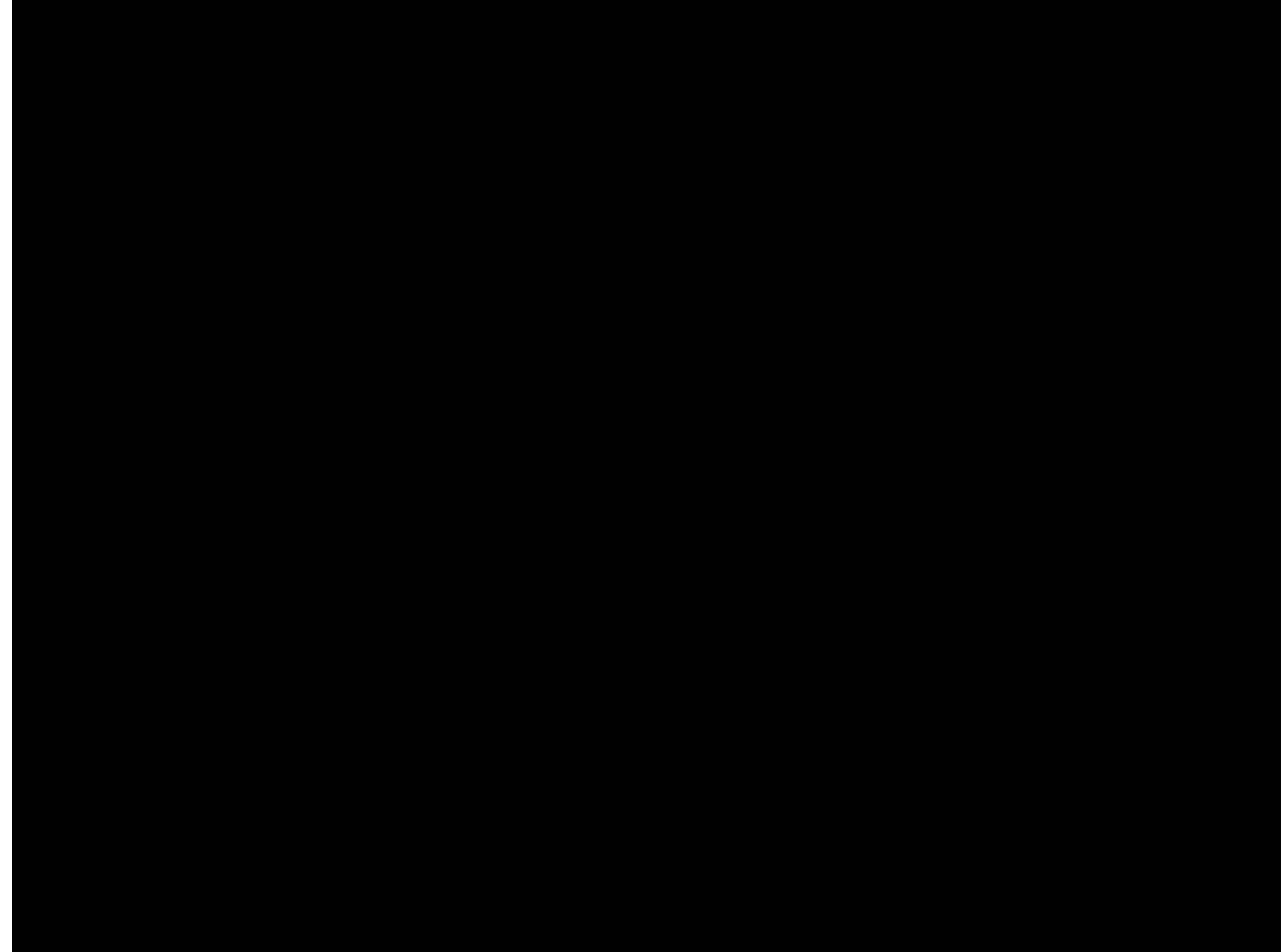


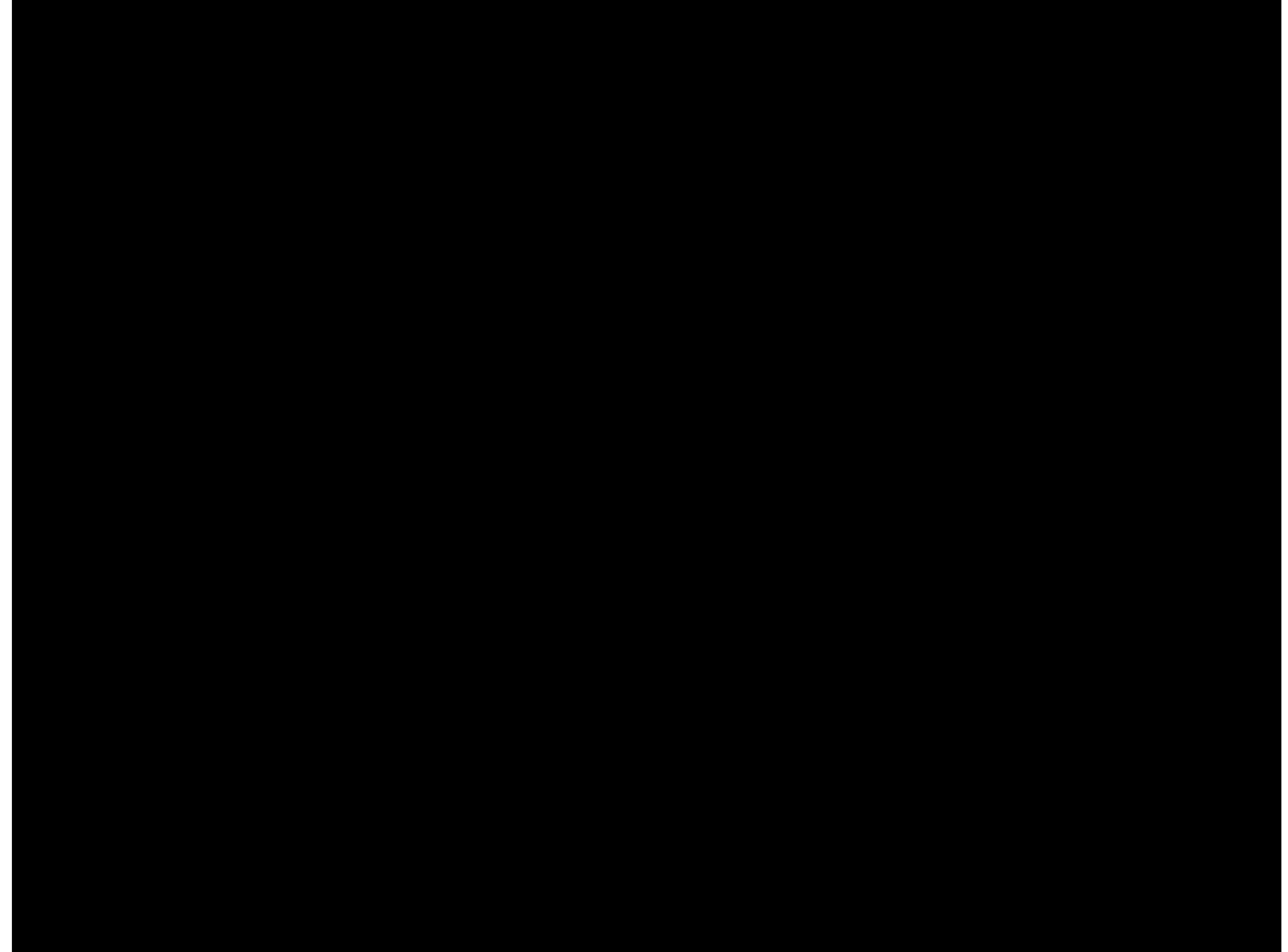


# Attention Blindness



**WHODUNNIT?**





# Take Home Points

To find meaning in what we see **we must selectively pay attention** to what is important

Low-level vision is driven by object features rather than a conscious effort where to look (e.g., pre-attentive processing)

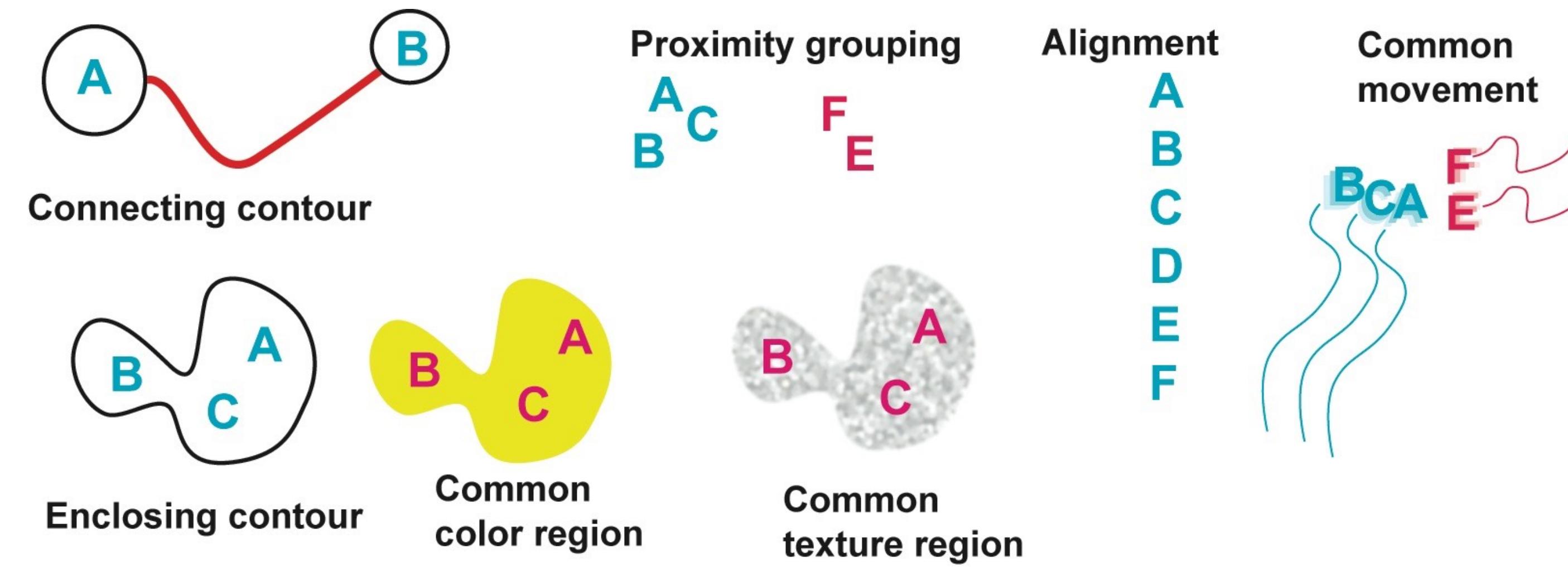
Attention is driven by preexisting knowledge, expectations, and goals stored in long-term memory

