

CSE 332  
INTRODUCTION TO VISUALIZATION  
VISUAL DESIGN & AESTHETICS

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Lecture	Topic	Projects
1	Intro, schedule, and logistics	
2	Applications of visual analytics, data, and basic tasks	
3	Data preparation and reduction	Project 1 out
4	Data preparation and reduction	
5	Data reduction and similarity metrics	
6	Dimension reduction	
7	Introduction to D3	Project 2 out
8	Bias in visualization	
9	Perception and cognition	
10	Visual design and aesthetics	
11	Cluster and pattern analysis	
12	High-Dimensional data visualization: linear methods	Project 3 out
13	High-D data vis.: non-linear methods, categorical data	
14	Computer graphics and volume rendering	
15	Techniques to visualize spatial (3D) data	
16	Scientific and medical visualization	
17	Scientific and medical visualization	
18	Non-photorealistic rendering	Project 4 out
19	Midterm	
20	Principles of interaction	
21	Visual analytics and the visual sense making process	
22	Visualization of graphs and hierarchies	
23	Visualization of text data	Project 5 out
24	Visualization of time-varying and time-series data	
25	Memorable visualizations, visual embellishments	
26	Evaluation and user studies	
27	Narrative visualization and storytelling	
28	Data journalism	

# THREE KEY VISUAL REPRESENTATIONS

## Gestalt Principles:

- the tendency to perceive elements as belonging to a group, based on certain visual properties

## Pre-attentiveness:

- certain low level visual aspects are recognized before conscious awareness

## Visual variables:

- the different visual aspects that can be used to encode information

# GESTALT

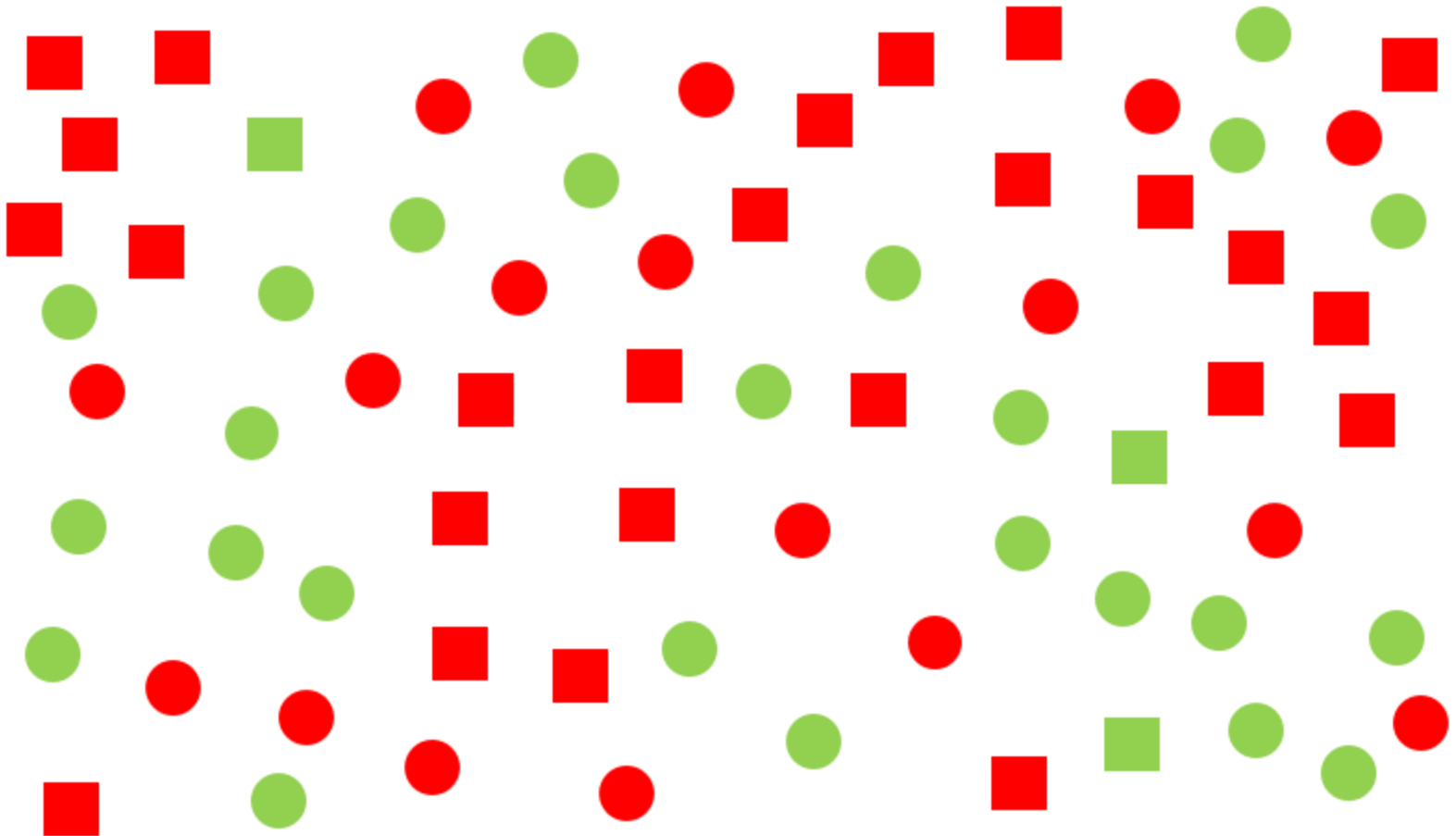
## Concept of totality

- you grasp the "totality" of something before worrying about the details



# PRE-ATTENTIVENESS

Also called pop-out (multiple conjunctions shown here):



# WHICH POPPED-OUT FASTER

Color (red vs. green)

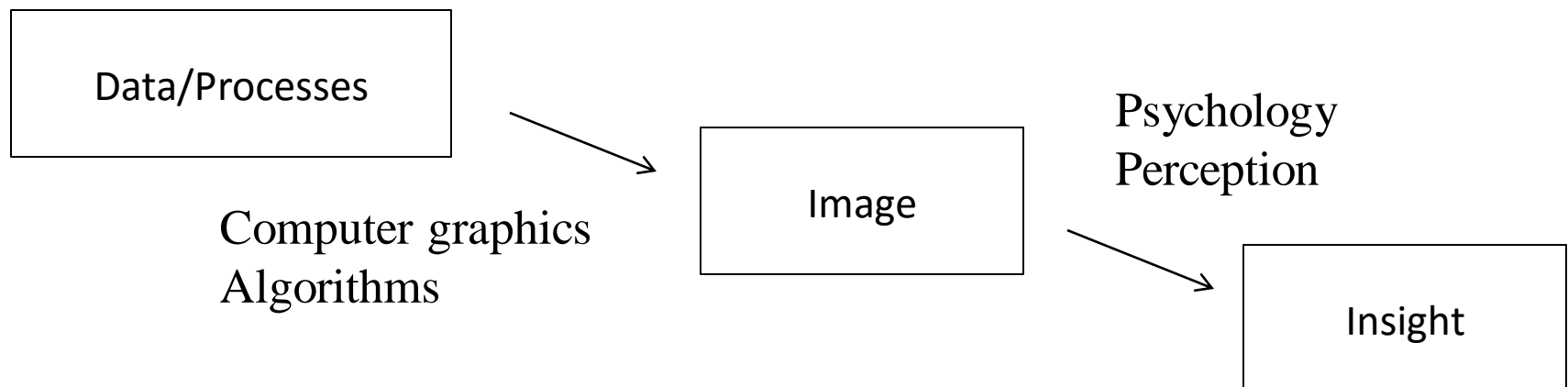
Shape (circle vs. square)

# VISUAL VARIABLES

Formal theory linking perception to visualization

Established by Jacques Bertin (1967)

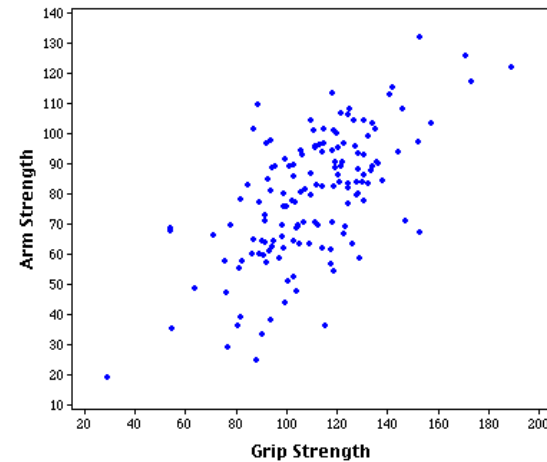
- he called it 'Image Theory'
- original book in French (*Sémiologie Graphique*) translated into English by W. Berg (1983)
- not formally linked to vision research more based on intuition
- but has been shown later by M. Green to be quite accurate



# VISUAL VARIABLES

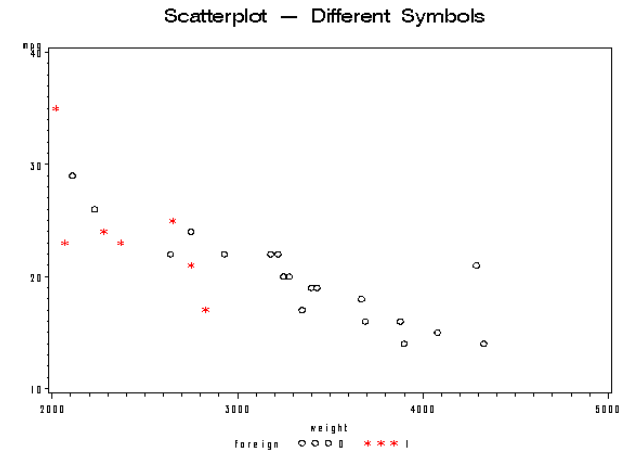
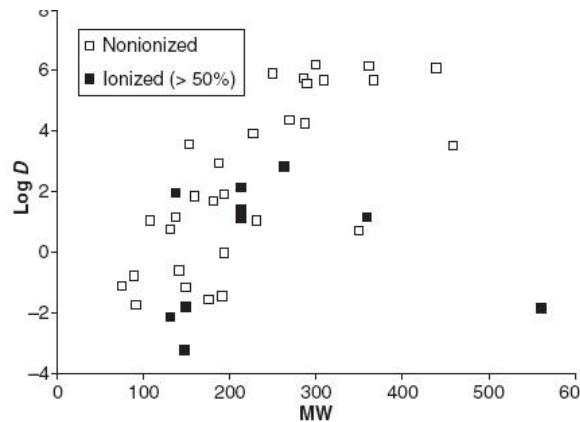
## Two planar variables