# Gestalt Principles

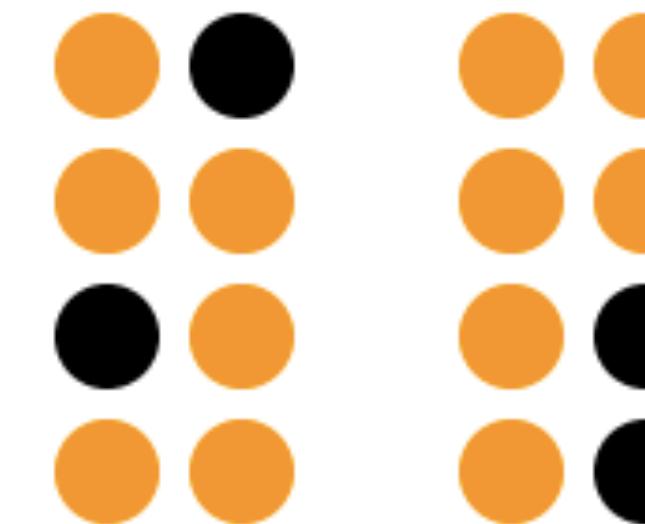
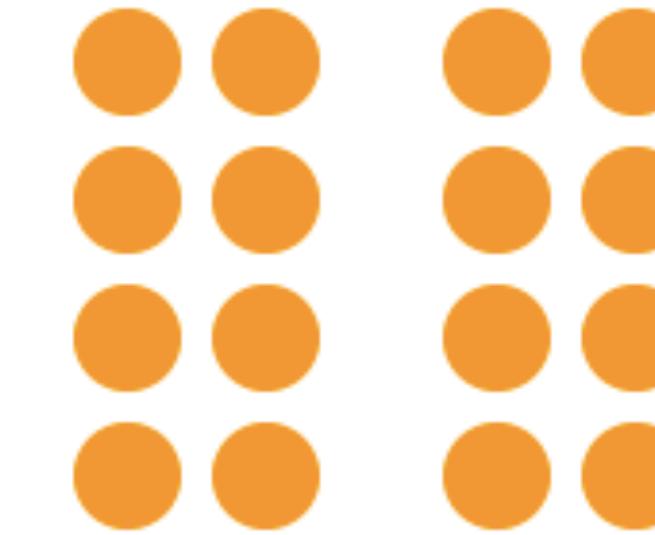
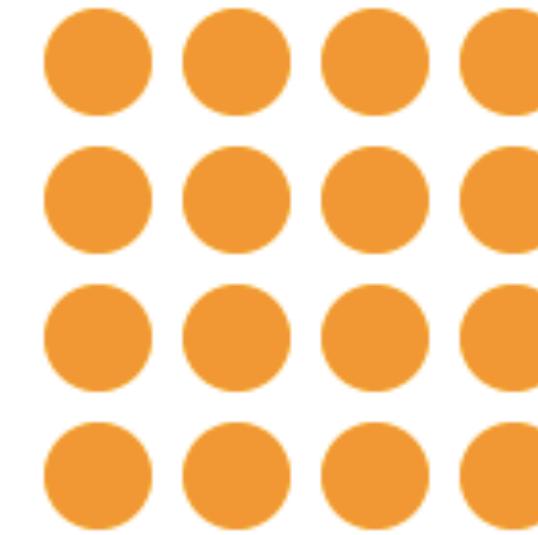
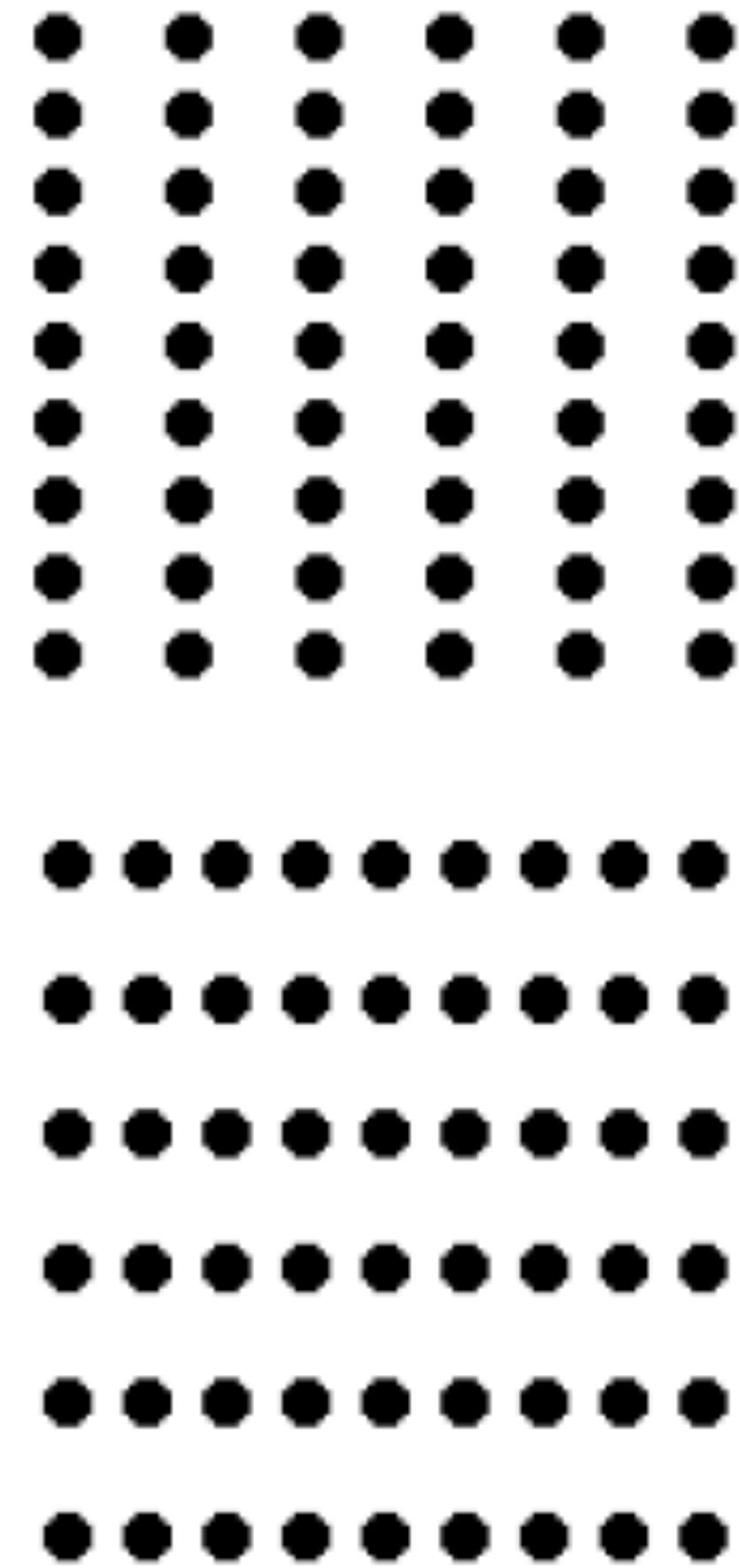
Wertheimer, 1923, and recent extensions

# Gestalt Principles

Patterns that transcend the visual stimuli that produced them

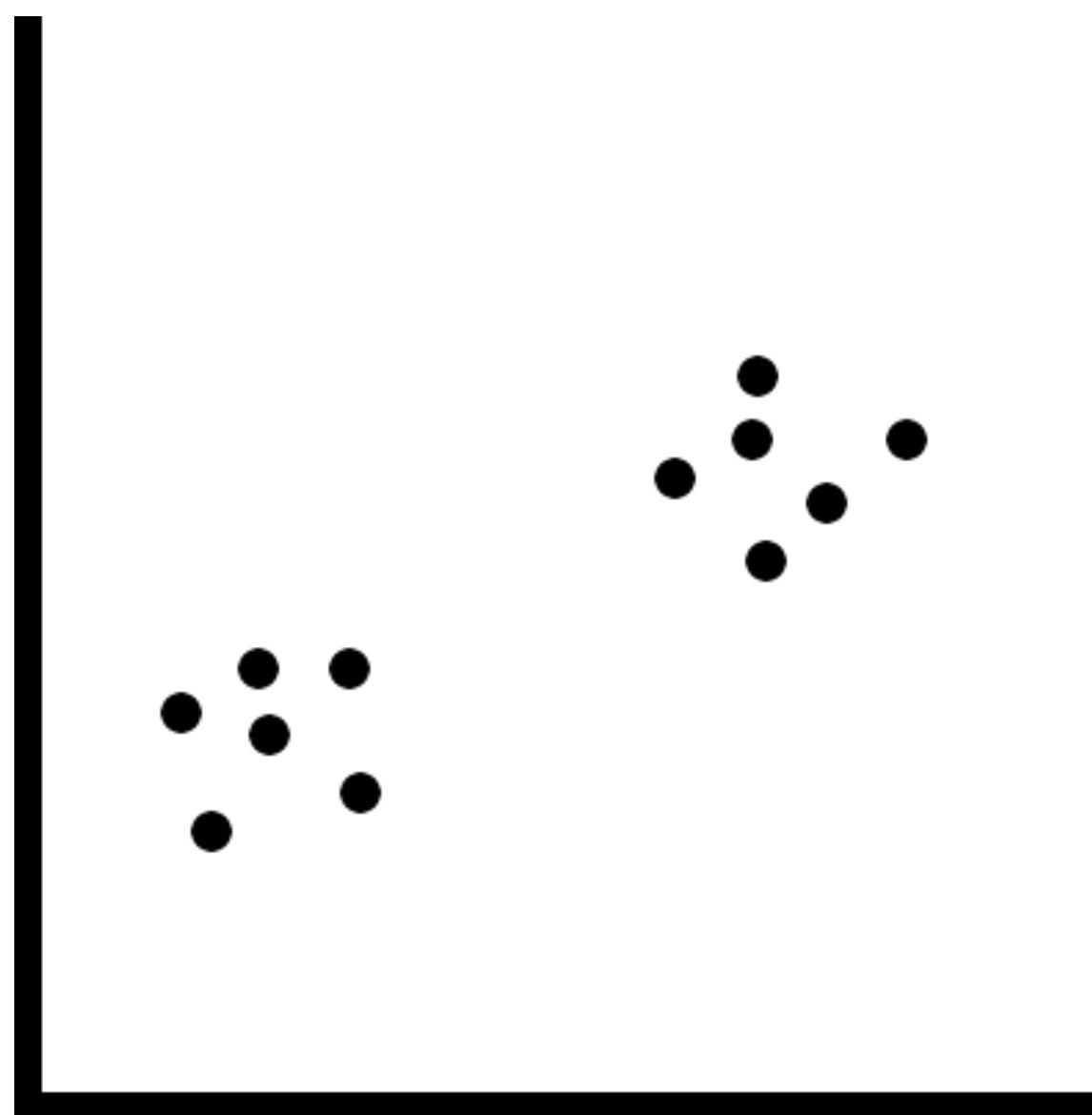


# Proximity

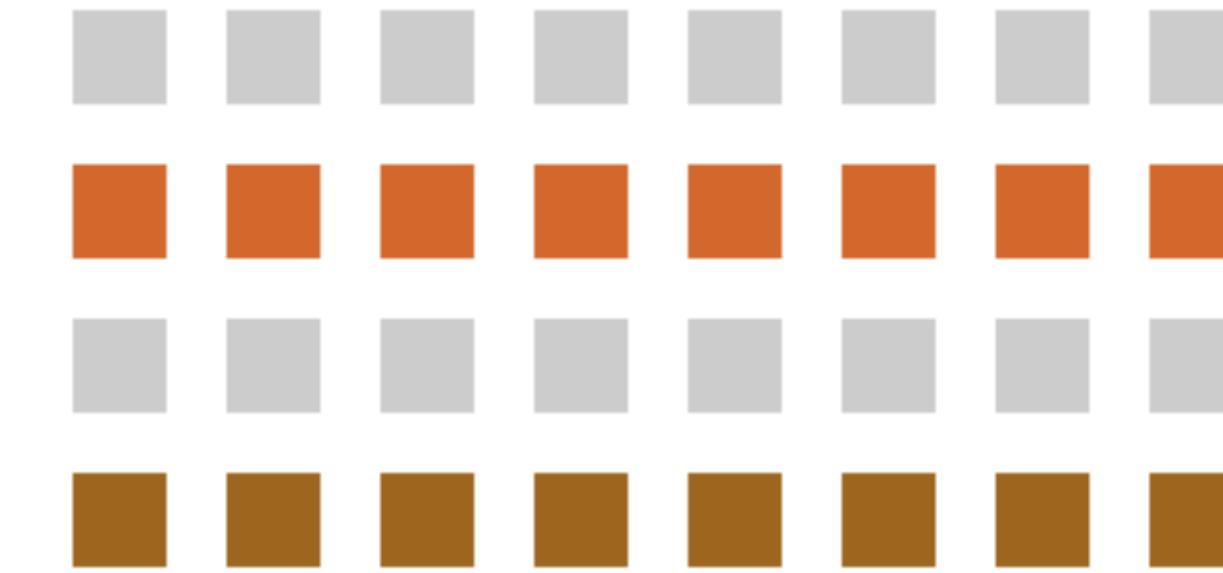


# Proximity

Grouping/linking by placing entities in close proximity



# Similarity

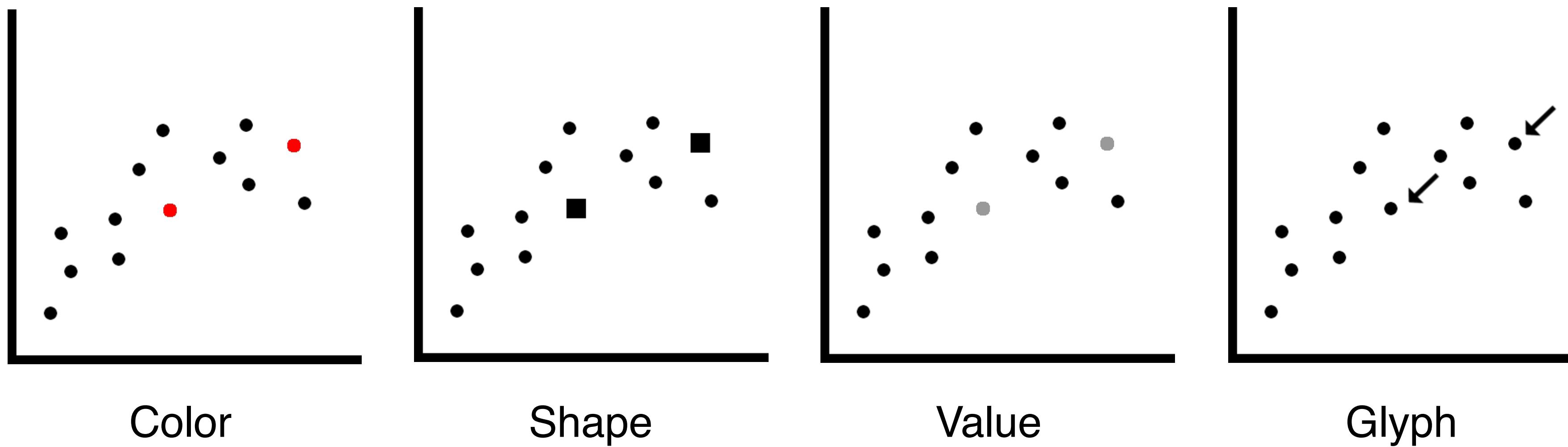


# Similarity

Co-modulation of a **channel**

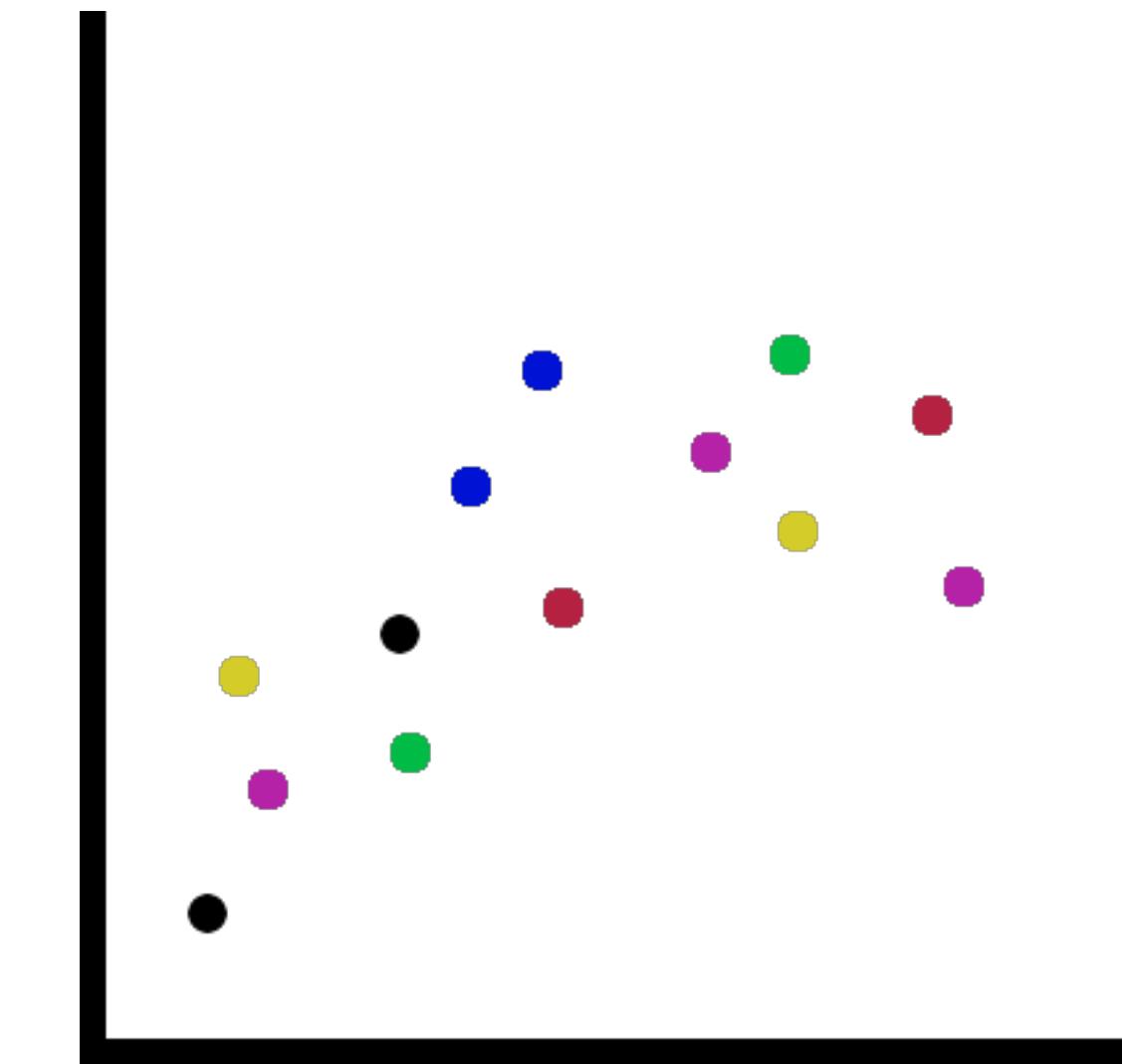
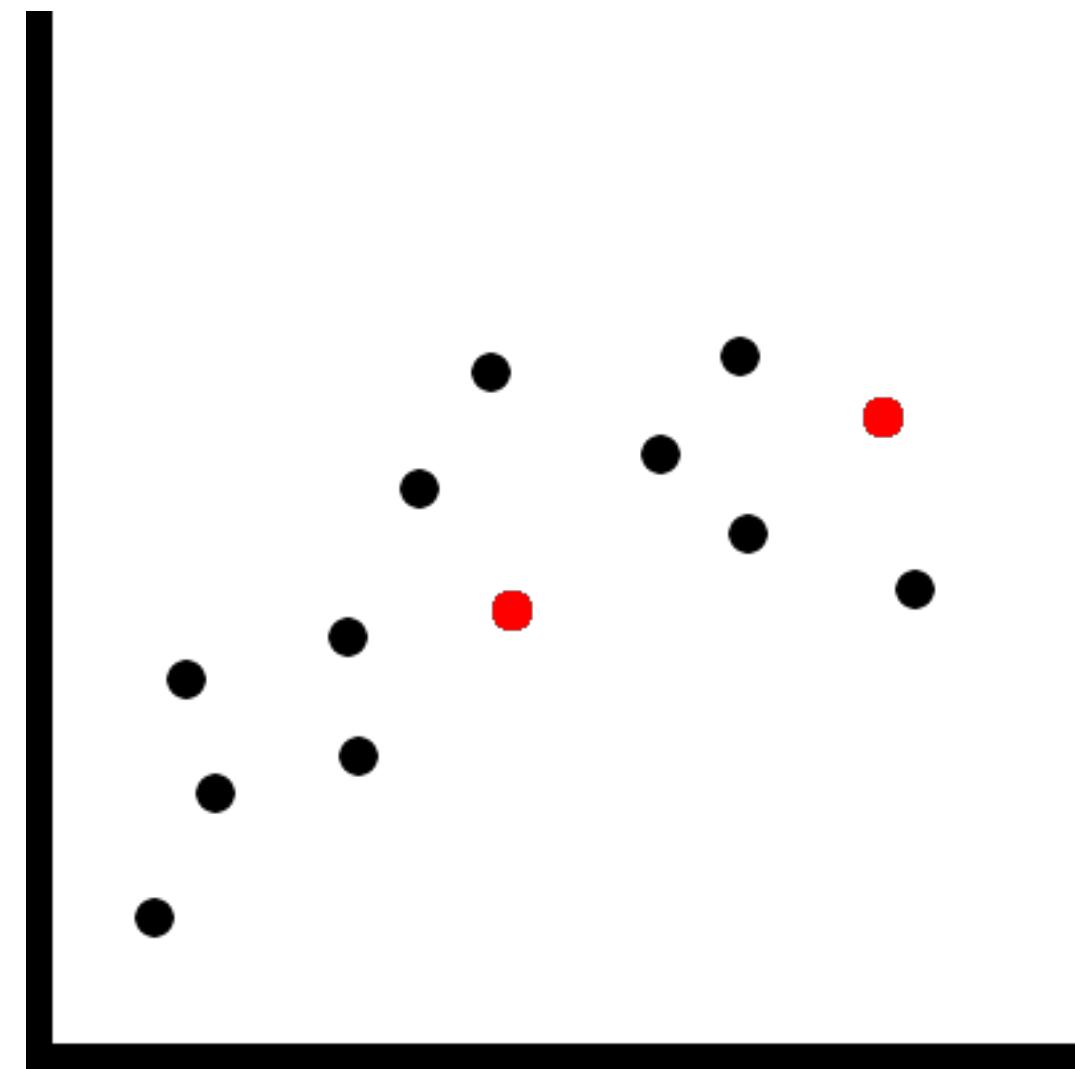
color, shape, size, value, orientation, texture, ...

Adding a glyph, label, frame, background



# Color – Perception Issues (1/2)

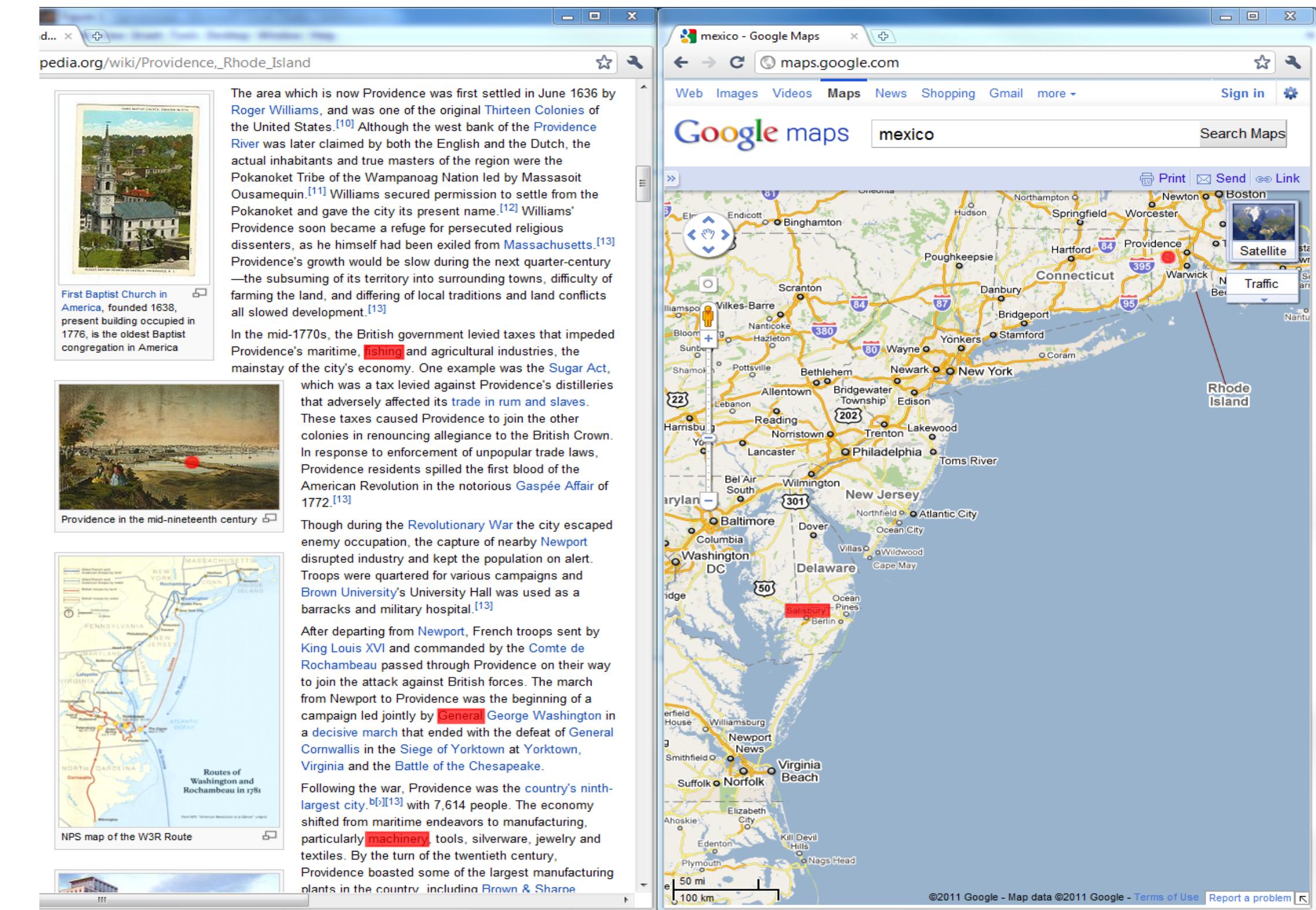
Preattentive properties: Very good for 1-2 simultaneous,  
**serial search for more**



# Color – Perception Issues (2/2)

Slower in a cluttered environment

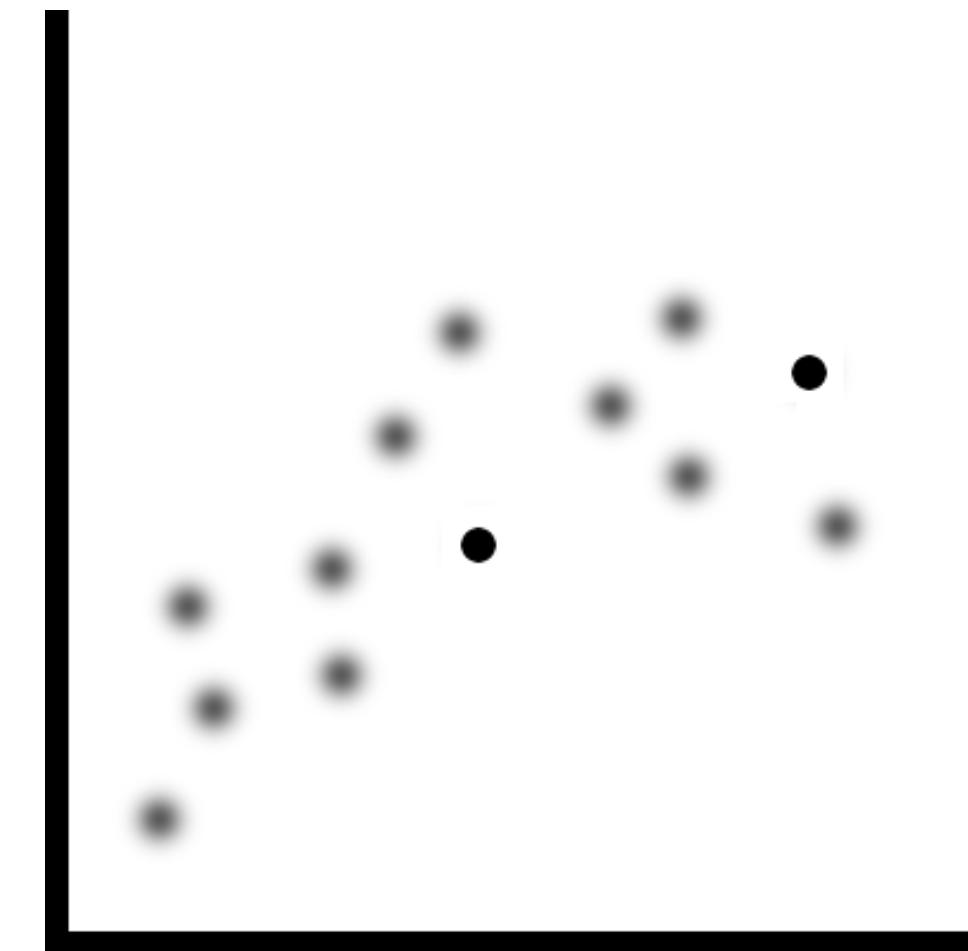
Size of colored object relevant.