- spatial dimensions
- map (arm, grip) to (x,y)



## Six retinal variables

- size
- color
- shape
- orientation
- texture
- brightness



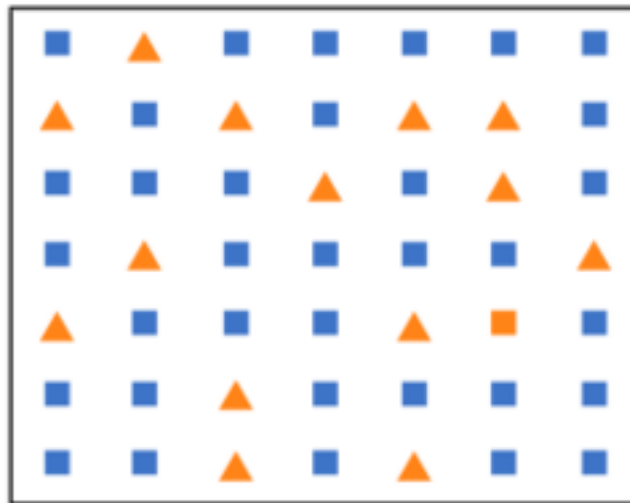
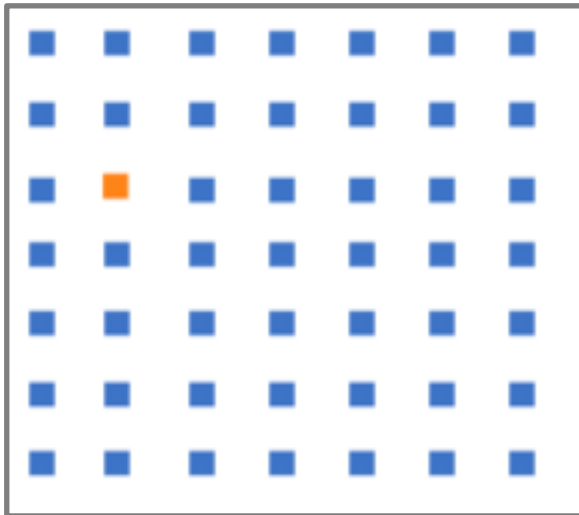
## Retinal variables allow for one more variable to be encoded

- more than three variables will hamper efficient visual search
- recall low decoding speed of conjunctions



# VISUAL SEARCH

Find the orange square



Left: just color (pre-attentive, no visual search needed)

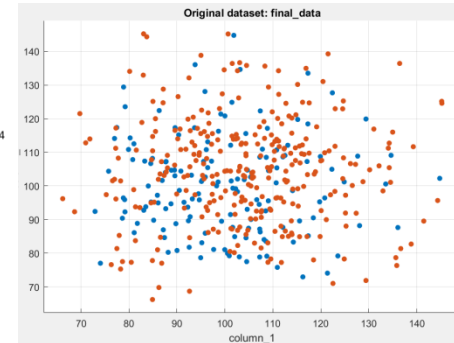
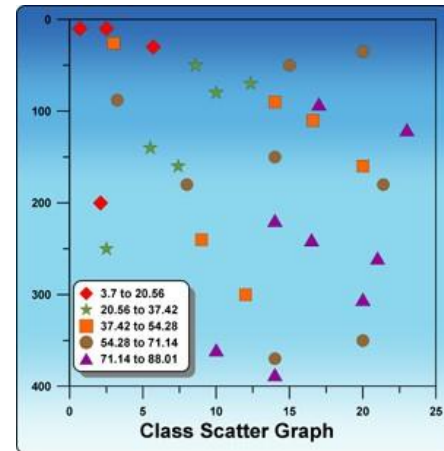
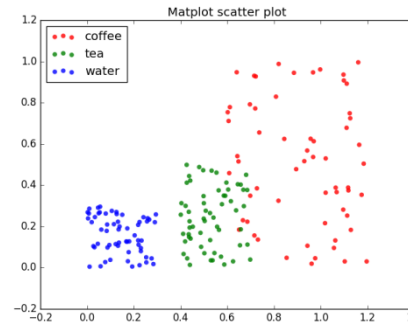
Right: color and shape (requires visual search)

# ASSOCIATIVE VS. SELECTIVE

Both are nominal qualities

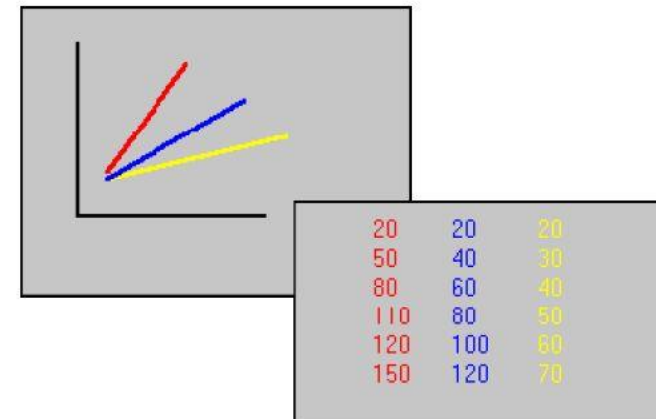
## Associative

- lowest organizational level
- enables **visual grouping** of all elements of a variable



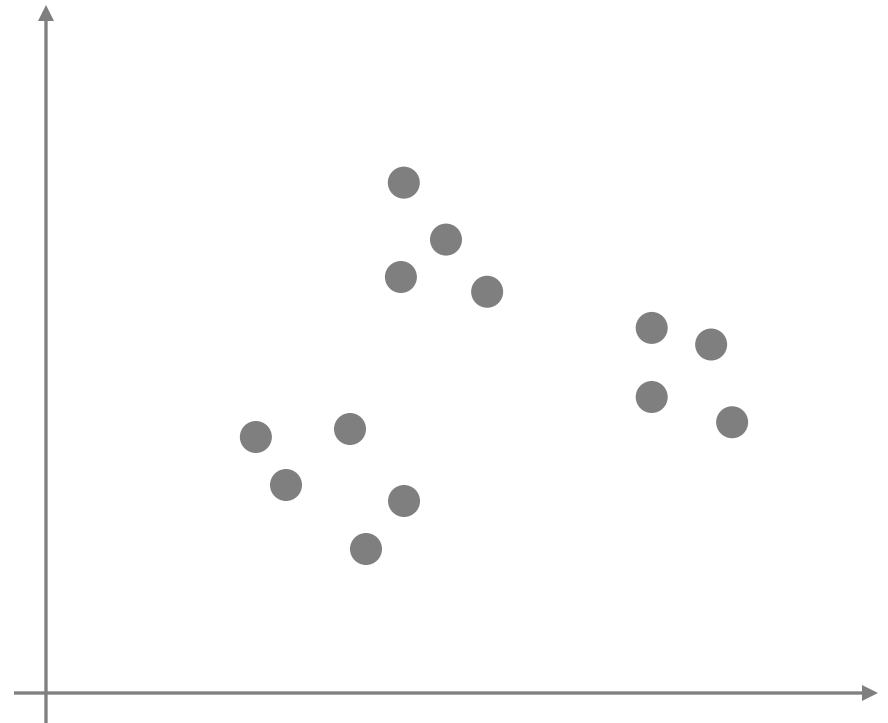
## Selective

- next lowest level
- enables viewer to **isolate encoded data** and ignore others



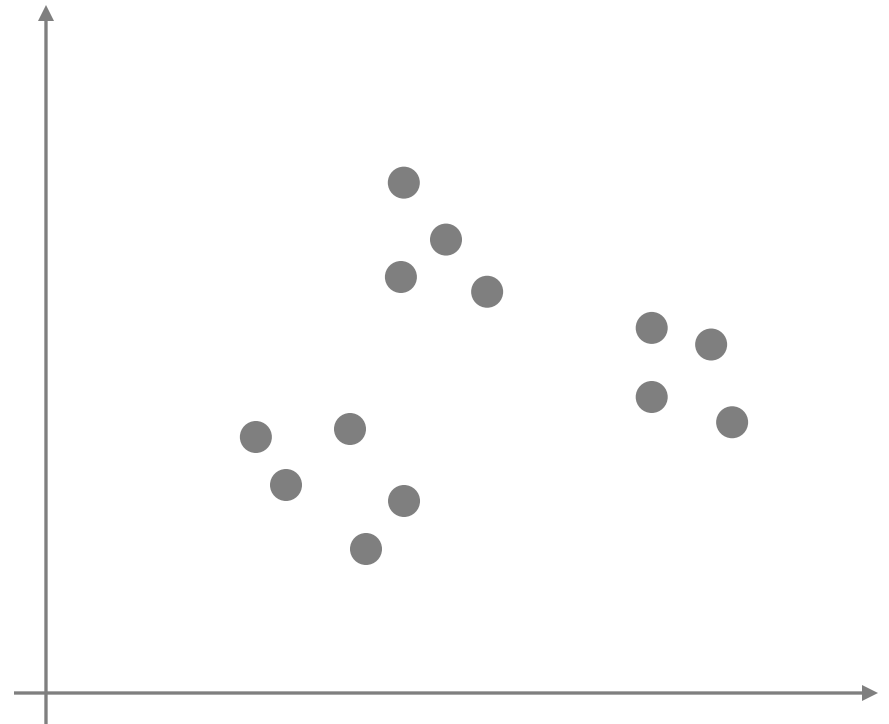
# VISUAL VARIABLE #1 – PLANAR

Visual property	Can convey
Associative	
Selective	
Ordered	
Quantitative	



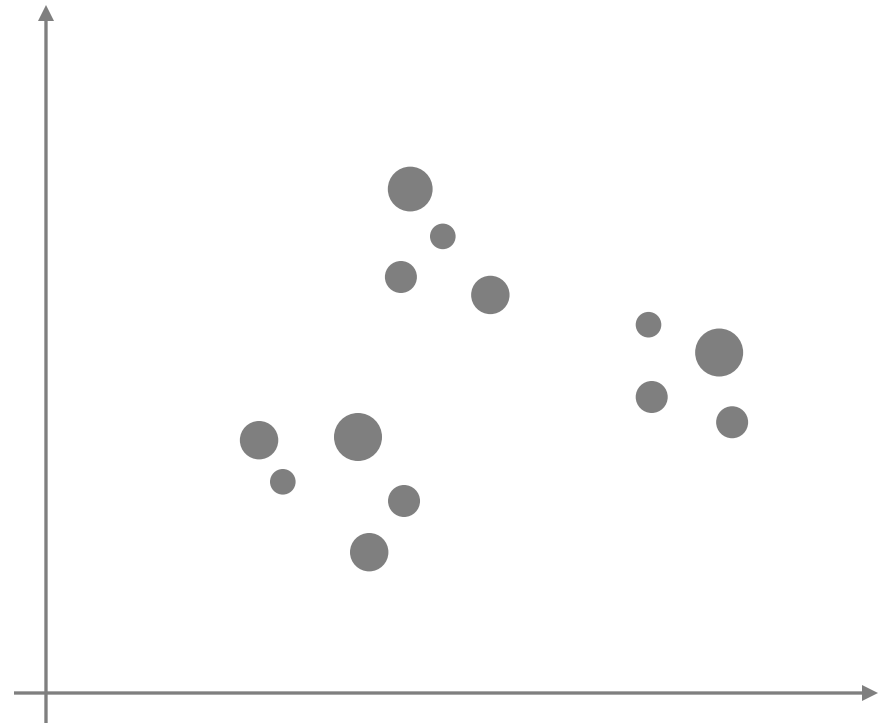
# VISUAL VARIABLE #1 – PLANAR

Visual property	Can convey
Associative	Y
Selective	Y
Ordered	Y
Quantitative	Y



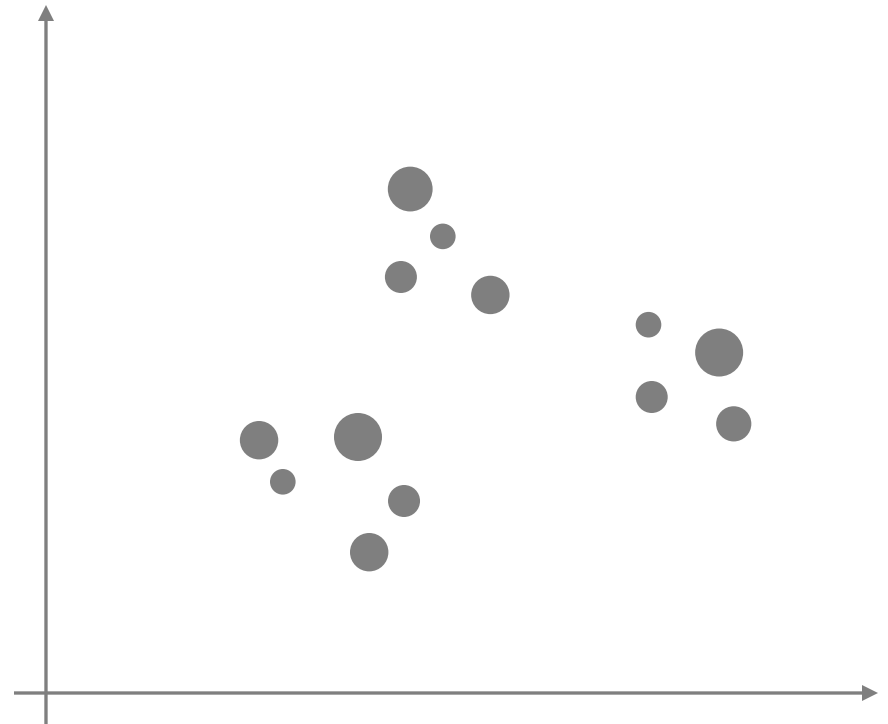
# VISUAL VARIABLE #2 – SIZE

Visual property	Can convey
Associative	
Selective	
Ordered	
Quantitative	



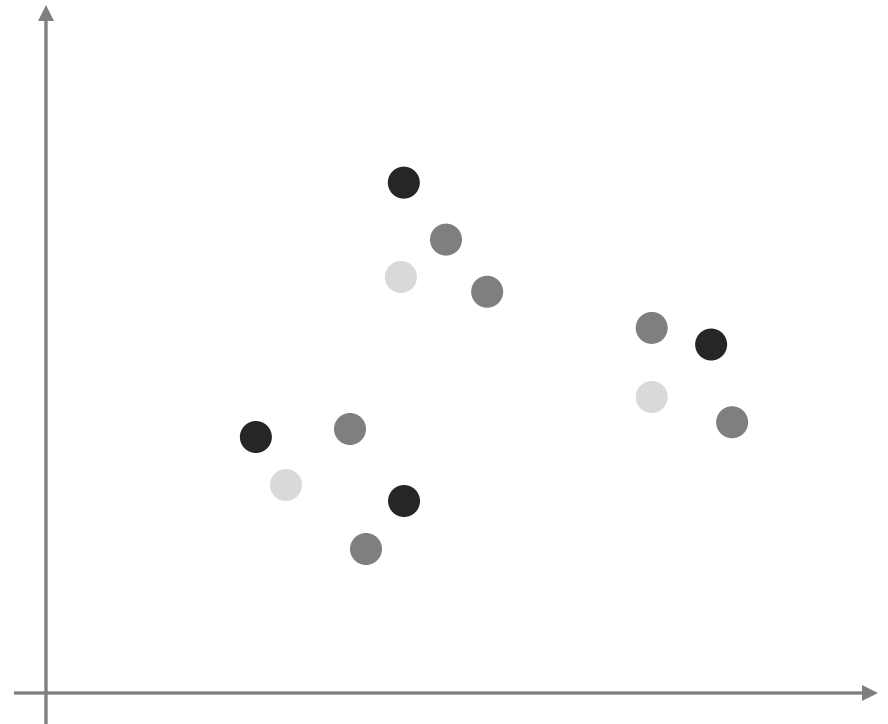
# VISUAL VARIABLE #2 – SIZE

Visual property	Can convey
Associative	Y
Selective	Y
Ordered	Y
Quantitative	(Y)



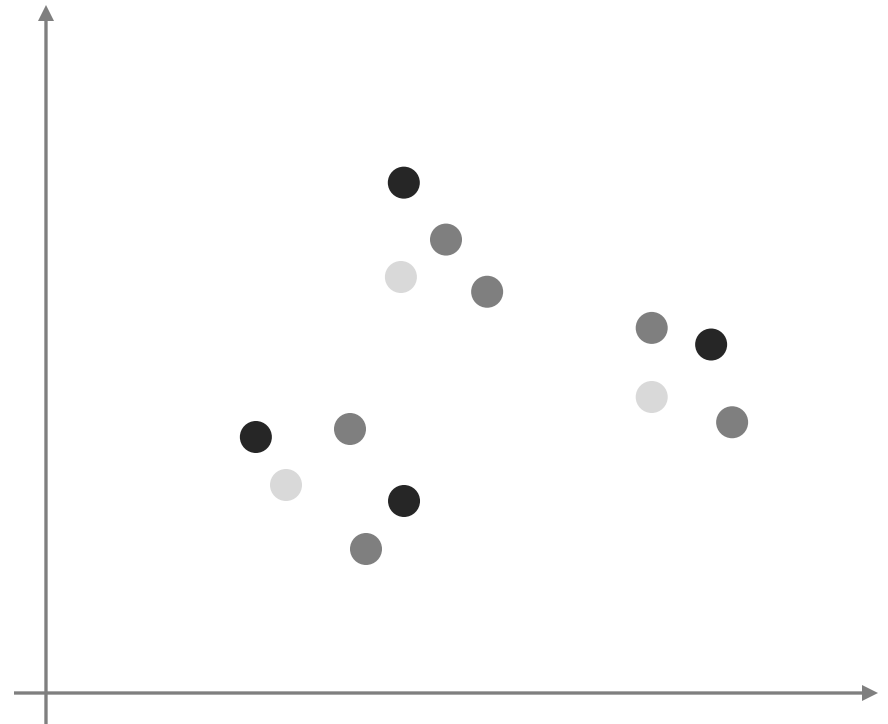
# VISUAL VARIABLE #3 – BRIGHTNESS

Visual property	Can convey
Associative	
Selective	
Ordered	
Quantitative	



# VISUAL VARIABLE #3 – BRIGHTNESS

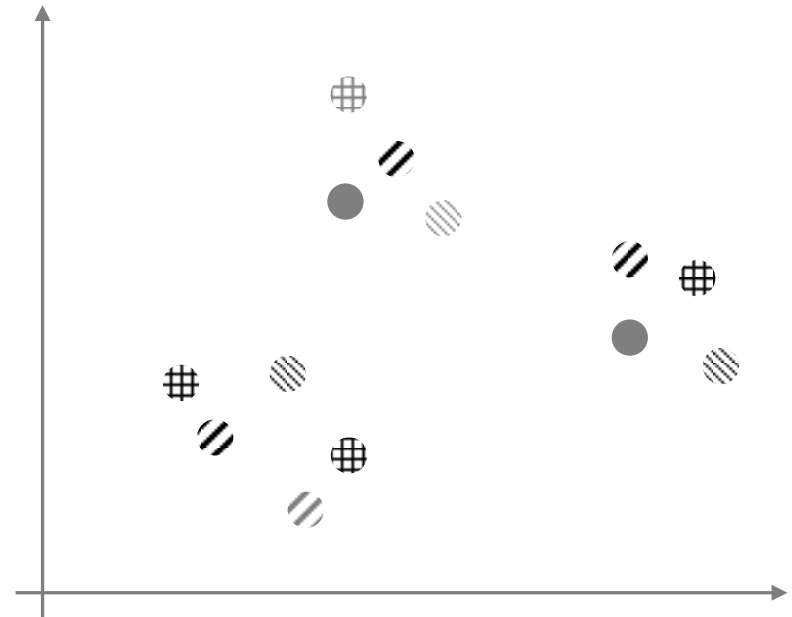
Visual property	Can convey
Associative	Y
Selective	Y
Ordered	Y
Quantitative	