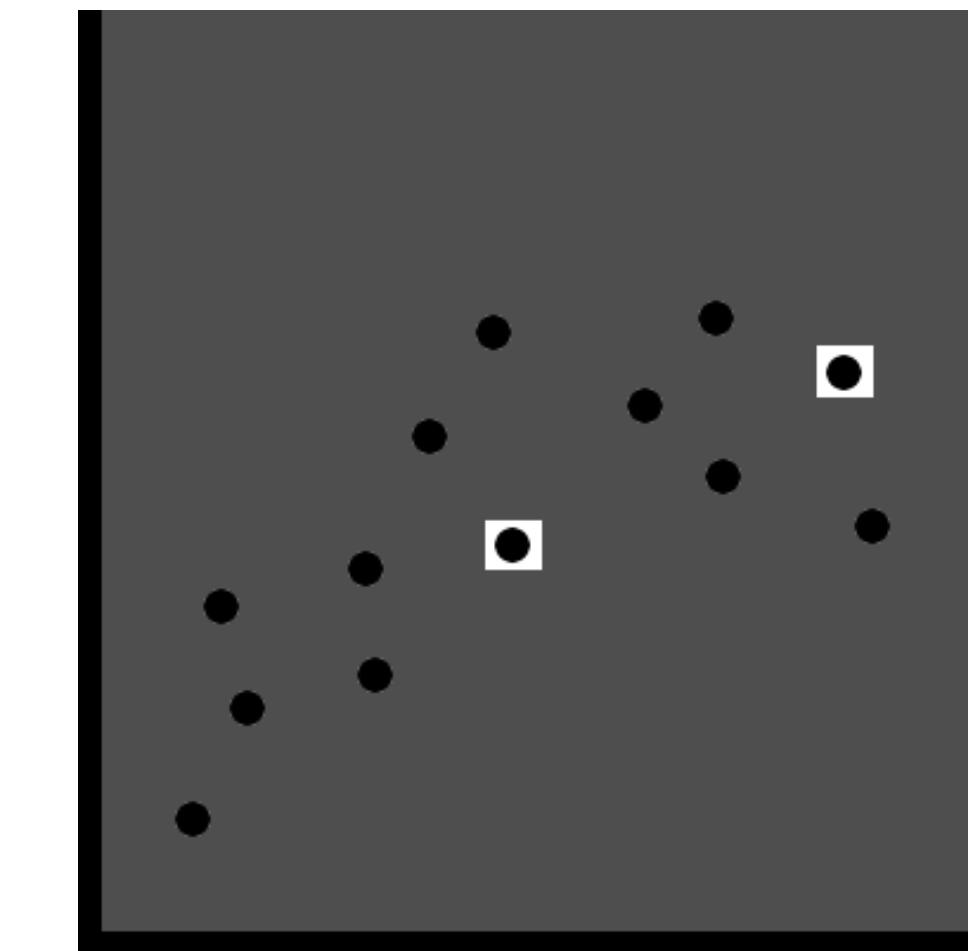
# Similarity

Modulate everything else

Blurring, darkening, desaturating, etc.



Blur



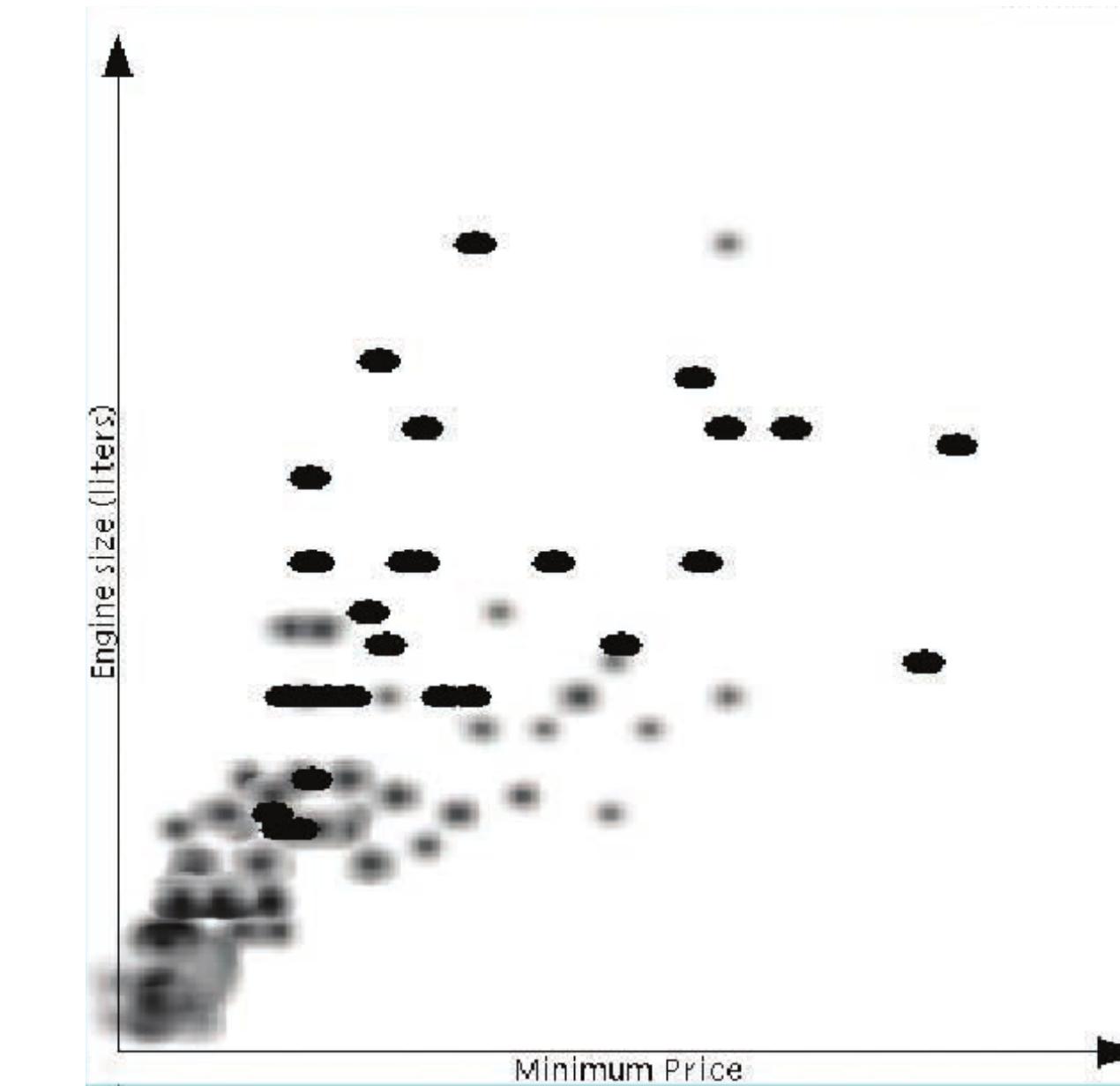
Darkening

# Modulating Everything Else: Reccomendation, Example

Don't use unless the sole objective is to guide attention toward one (set of) items

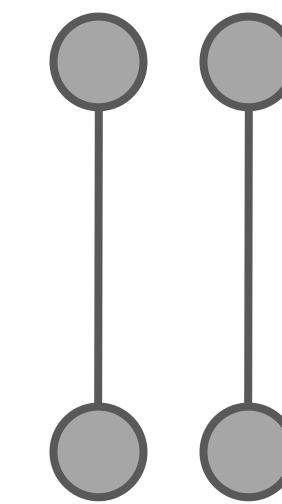


[Zhai et al., 1997]

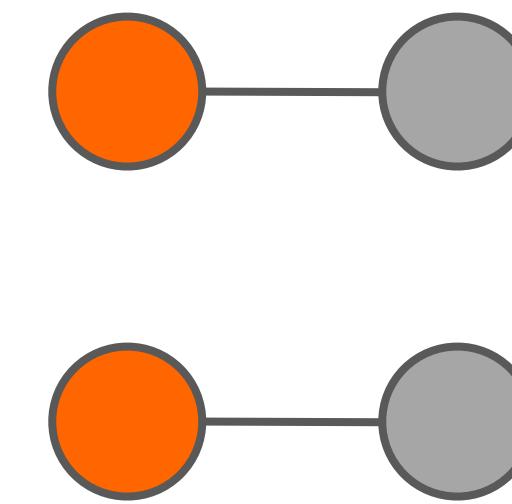


[Kosara et al., 2002]

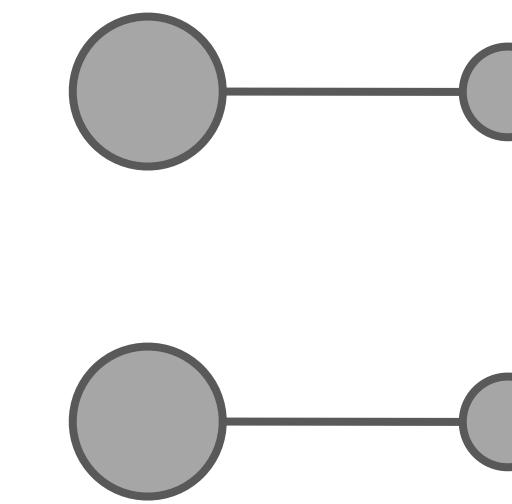
# A Little Experiment...