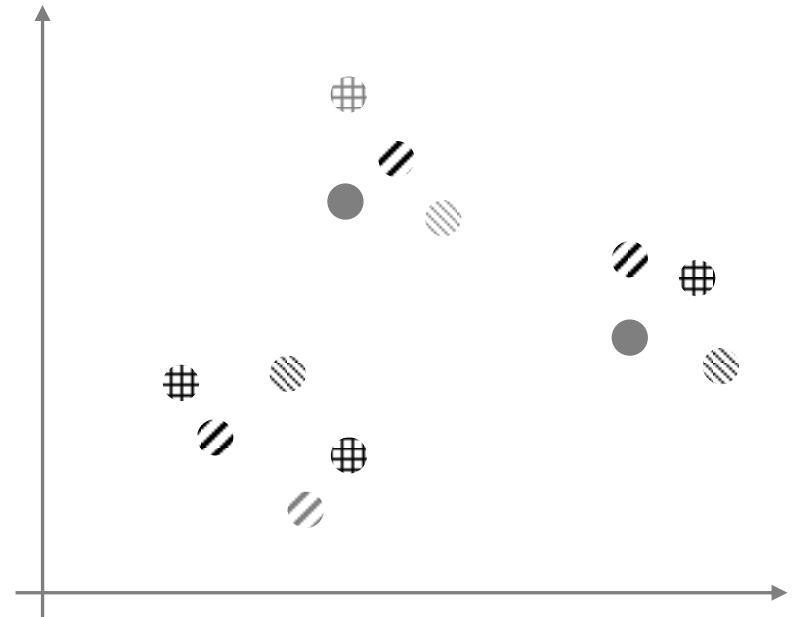
# VISUAL VARIABLE #4 – TEXTURE

Visual property	Can convey
Associative	
Selective	
Ordered	
Quantitative	



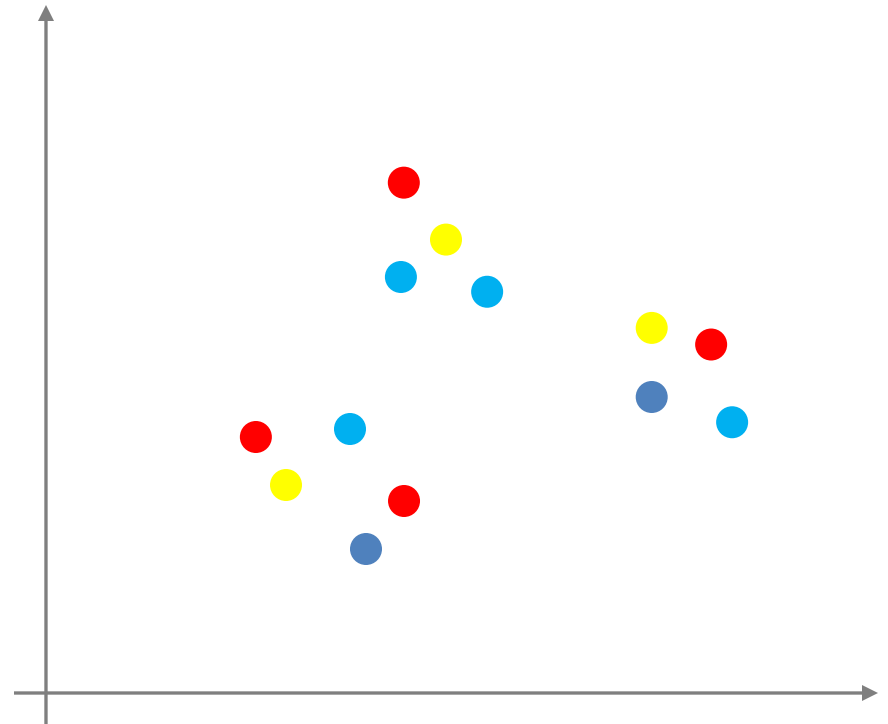
# VISUAL VARIABLE #4 – TEXTURE

Visual property	Can convey
Associative	Y
Selective	Y
Ordered	
Quantitative	



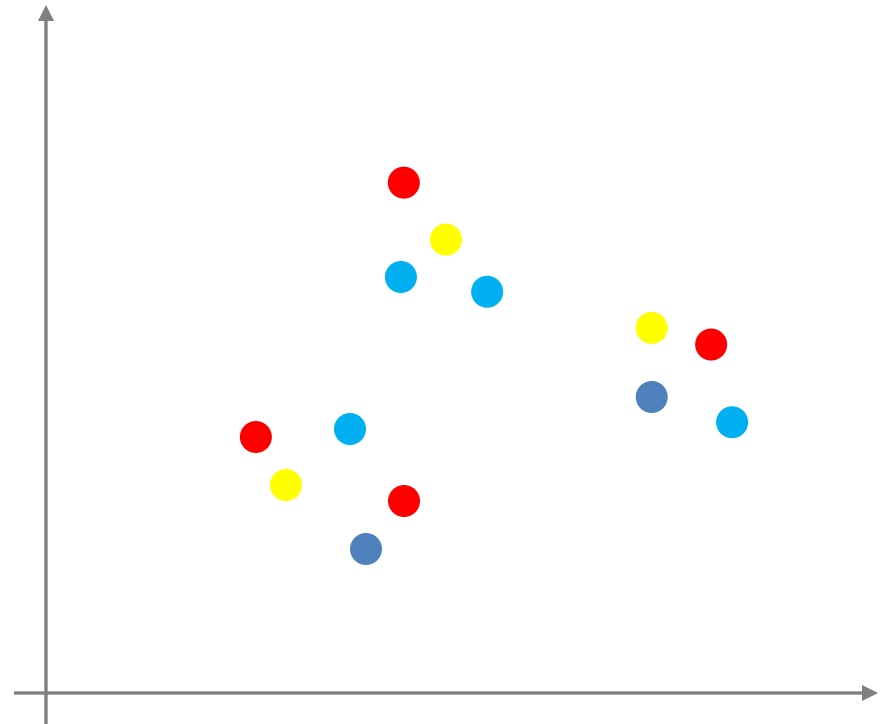
# VISUAL VARIABLE #4 – COLOR

Visual property	Can convey
Associative	
Selective	
Ordered	
Quantitative	



# VISUAL VARIABLE #4 – COLOR

Visual property	Can convey
Associative	Y
Selective	Y
Ordered	
Quantitative	



# VISUAL VARIABLE #5 – ORIENTATION

Visual property	Can convey
Associative	
Selective	
Ordered	
Quantitative	



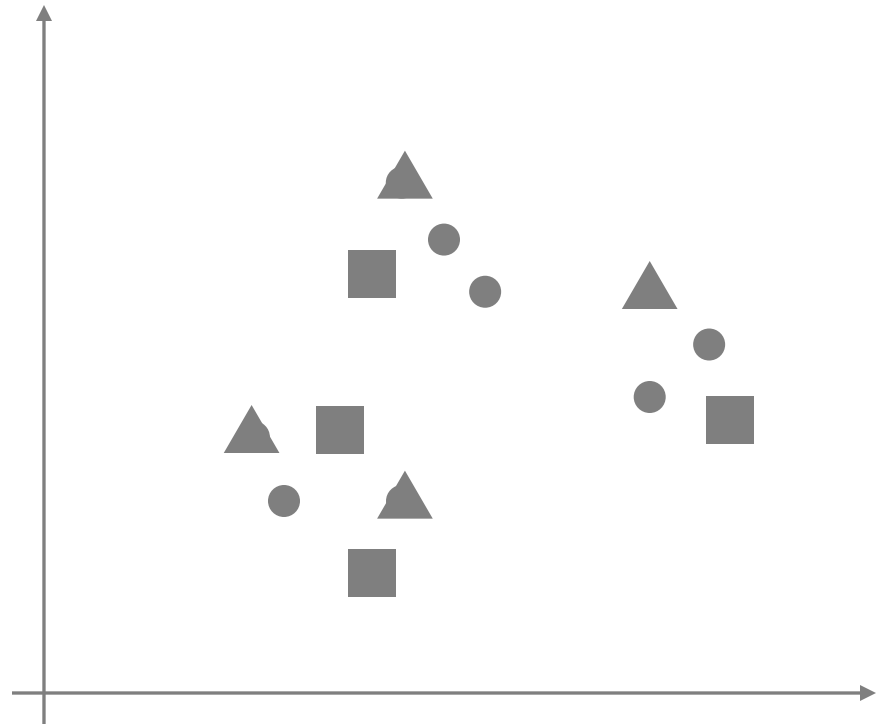
# VISUAL VARIABLE #5 – ORIENTATION

Visual property	Can convey
Associative	(Y)
Selective	(Y)
Ordered	
Quantitative	



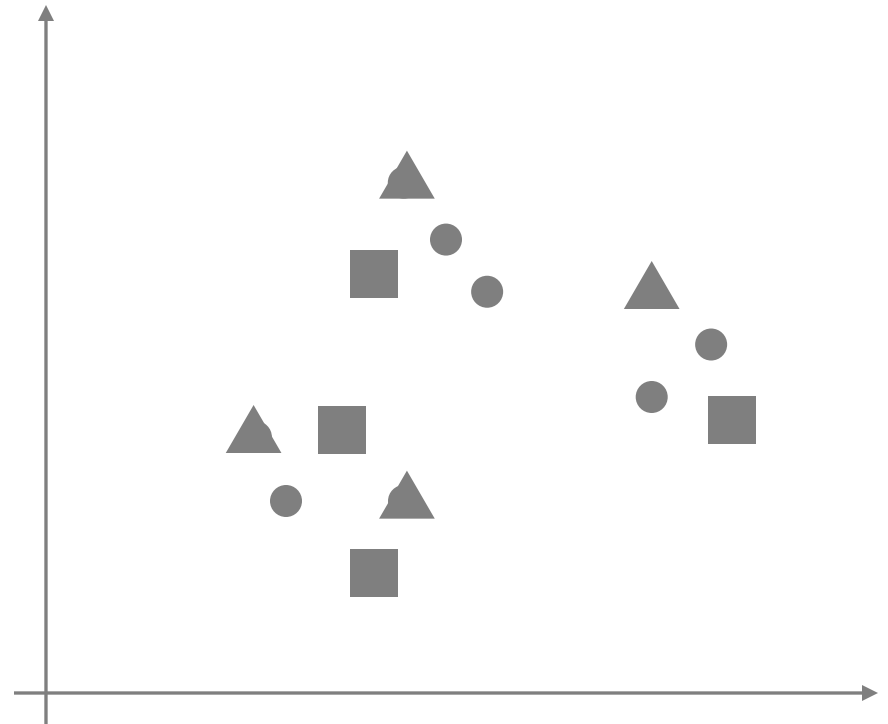
# VISUAL VARIABLE #6 – SHAPE

Visual property	Can convey
Associative	
Selective	
Ordered	
Quantitative	



# VISUAL VARIABLE #6 – SHAPE

Visual property	Can convey
Associative	(Y)
Selective	(Y)
Ordered	
Quantitative	





# LEVELS OF ORGANIZATION

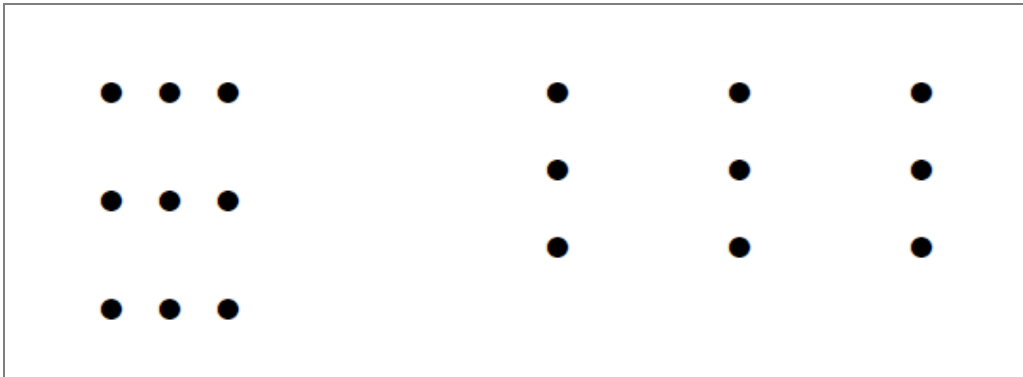
Visual variables differ in what data properties they can convey