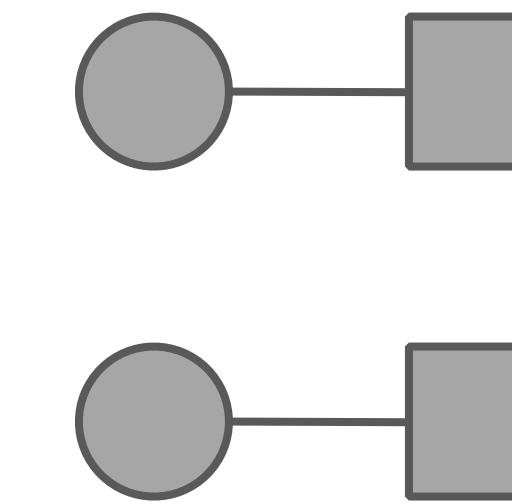
Proximity



Color



Size

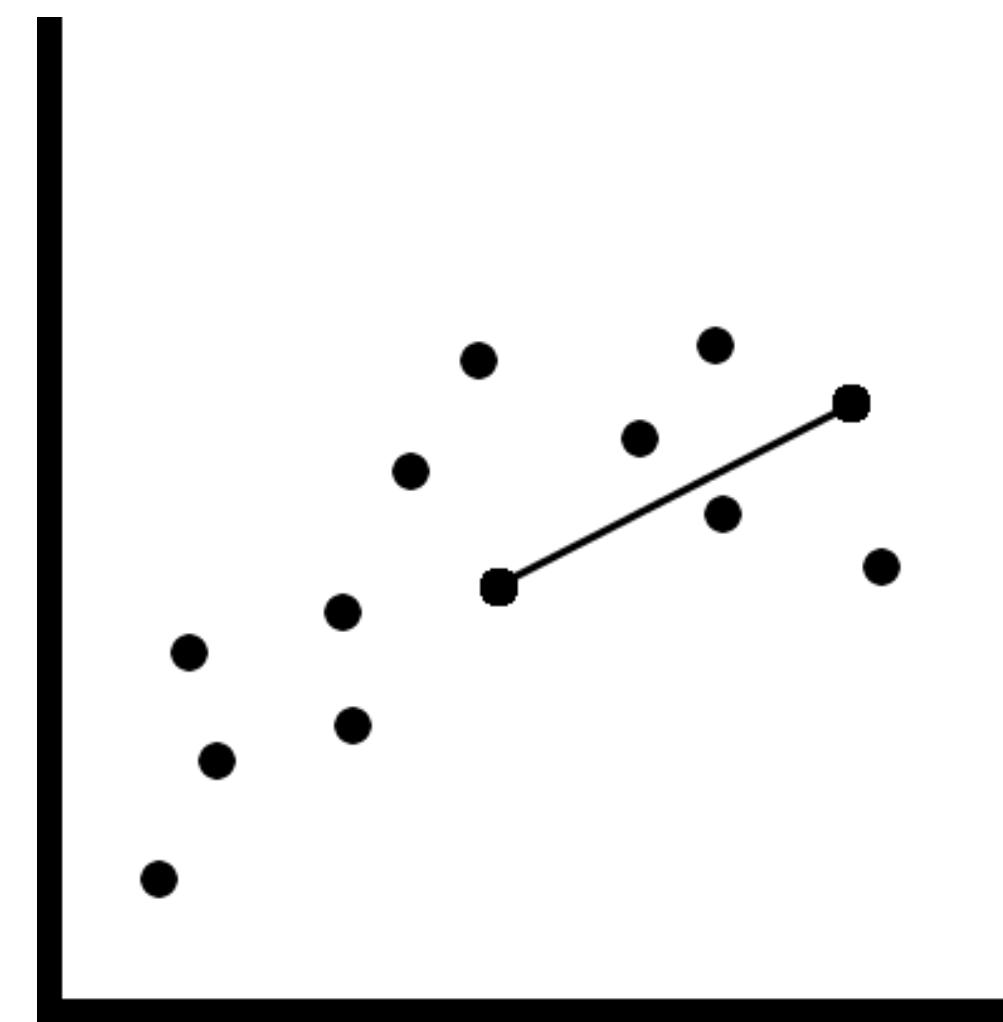


Shape

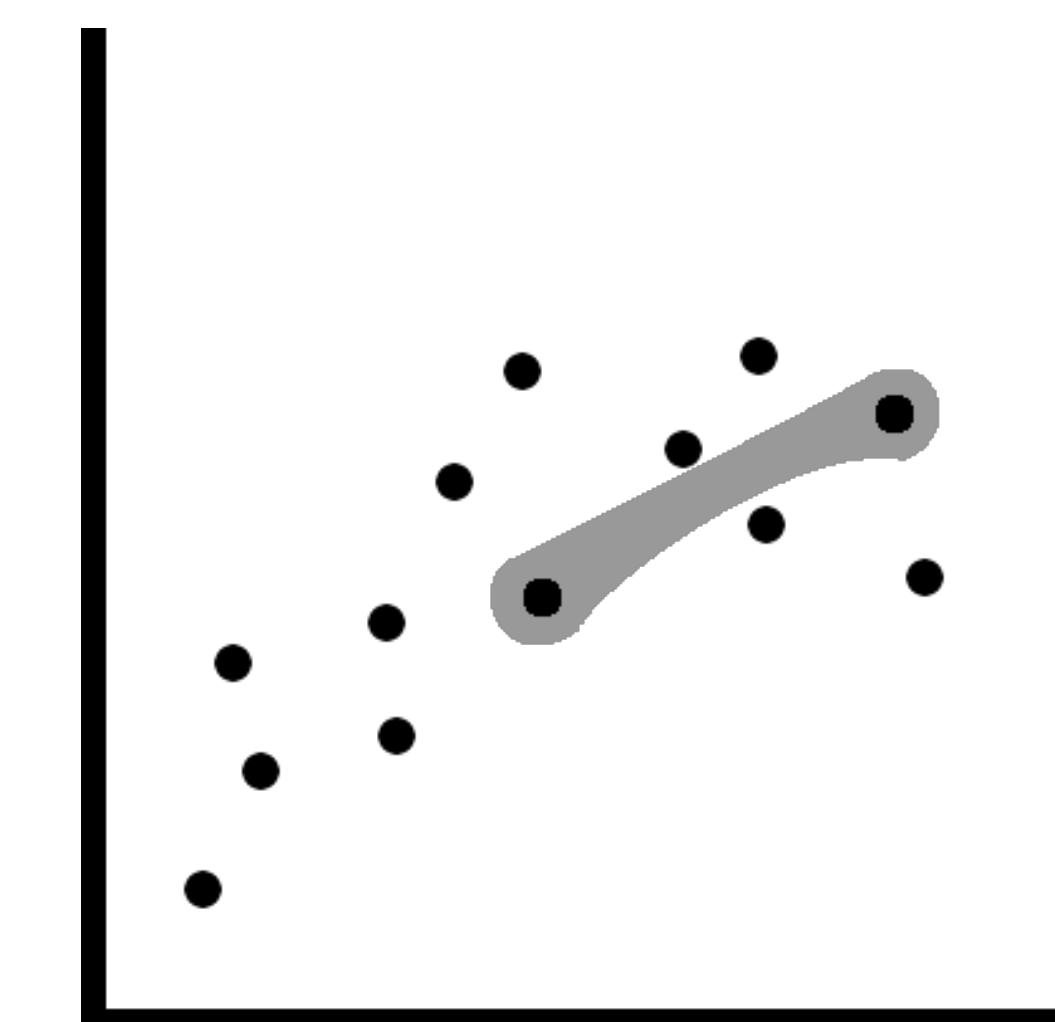
# Connectedness and Common Region

Connected items with a line or curve

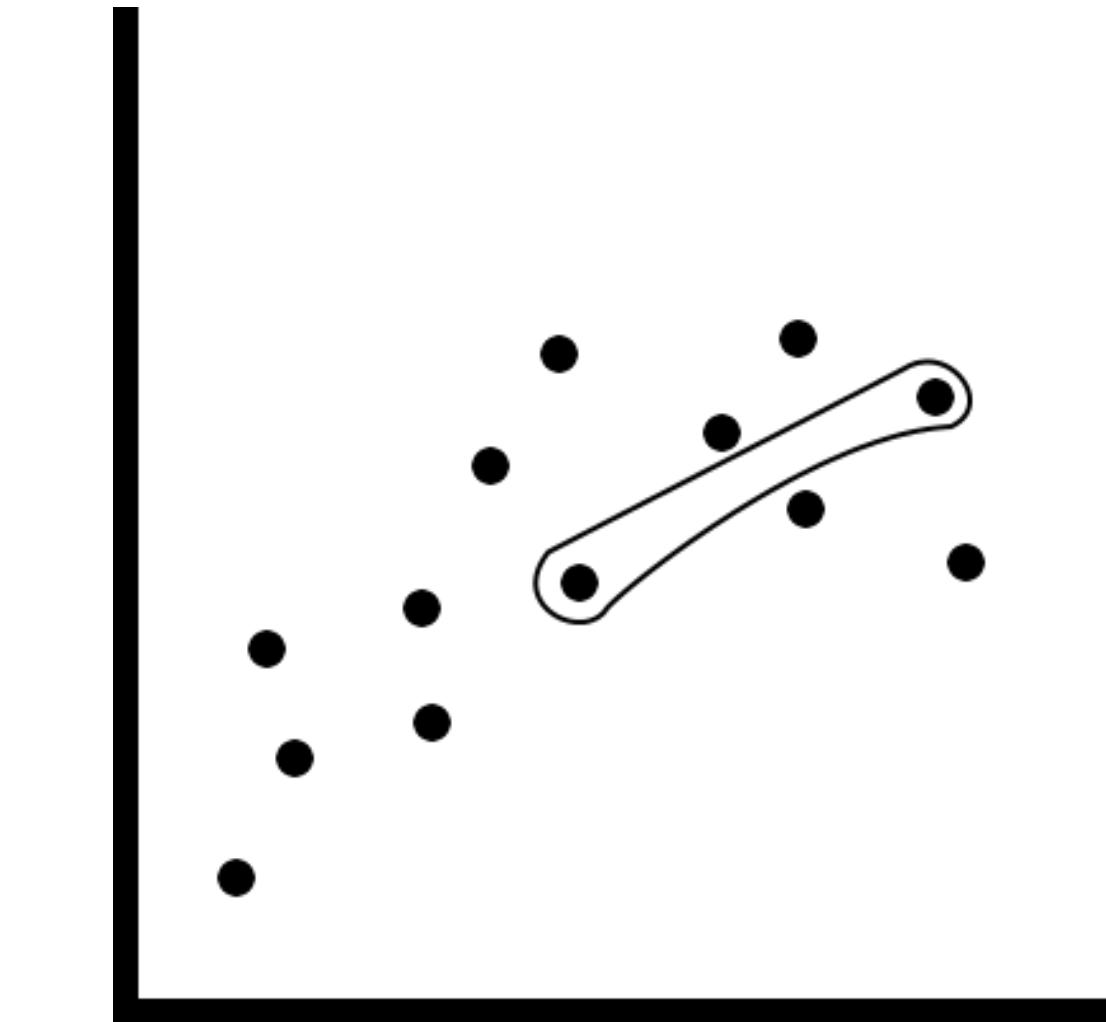
Surround items with a outline, surface, volume