	Associative	Selective	Ordered	Quantitative
Planar	yes	yes	yes	yes
Size	yes	yes	yes	(yes)
Brightness (Value)	yes	yes	yes	
Texture	yes	yes		
Color (Hue)	yes	yes		
Orientation	(yes)	(yes)		
Shape	(yes)	(yes)		

# TAKE-AWAYS (1)

Planar variable is the single most strongest visual variable

- maps to proximity
- provides an intuitive organization of information
- things close together are perceptually grouped together



**TYPICAL WEB FORM**

**Personal Information**

First Name

Last Name

**Contact Information**

Address

City

Country  
-- Select Country --

Post Code  Country

| [Cancel](#)

PRIMARY ACTION | SECONDARY ACTION

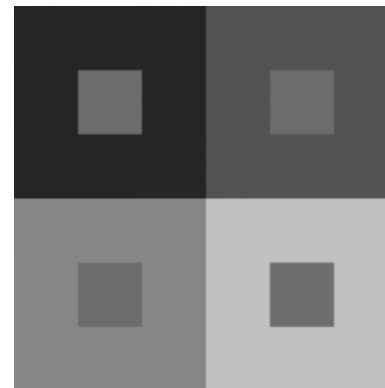
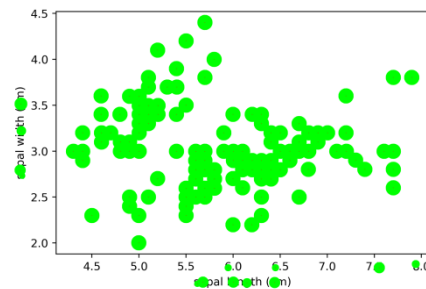
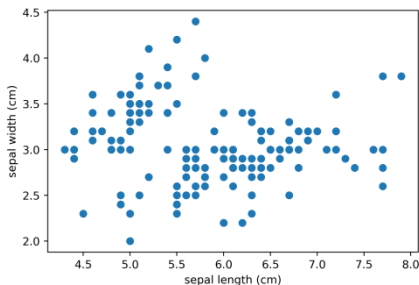
# TAKE-AWAYS (2)

Size and brightness are good secondary visual variables to encode relative magnitude

- size appeals to spatial perceptive channels

What are the advantages and disadvantages of brightness

- + brightness does not consume extra space (bigger disks do)
- brightness depends on environmental lighting (size does not)  
where do you view the visualization (office, outdoors, night or day?)

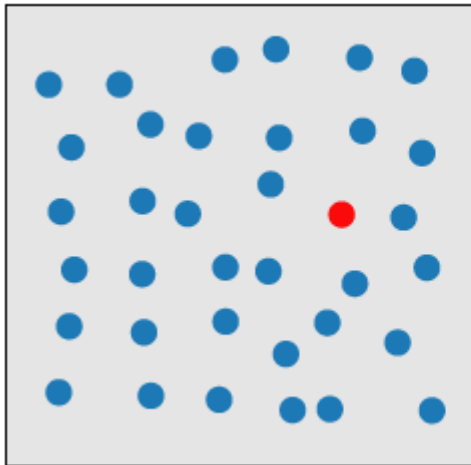


brightness

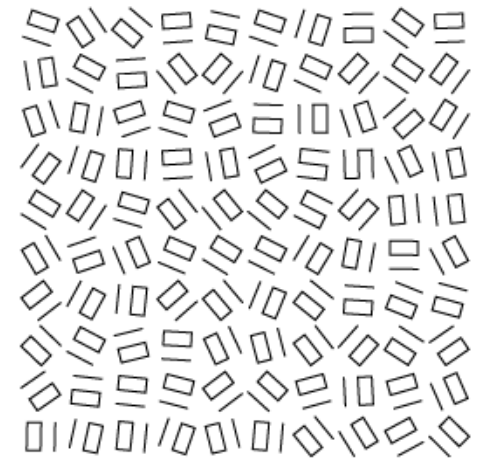
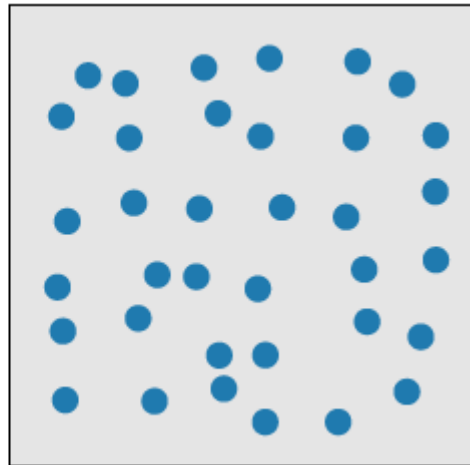
# TAKE-AWAYS (3)

Color is a good visual variable for labeling

- texture can do this as well, but it does not support pop-out much



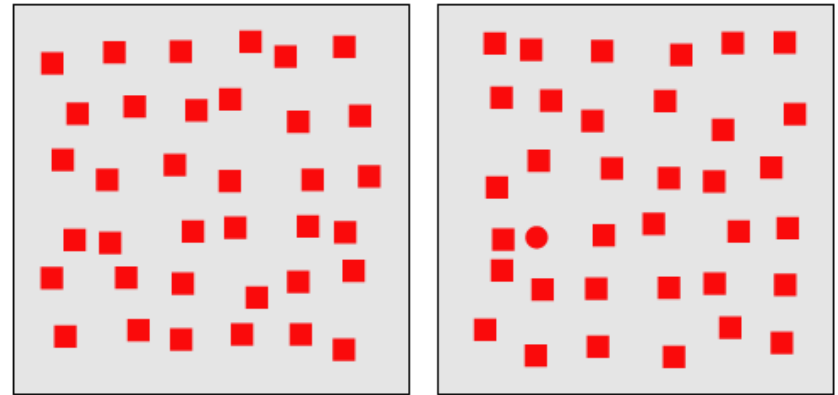
color pop-out



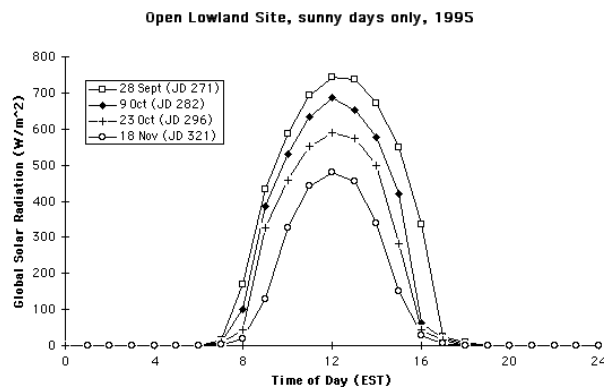
texture pop-out?

# TAKE AWAYS (4)

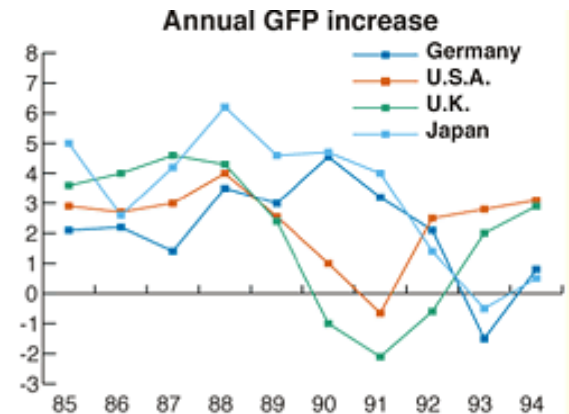
*Shape* provides only limited pop-out



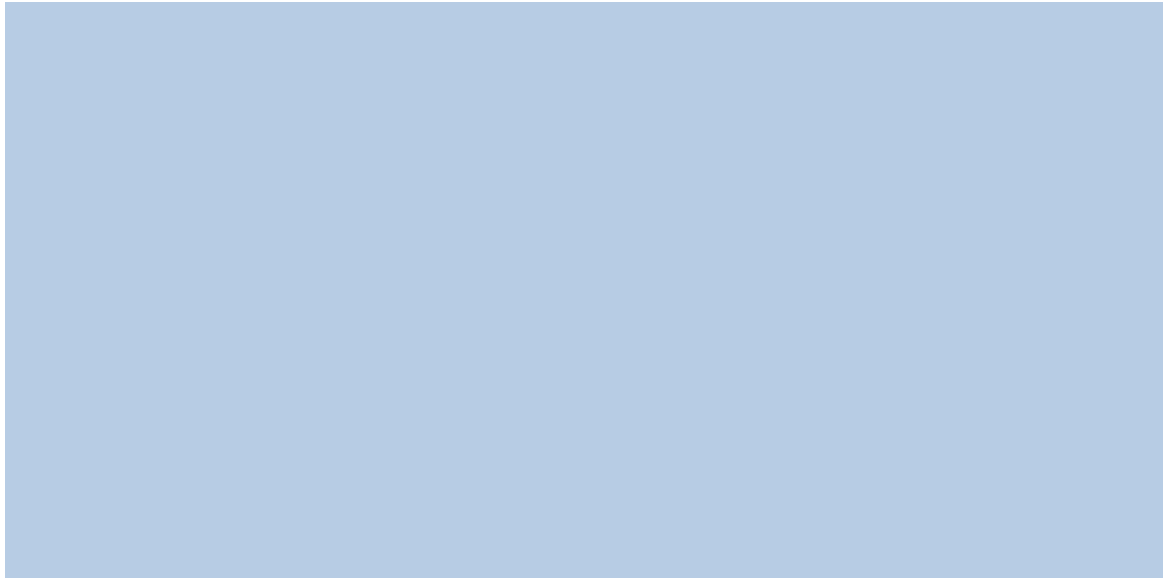
- compare with color pop-out on the previous slide
- another example: coloring of graphs



VS.