Connectedness



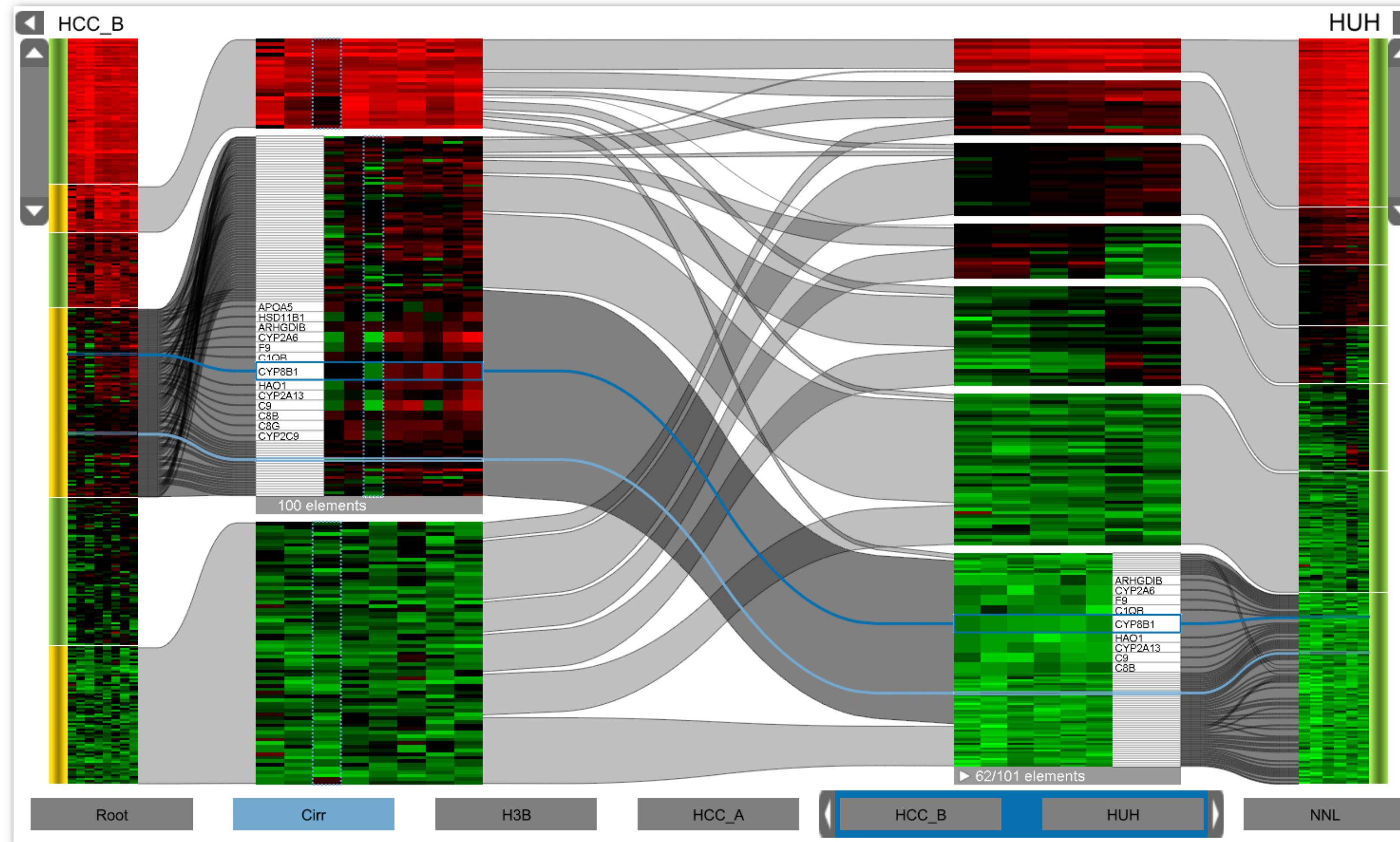
Surface



Common Region

Outline

# Connection

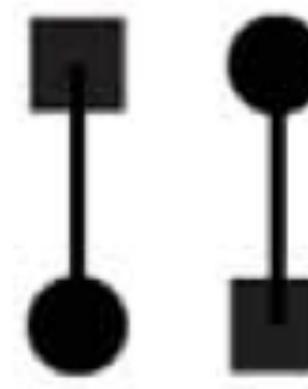


# Enclosure

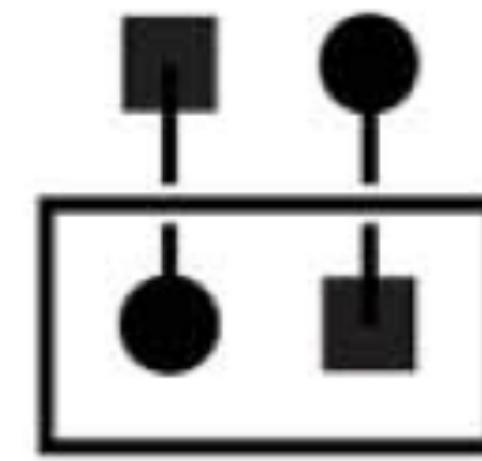
Similarity



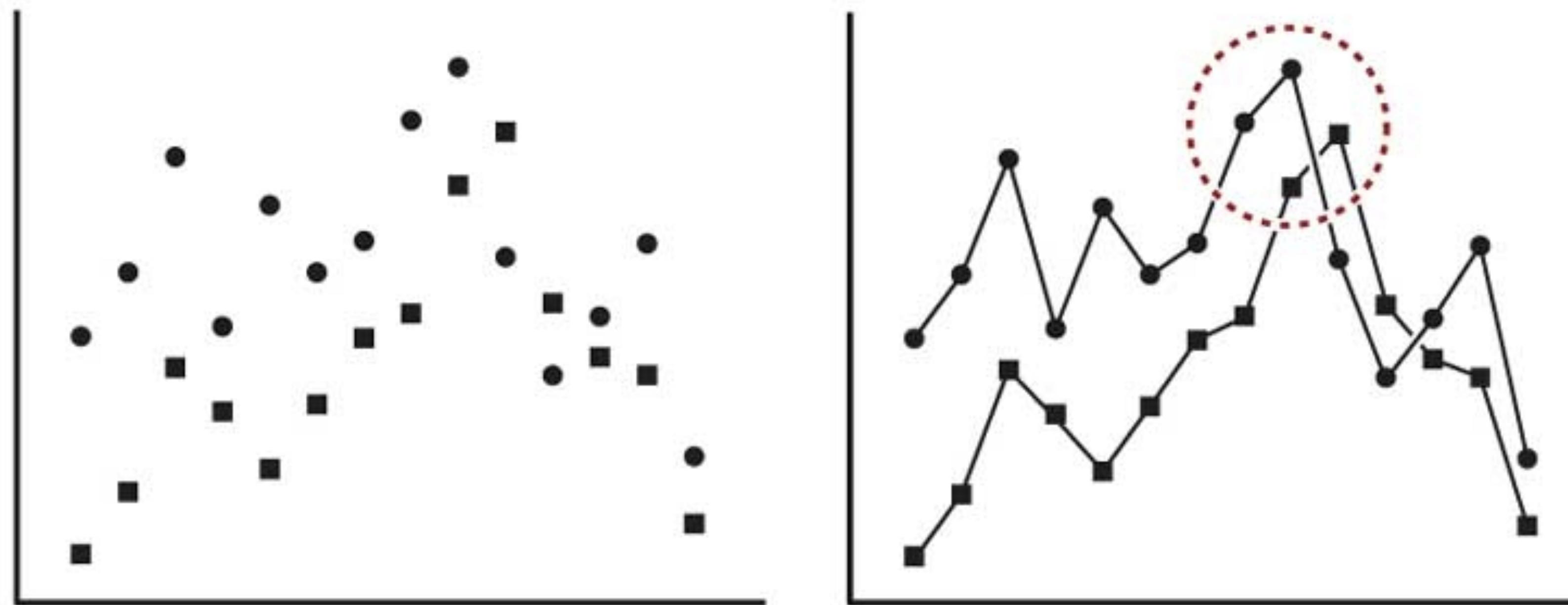
Connection



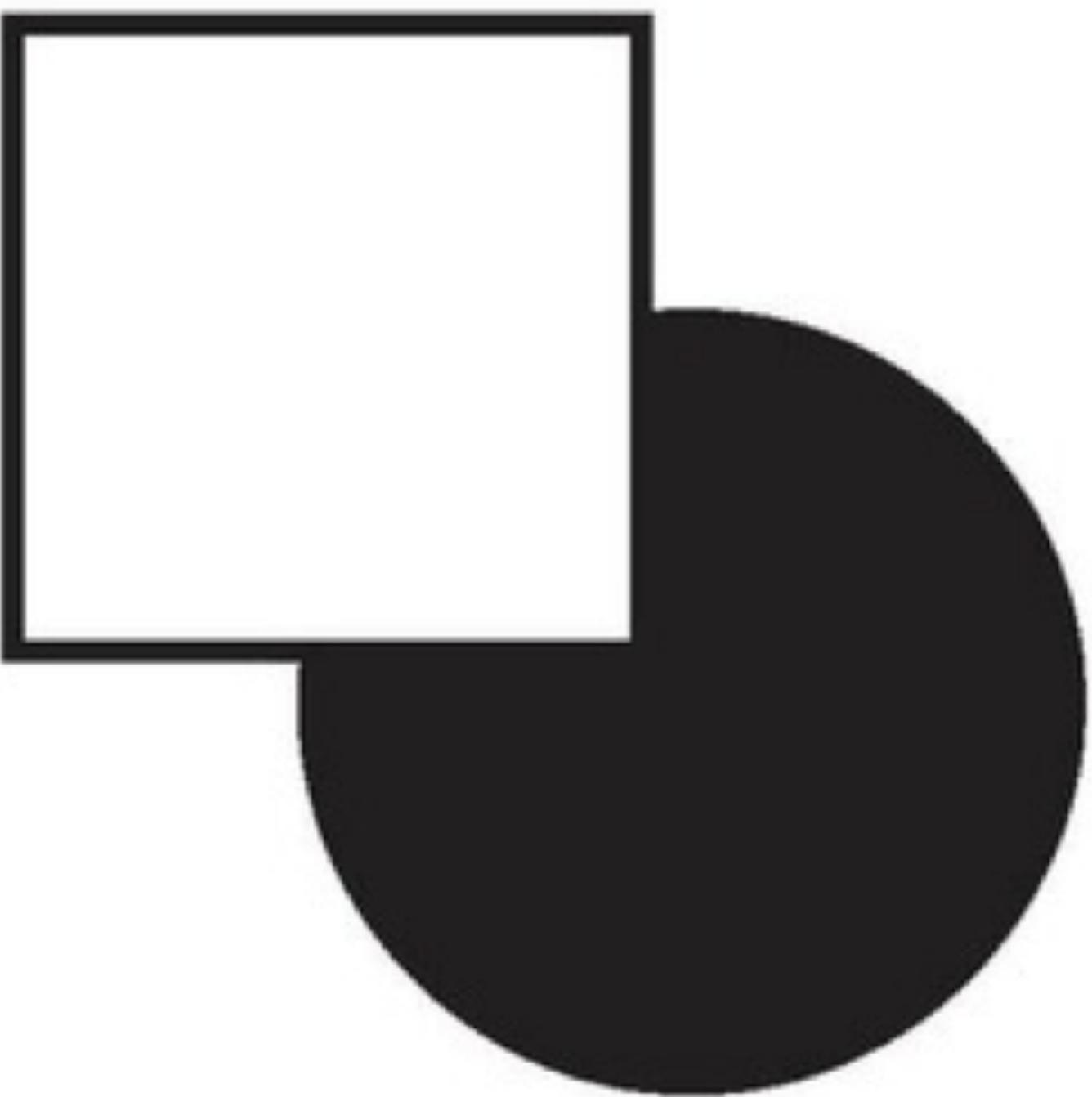
Enclosure



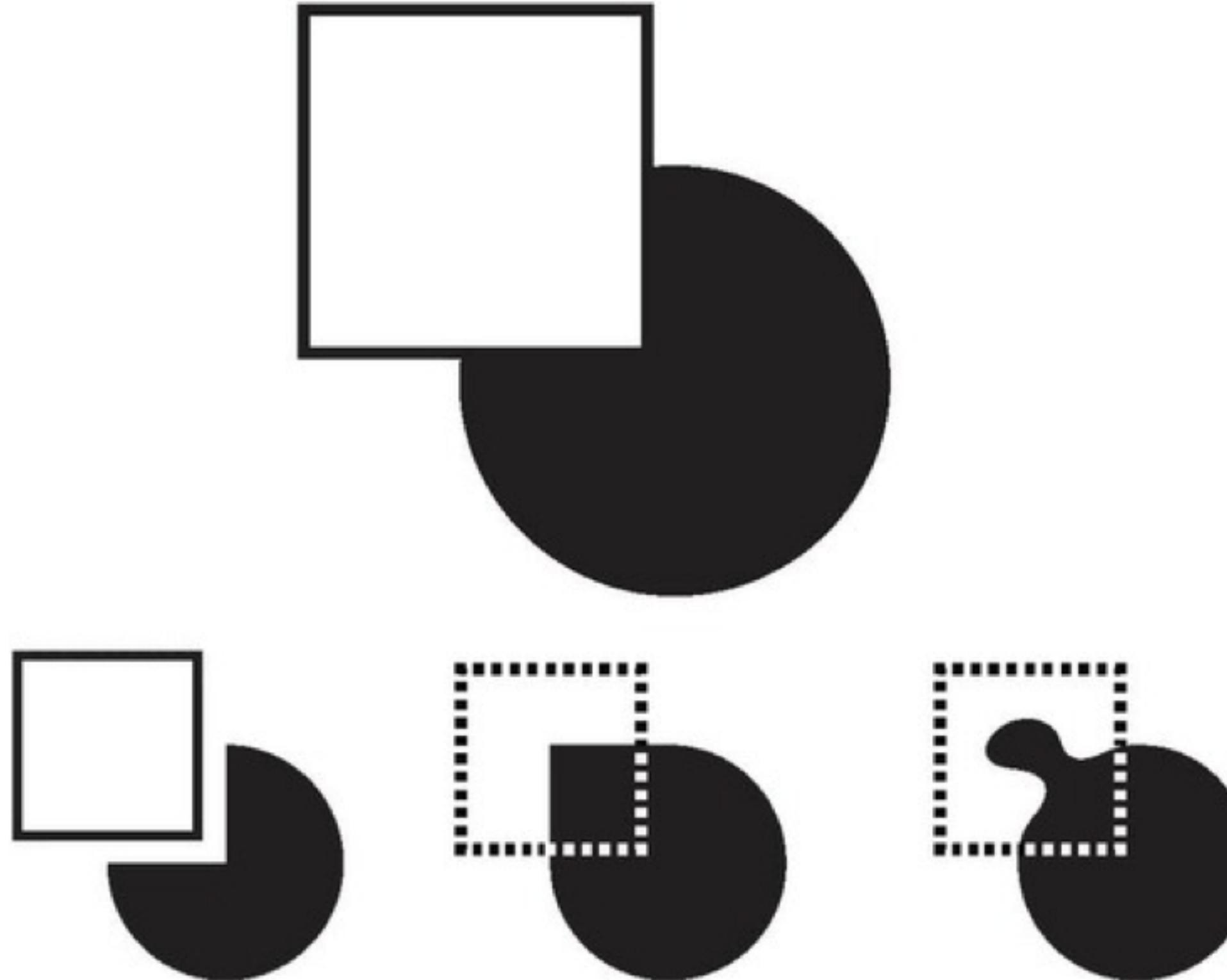
# Enclosure



# Continuity

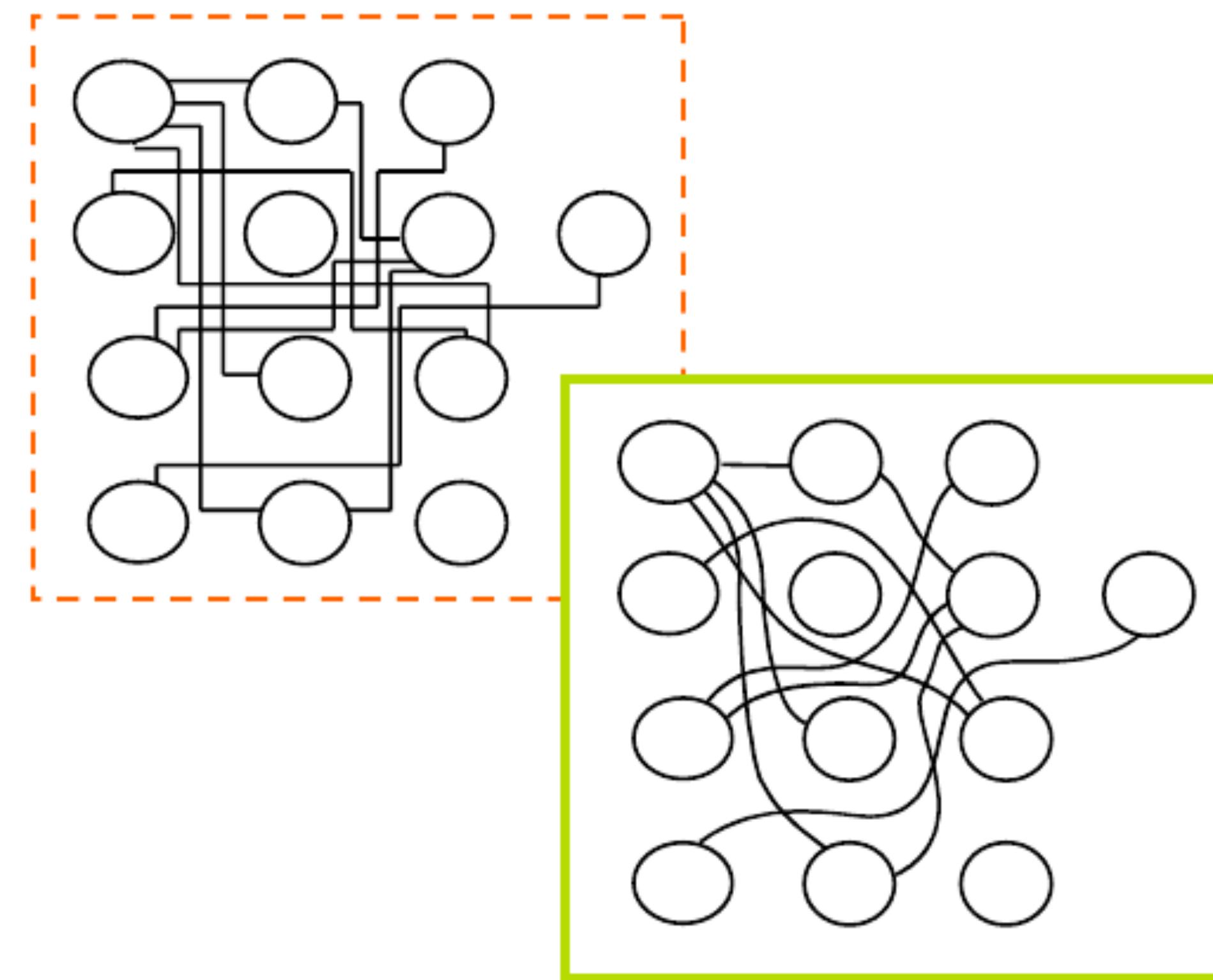
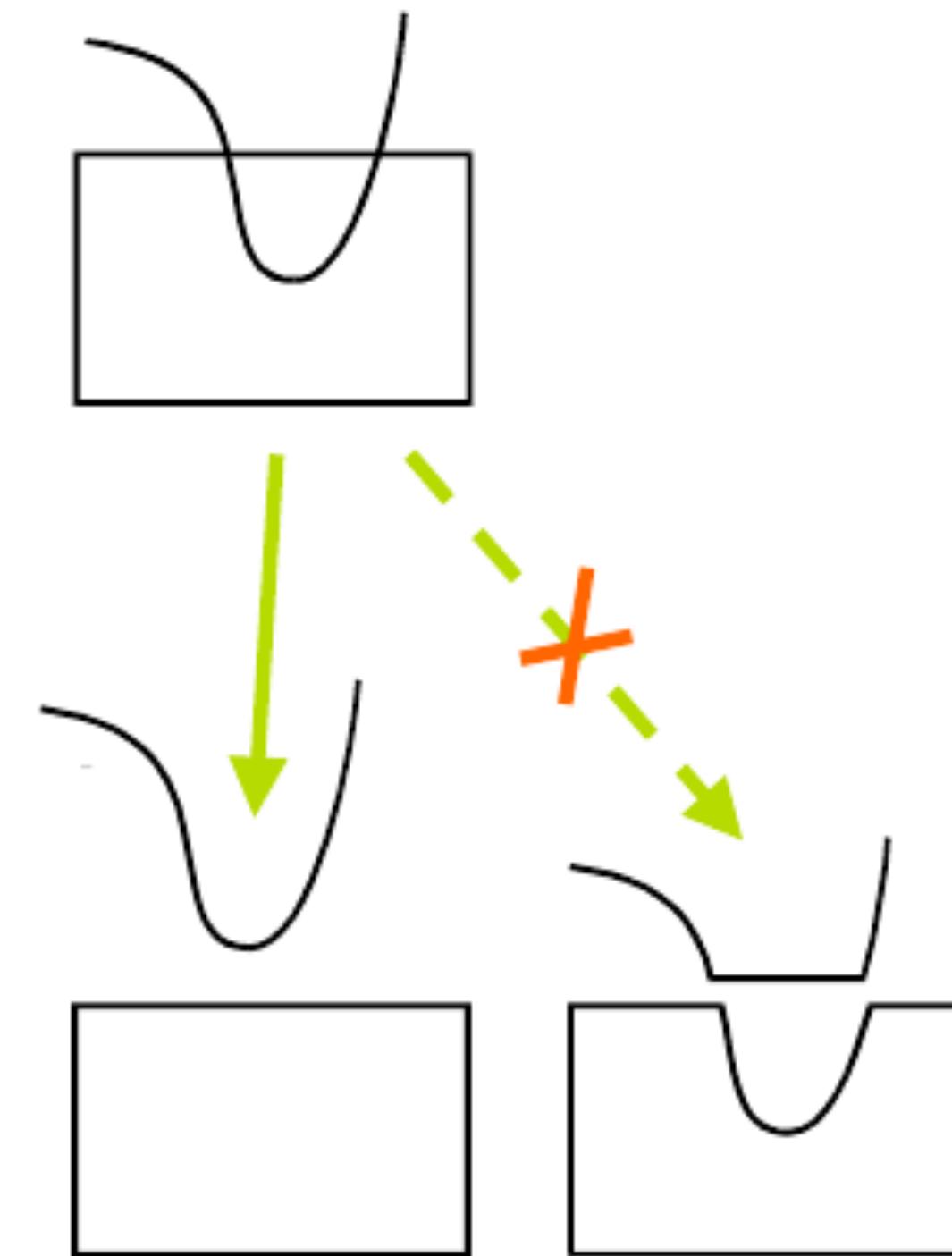