# COLOR AND CONTRAST



Background with same-colored object at the same brightness

- can you see the shape?
- can you count the number of gaps?

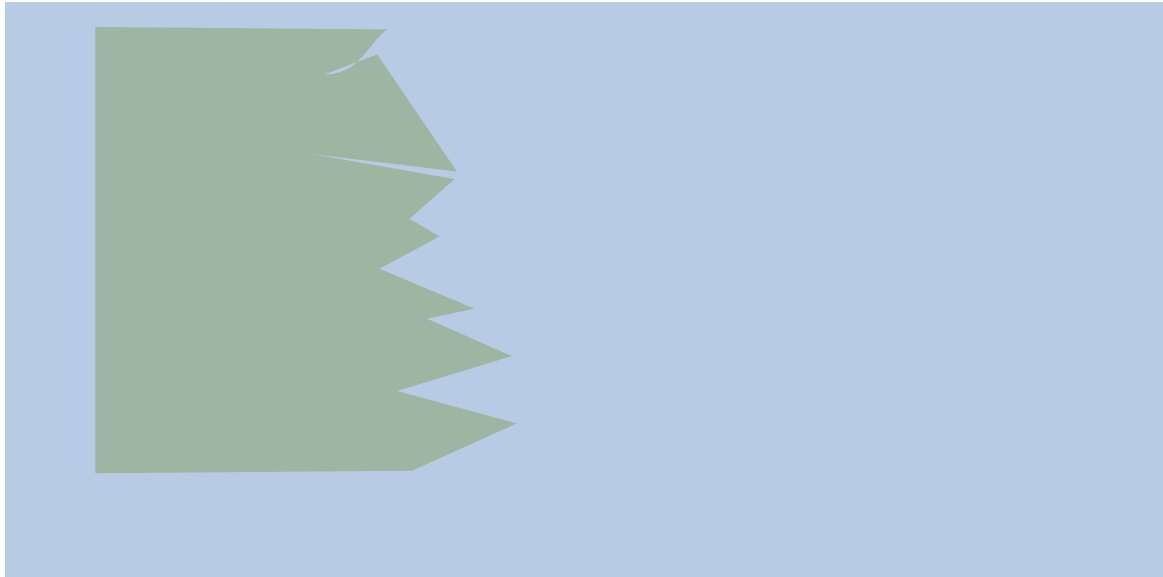
# COLOR AND CONTRAST



Background with different-colored object at similar brightness

- can you see the shape?
- can you count the number of gaps?

# COLOR AND CONTRAST



Background with different-colored object at lower brightness

- can you see the shape?
- can you count the number of gaps?



# COLOR AND CONTRAST



Background with different-colored object at higher brightness

- can you see the shape?
- can you count the number of gaps?

# WHAT DID WE LEARN FROM THAT EXPERIMENT?

Color is for ...

Brightness (intensity, luminance) is for ...

# ROLE OF SATURATION

## Art & Money

By: JeanAbbateci



### ART & MONEY

#datavisualisation



This Animated Bubble Chart shows the 270 most expensive artworks sold in auction since 2008 until end 2011

drawing painting  
 silkscreen sculpture

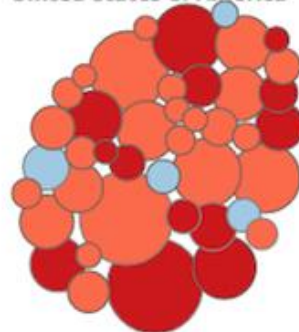
Share 1161 Tweet 558

#### SORTING

- year by year
- top 10 artworks
- men / women
- dead / alive
- by nationality**
- best-selling artists
- auction houses
- size of artworks
- date of creation (all centuries)

#### AMERICAS

United States of America

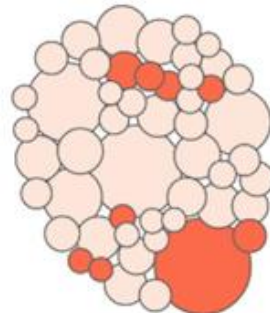


Argentina



#### ASIA

China

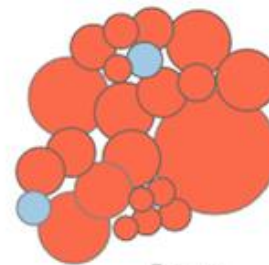


Japan

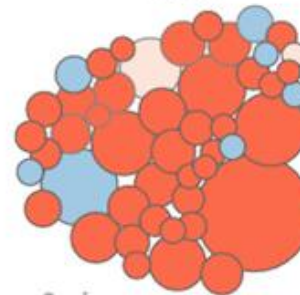


#### EUROPA

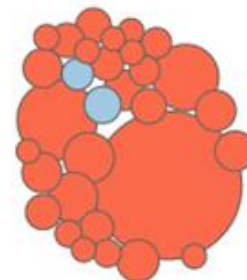
Great Britain



France



Spain



Italy



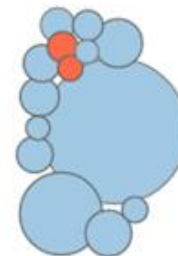
Russia



Netherlands - Belgium



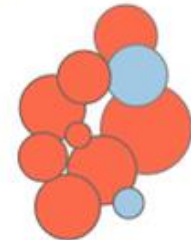
Switzerland



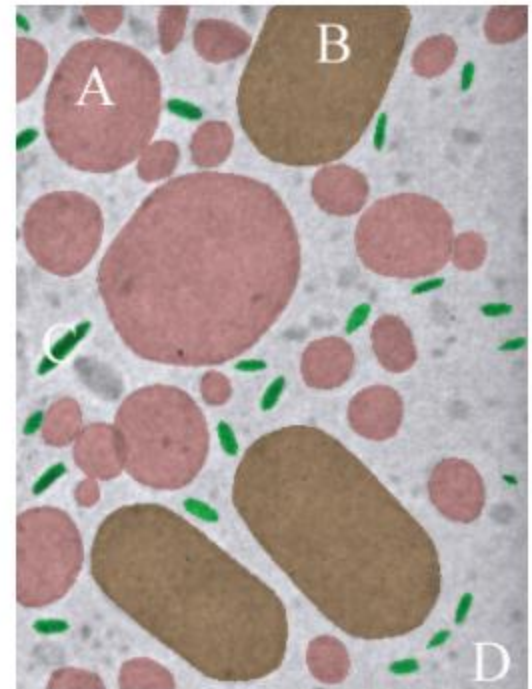
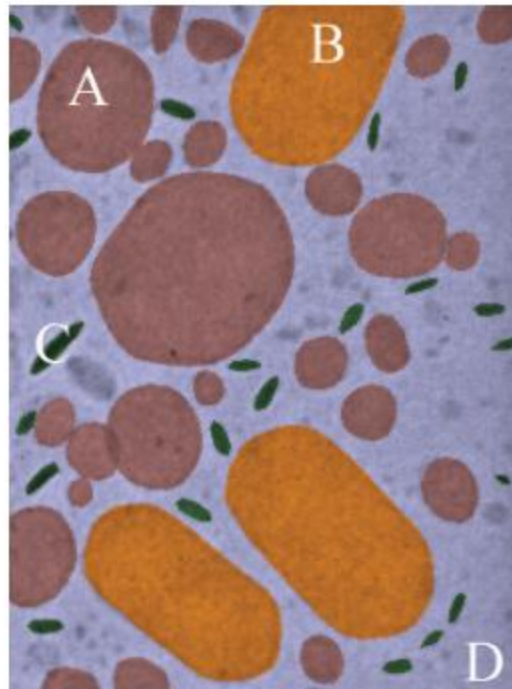
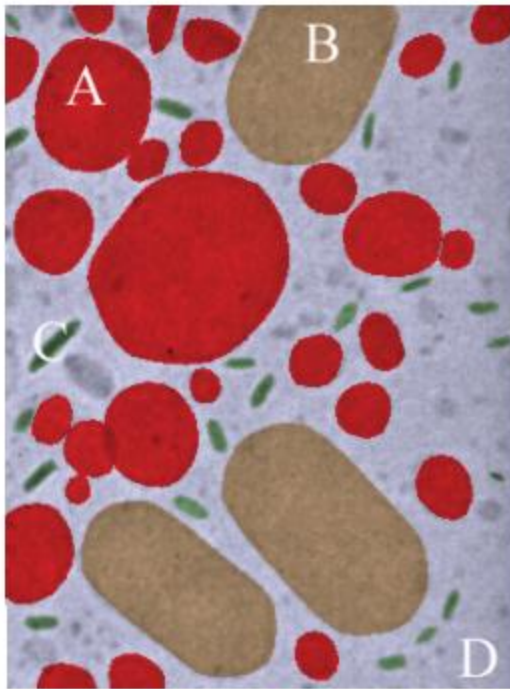
Germany



Others



# COLOR TAGGING FOR IMPORTANCE

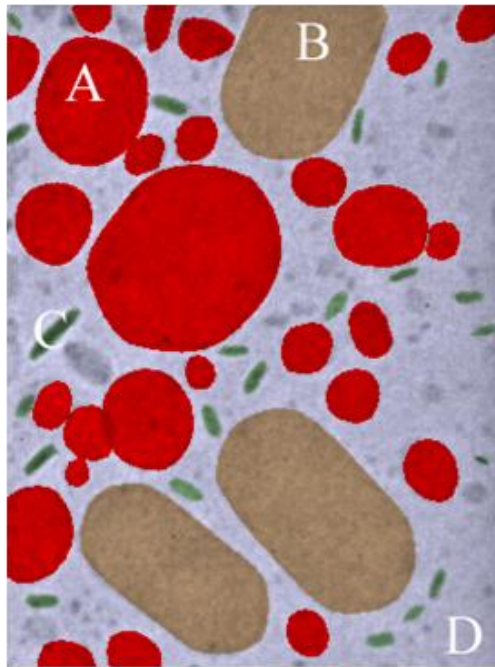


Which is the most important structure in each (as intended by the author)

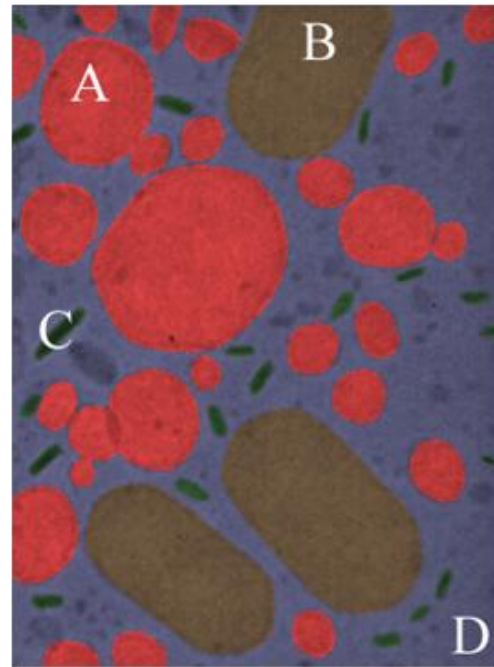
# HOW ABOUT AESTHETICS?

Which one do people like better?

- perceived importance level of red object is the same



Vis 1



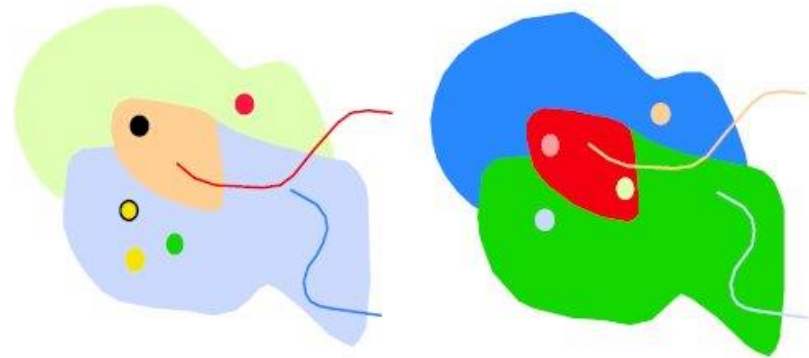
Vis 2



aesthetics

# COLOR CODING AND COLORMAPS

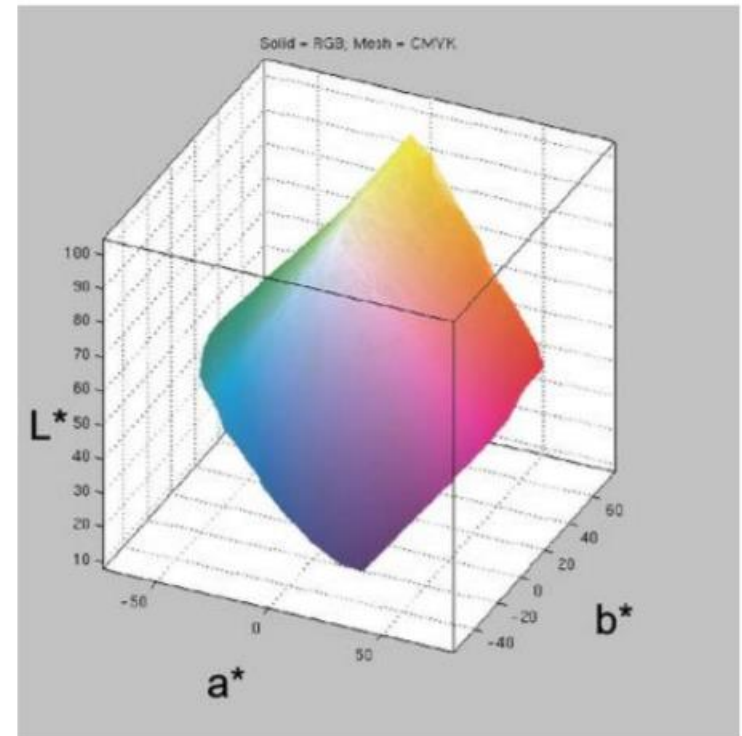
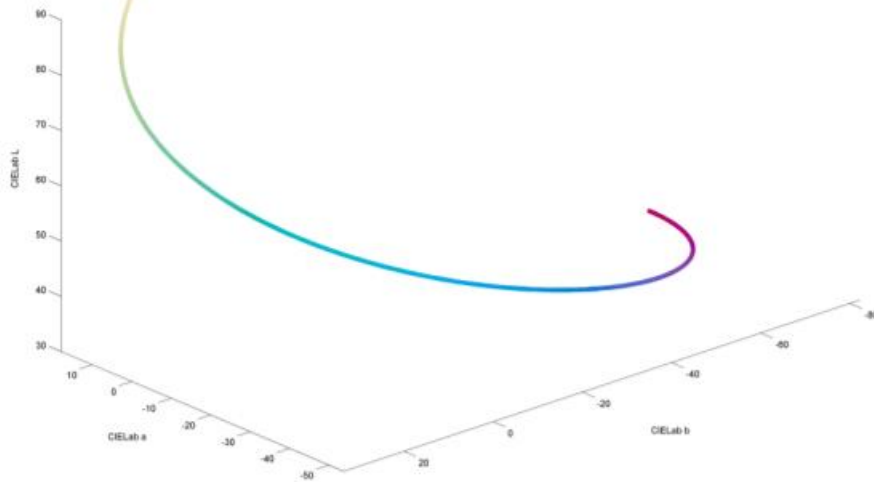
- Color coding
  - large areas: low saturation
  - small areas: high saturation
  - maintain luminance contrast
  - break iso-luminances with borders
- Pseudo-coloring: assign colors to grey levels by indexing the grey levels into a color map



# SPIRAL THROUGH COLOR SPACE

Varies hue and intensity at the same time

- shown here: CIE Lab color space



# THE RAINBOW COLORMAP

As we saw, colors can add detail information to a visualization

- instead of 256 levels get  $256^3 = 16,777,216$

Oftentimes you have a visualization with just one variable

- this would give you a grey level image
- how to turn this into a color image for better detail

Solution 1:

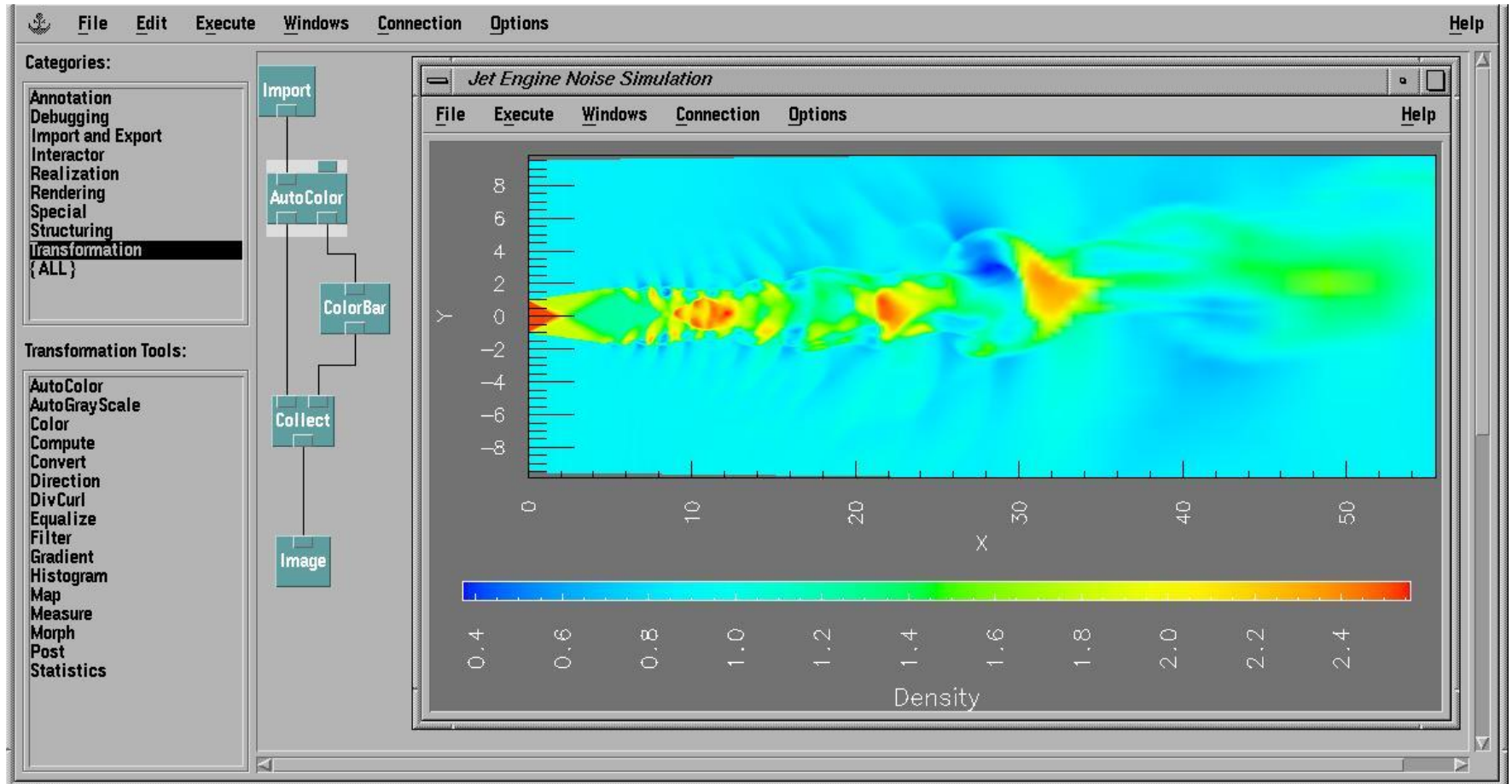
- map to hue → the rainbow colormap



- can you see all adjacent colors at the same contrast?



# AVOID RAINBOW COLORMAPS



# BETTER: LINEAR HUE

The image displays a software interface for "Jet Engine Noise Simulation". The main window shows a 2D density plot with a color scale ranging from 0.4 to 2.4. The plot is titled "Jet Engine Noise Simulation" and has a menu bar with "File", "Execute", "Windows", "Connection", "Options", and "Help". The plot's Y-axis ranges from -8 to 8, and the X-axis ranges from 0 to 50. A color bar below the plot indicates density values from 0.4 to 2.4. The plot shows a complex, elongated structure with a central yellow region and surrounding blue regions.