# Continuity

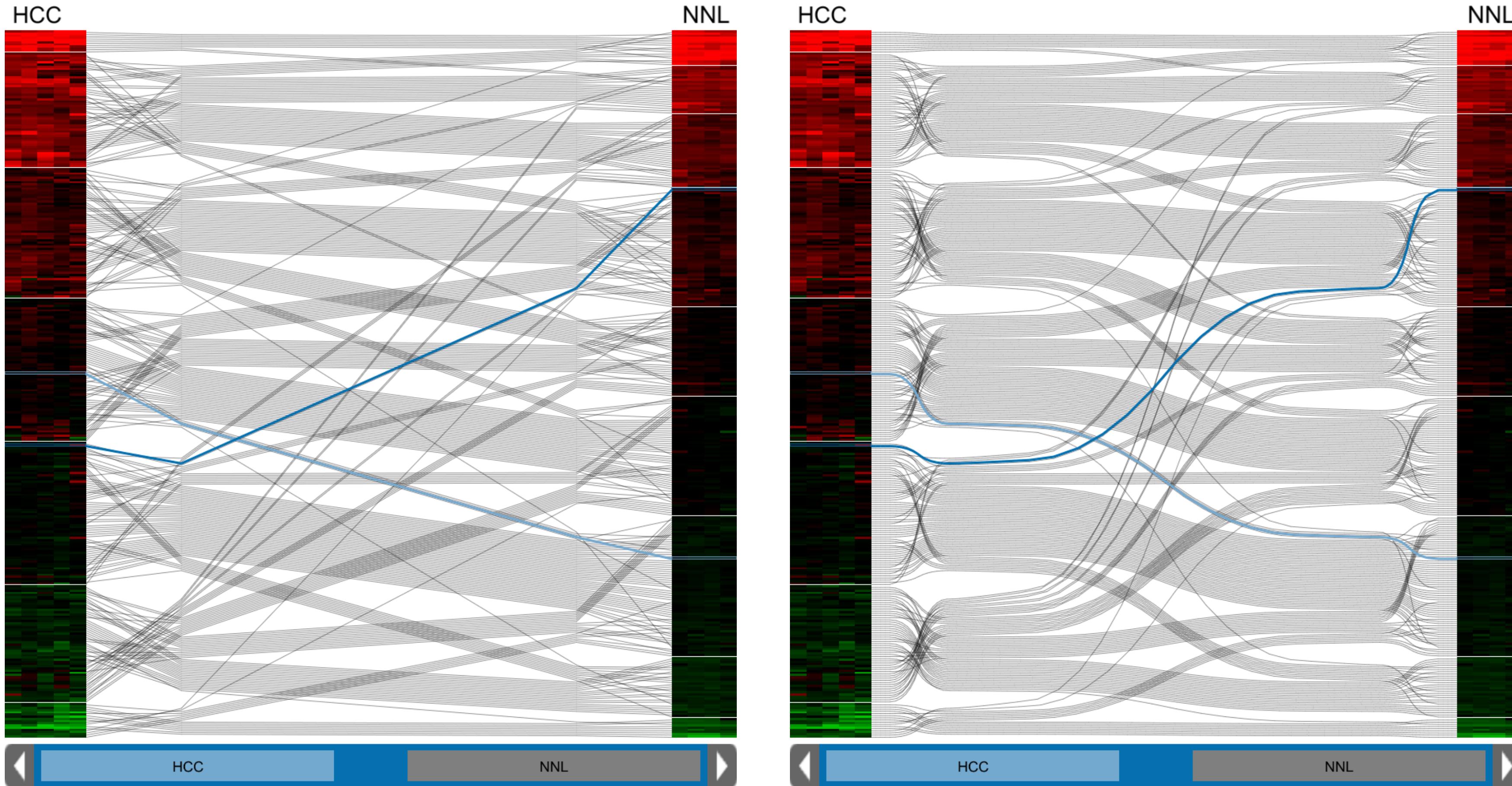


# Continuity

Things: smooth & continuous



# Continuity



# Closure

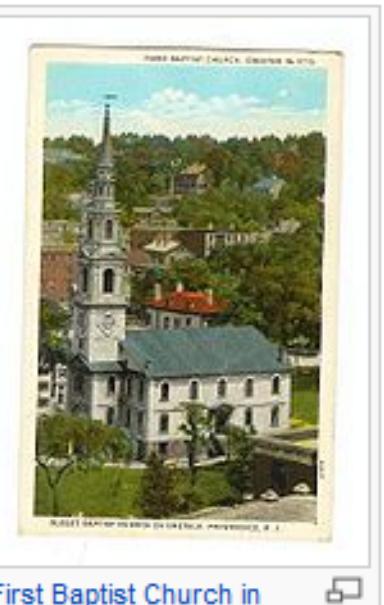


# Closure



# Applications in Vis

[d... pedia.org/wiki/Providence,\\_Rhode\\_Island](https://en.wikipedia.org/wiki/Providence,_Rhode_Island)



The area which is now Providence was first settled in June 1636 by [Roger Williams](#), and was one of the original [Thirteen Colonies](#) of the United States.<sup>[10]</sup> Although the west bank of the [Providence River](#) was later claimed by both the English and the Dutch, the actual inhabitants and true masters of the region were the Pokanoket Tribe of the Wampanoag Nation led by Massasoit Ousamequin.<sup>[11]</sup> Williams secured permission to settle from the Pokanoket and gave the city its present name.<sup>[12]</sup> Williams' Providence soon became a refuge for persecuted religious dissenters, as he himself had been exiled from [Massachusetts](#).<sup>[13]</sup> Providence's growth would be slow during the next quarter-century—the subsuming of its territory into surrounding towns, difficulty of farming the land, and differing of local traditions and land conflicts all slowed development.<sup>[13]</sup>

In the mid-1770s, the British government levied taxes that impeded Providence's maritime, fishing and agricultural industries, the mainstay of the city's economy. One example was the [Sugar Act](#), which was a tax levied against Providence's distilleries that adversely affected its [trade in rum and slaves](#). These taxes caused Providence to join the other colonies in renouncing allegiance to the British Crown. In response to enforcement of unpopular trade laws, Providence residents spilled the first blood of the American Revolution in the notorious [Gaspée Affair](#) of 1772.<sup>[13]</sup>

Though during the [Revolutionary War](#) the city escaped enemy occupation, the capture of nearby [Newport](#) disrupted industry and kept the population on alert. Troops were quartered for various campaigns and [Brown University](#)'s University Hall was used as a barracks and military hospital.<sup>[13]</sup>

After departing from [Newport](#), French troops sent by King Louis XVI and commanded by the [Comte de Rochambeau](#) passed through Providence on their way to join the attack against British forces. The march from Newport to Providence was the beginning of a campaign led jointly by General [George Washington](#) in a [decisive march](#) that ended with the defeat of General Cornwallis in the [Siege of Yorktown](#) at Yorktown, Virginia and the [Battle of the Chesapeake](#).

Following the war, Providence was the [country's ninth-largest city](#).<sup>b[b][13]</sup> with 7,614 people. The economy shifted from maritime endeavors to manufacturing, particularly machinery, tools, silverware, jewelry and textiles. By the turn of the twentieth century, Providence boasted some of the largest manufacturing plants in the country including [Brown & Sharpe](#).



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This Google Map displays the region around Rhode Island, showing state boundaries and major roads. The map includes labels for Boston, Providence, and several cities in Connecticut, Massachusetts, New York, New Jersey, Delaware, Maryland, and Virginia. A red arrow points from the text in the left window to the location of Rhode Island on the map.

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[https://en.wikipedia.org/wiki/Providence,\\_Rhode\\_Island](https://en.wikipedia.org/wiki/Providence,_Rhode_Island)

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Though during the Revolutionary War the city escaped enemy occupation, the capture of nearby Newport disrupted industry and kept the population on alert. Troops were quartered for various campaigns and Brown University's University Hall was used as a barracks and military hospital.<sup>[16]</sup>

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**First Baptist Church in America**, founded 1638, present building occupied in 1776, is the oldest Baptist congregation in America

**Providence in the mid-nineteenth century**

**NPS map of the WSR Route**

<https://www.google.com/maps>

Google maps

mexico

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Satellite

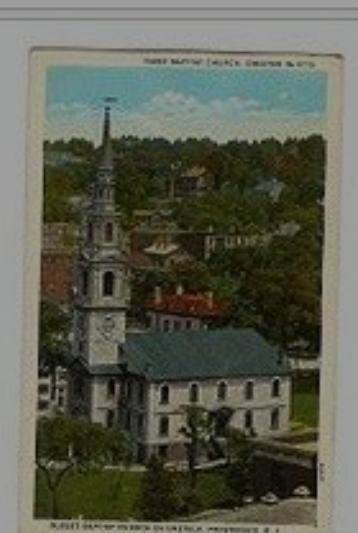
Traffic

Rhode Island

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This is a screenshot of a Google Maps search for "mexico". The map displays the eastern coast of North America, specifically the region from New England down to the southern tip of the continent. Major cities and geographical features are visible, including Boston, Providence, Hartford, Springfield, Worcester, Albany, and various coastal towns. A red arrow points from the text "Rhode Island" in the left sidebar to the small island of Rhode Island on the map. The map interface includes standard controls for zooming and panning.

[https://en.wikipedia.org/wiki/Providence,\\_Rhode\\_Island](https://en.wikipedia.org/wiki/Providence,_Rhode_Island)



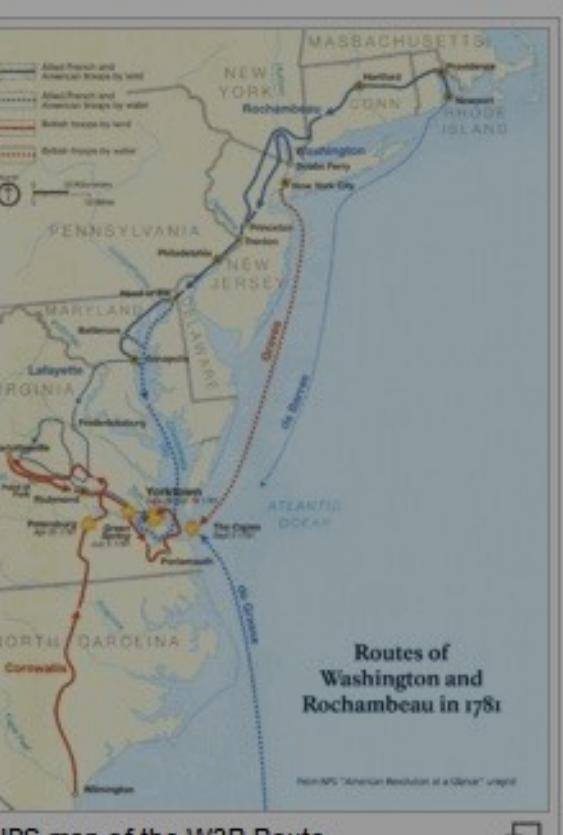
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In the mid-1770s, the British government levied taxes that impeded Providence's maritime, fishing and agricultural industries, the mainstay of the city's economy. One example was the Sugar Act, which was a tax levied against Providence's distilleries that adversely affected its trade in rum and slaves. These taxes caused Providence to join the other colonies in renouncing allegiance to the British Crown. In response to enforcement of unpopular trade laws, Providence residents spilled the first blood of the American Revolution in the notorious Gaspée Affair of 1772.<sup>[13]</sup>

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Following the war, Providence was the country's ninth-largest city.<sup>b[13]</sup> with 7,614 people. The economy shifted from maritime endeavors to manufacturing, particularly machinery, tools, silverware, jewelry and textiles. By the turn of the twentieth century, Providence boasted some of the largest manufacturing plants in the country including Brown & Sharpe.



NPS map of the W3R Route

<http://maps.google.com>

Google maps

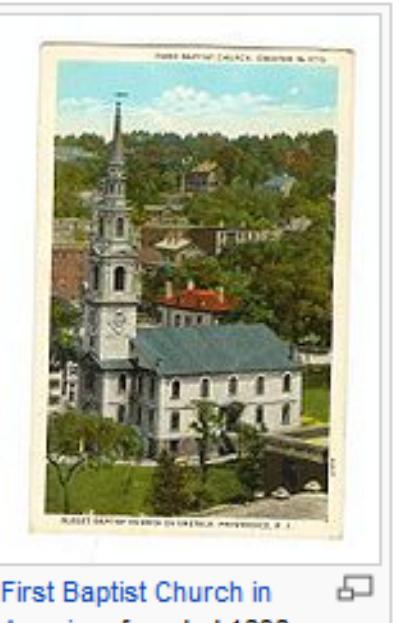
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A Google Map showing the location of Rhode Island. The map includes state boundaries and major cities such as Boston, Providence, Hartford, and New York. Major highways like I-95, I-90, and I-84 are visible. A 'Traffic' overlay is shown on the right side of the map.

[d... pedia.org/wiki/Providence,\\_Rhode\\_Island](http://en.wikipedia.org/wiki/Providence,_Rhode_Island)



The area which is now Providence was first settled in June 1636 by [Roger Williams](#), and was one of the original [Thirteen Colonies](#) of the United States.<sup>[10]</sup> Although the west bank of the [Providence River](#) was later claimed by both the English and the Dutch, the actual inhabitants and true masters of the region were the Pokanoket Tribe of the Wampanoag Nation led by Massasoit Ousamequin.<sup>[11]</sup> Williams secured permission to settle from the Pokanoket and gave the city its present name.<sup>[12]</sup> Williams' Providence soon became a refuge for persecuted religious dissenters, as he himself had been exiled from [Massachusetts](#).<sup>[13]</sup> Providence's growth would be slow during the next quarter-century—the subsuming of its territory into surrounding towns, difficulty of farming the land, and differing of local traditions and land conflicts all slowed development.<sup>[13]</sup>

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NPS map of the W3R Route

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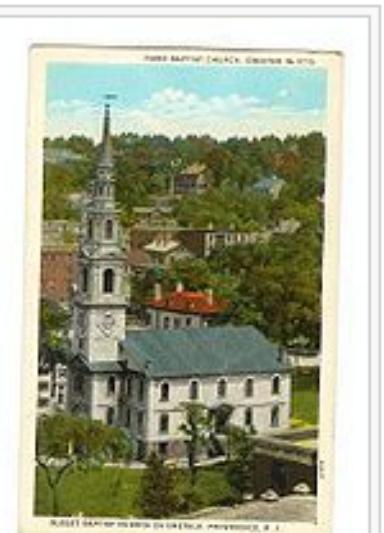
Satellite

Traffic



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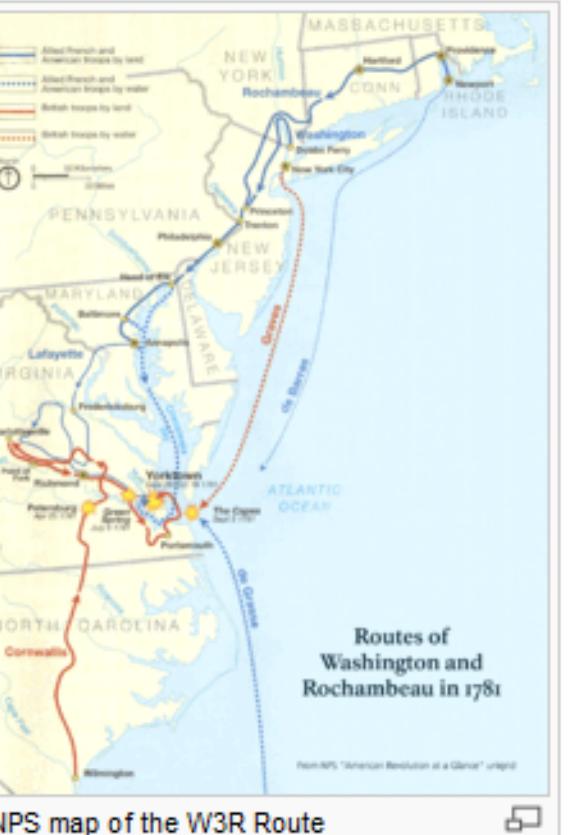
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In the mid-1770s, the British government levied taxes that impeded Providence's maritime, [fishing](#) and agricultural industries, the mainstay of the city's economy. One example was the [Sugar Act](#), which was a tax levied against Providence's distilleries that adversely affected its [trade in rum and slaves](#). These taxes caused Providence to join the other colonies in renouncing allegiance to the British Crown. In response to enforcement of unpopular trade laws, Providence residents spilled the first blood of the American Revolution in the notorious [Gaspée Affair](#) of 1772.<sup>[13]</sup>

Though during the [Revolutionary War](#) the city escaped enemy occupation, the capture of nearby [Newport](#) disrupted industry and kept the population on alert. Troops were quartered for various campaigns and [Brown University](#)'s University Hall was used as a barracks and military hospital.<sup>[13]</sup>

After departing from [Newport](#), French troops sent by King Louis XVI and commanded by the [Comte de Rochambeau](#) passed through Providence on their way to join the attack against British forces. The march from Newport to Providence was the beginning of a campaign led jointly by [General George Washington](#) in a decisive march that ended with the defeat of General Cornwallis in the [Siege of Yorktown](#) at Yorktown, Virginia and the [Battle of the Chesapeake](#).

Following the war, Providence was the [country's ninth-largest city](#).<sup>[13]</sup> with 7,614 people. The economy shifted from maritime endeavors to manufacturing, particularly [machinery](#), tools, silverware, jewelry and textiles. By the turn of the twentieth century, Providence boasted some of the largest manufacturing plants in the country including [Brown & Sharpe](#).



NPS map of the W3R Route

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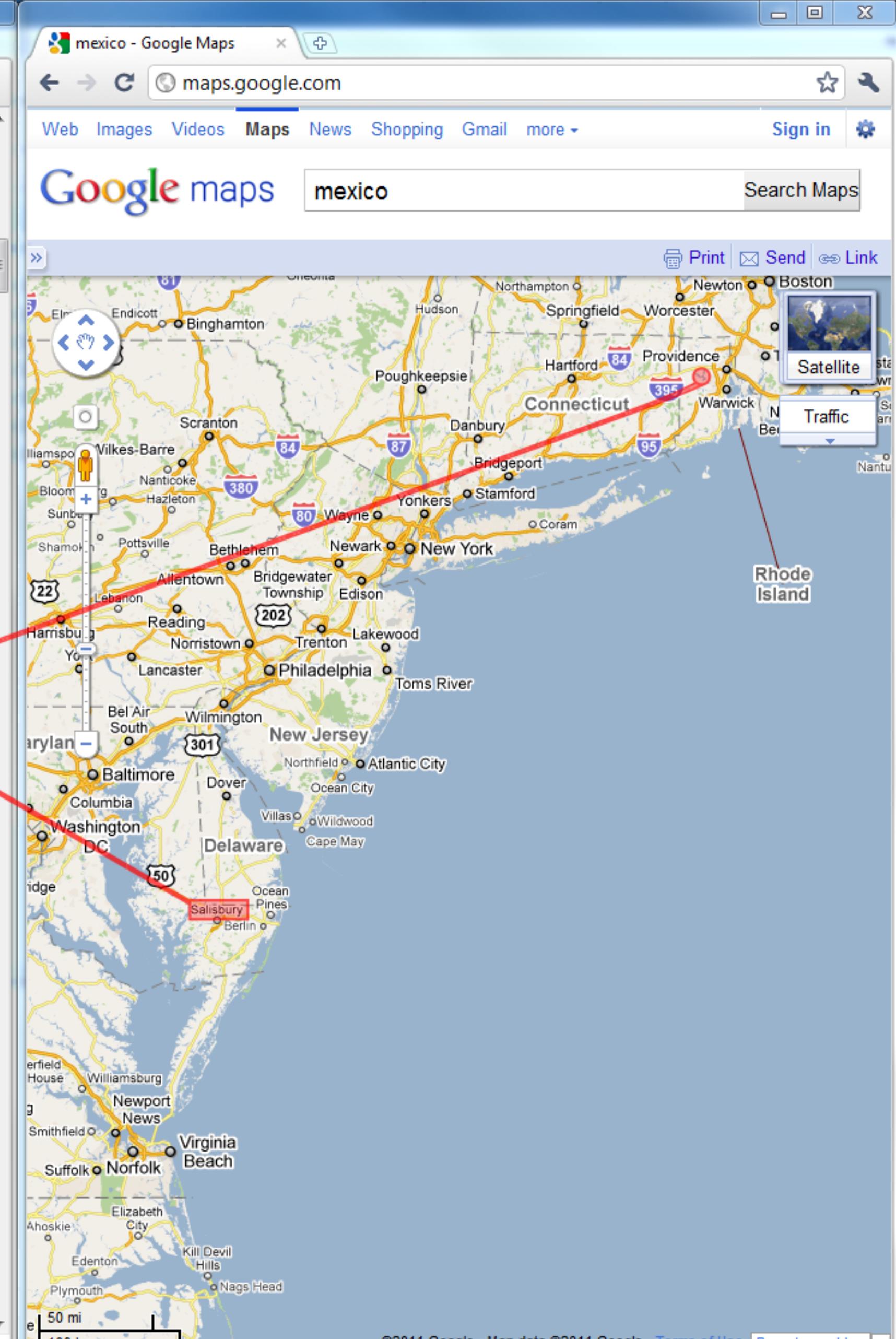
The area which is now Providence was first settled in June 1636 by Roger Williams, and was one of the original Thirteen Colonies of the United States.<sup>[10]</sup> Although the west bank of the Providence River was later claimed by both the English and the Dutch, the actual inhabitants and true masters of the region were the Pokanoket Tribe of the Wampanoag Nation led by Massasoit Ousamequin.<sup>[11]</sup> Williams secured permission to settle from the Pokanoket and gave the city its present name.<sup>[12]</sup> Williams' Providence soon became a refuge for persecuted religious dissenters, as he himself had been exiled from Massachusetts.<sup>[13]</sup> Providence's growth would be slow during the next quarter-century—the subsuming of its territory into surrounding towns, difficulty of farming the land, and differing of local traditions and land conflicts all slowed development.<sup>[13]</sup>

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# What is the problem?

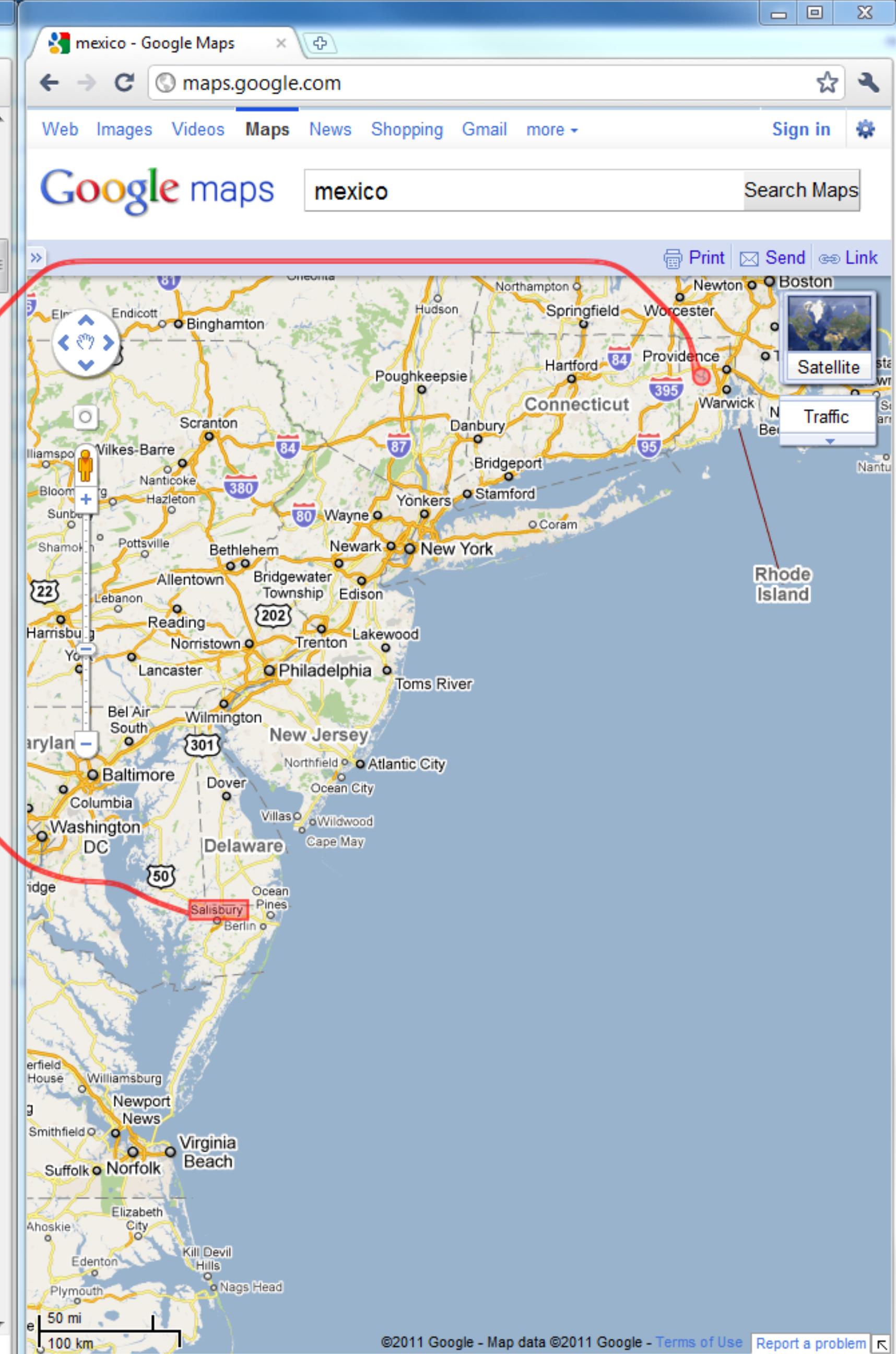
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# Context-Preserving Visual Links

# Takeaways

Knowing about Perception is important for Vis and UI design

How to choose your colors

How to show relationships

How to draw attention

How to minimize risk of overlooking