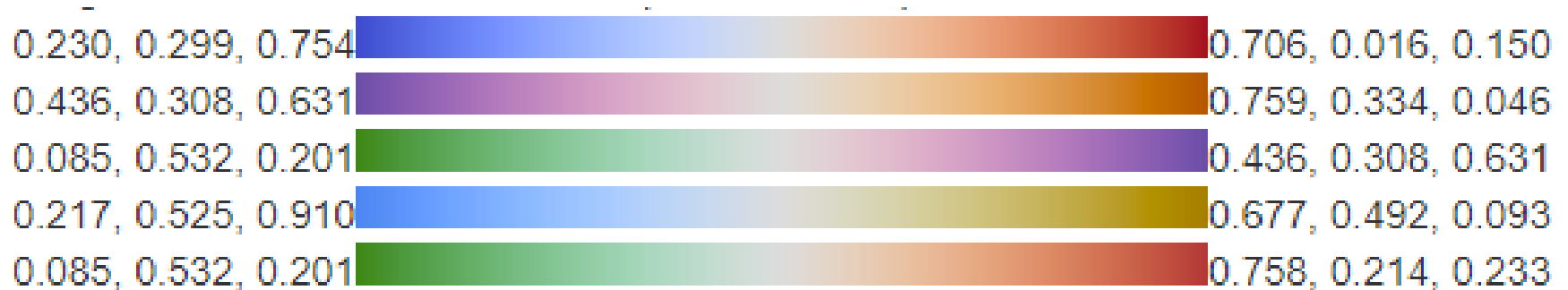
On the left side, there is a "Categories:" panel with a tree view showing "Import", "Selector", "PRAVDAColor", "Color", "ColorBar", "Collect", and "Image". Below this is a "PRAVDA Tools:" panel with a list of tools: "AutoRuleColor", "ColorMapLookup", "ColorMapPicker", "PRAVDAColor", "RuleColor", "ScaleColorMapData", "SpatialFreq", and "Width". The "PRAVDA Tools:" panel also contains three color maps labeled "Map 1", "Map 2", and "Map 3".

At the bottom right, there is a "Control Panel" window with a menu bar and a "Coloring Task" dropdown menu set to "Isomorphic".

# MORELAND'S DIVERGING COLORMAPS

## Algorithmically generated

- all have the same midpoint value (0.865, 0.865, 0.865)
- begin and end point listed here



<https://www.kennethmoreland.com/color-maps/>

# BREWER SCALES

## Nominal scales

- distinct hues, but similar emphasis

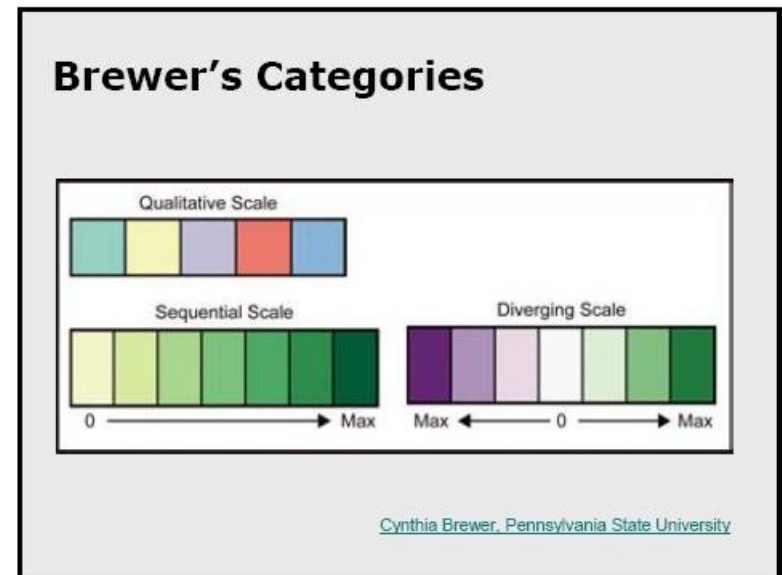
## Sequential scales

- vary in lightness and saturation
- vary slightly in hue

<http://colorbrewer2.org/>

## Diverging scale

- complementary sequential scales
- neutral at "zero"



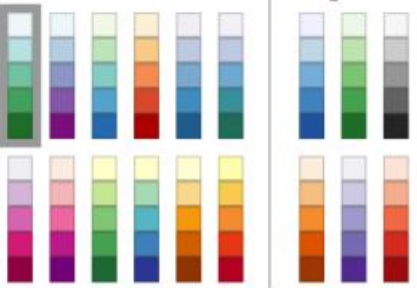
# COLOR BREWER

Number of data classes: 3 i [how to use](#) [updates](#) [downloads](#) [credits](#)

Nature of your data: i  
 sequential  diverging  qualitative

Pick a color scheme:

Multi-hue: Single hue:



Only show: i  
 colorblind safe  
 print friendly  
 photocopy safe

Context: i  
 roads  
 cities  
 borders

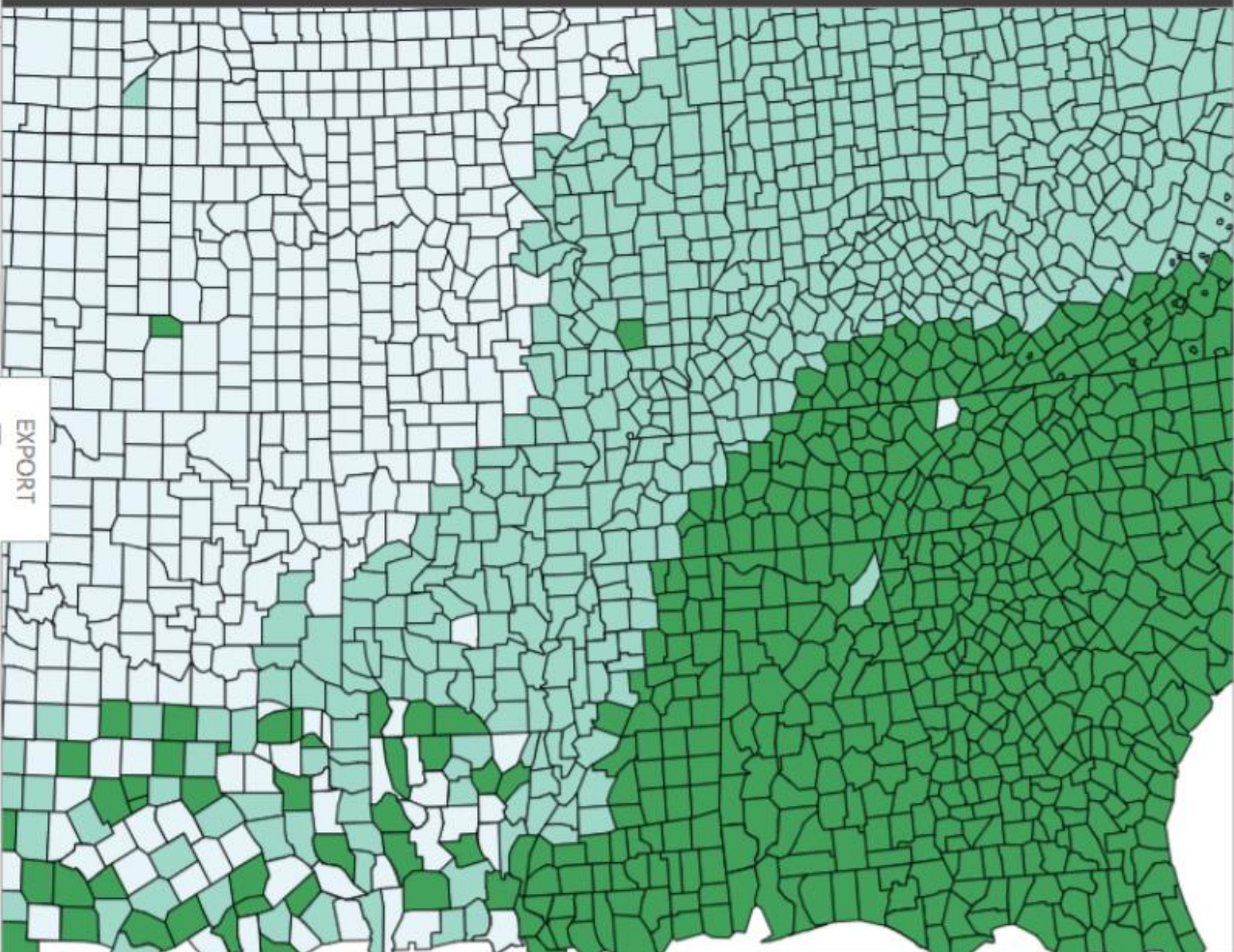
Background:  
 solid color  terrain  
color transparency

3-class BuGn EXPORT

HEX ▼

- #e5f5f9
- #99d8c9
- #2ca25f

**COLORBREWER 2.0**  
color advice for cartography



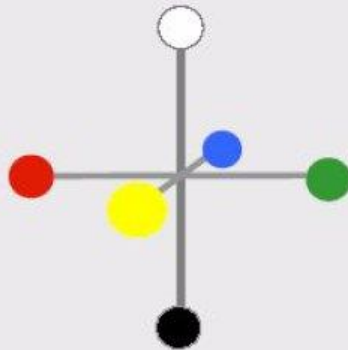
# OPPONENT COLOR

## Definition

- Achromatic axis
- R-G and Y-B axis
- Separate lightness from chroma channels

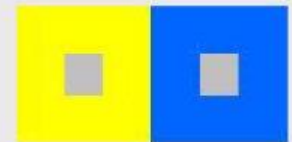
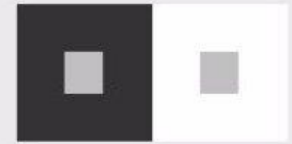
## First level encoding

- Linear combination of LMS
- Before optic nerve
- Basis for perception
- Defines "color blindness"



## Add Opponent Color

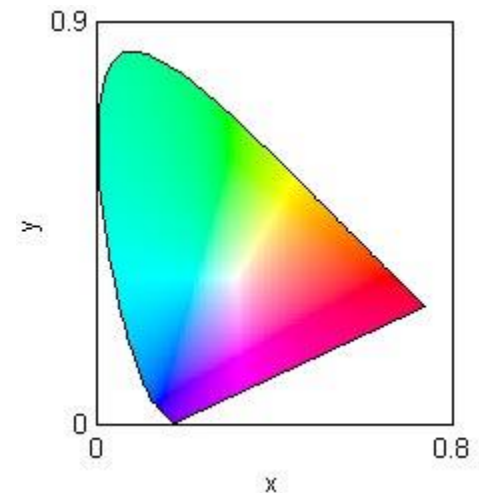
- Dark adds light
- Red adds green
- Blue adds yellow



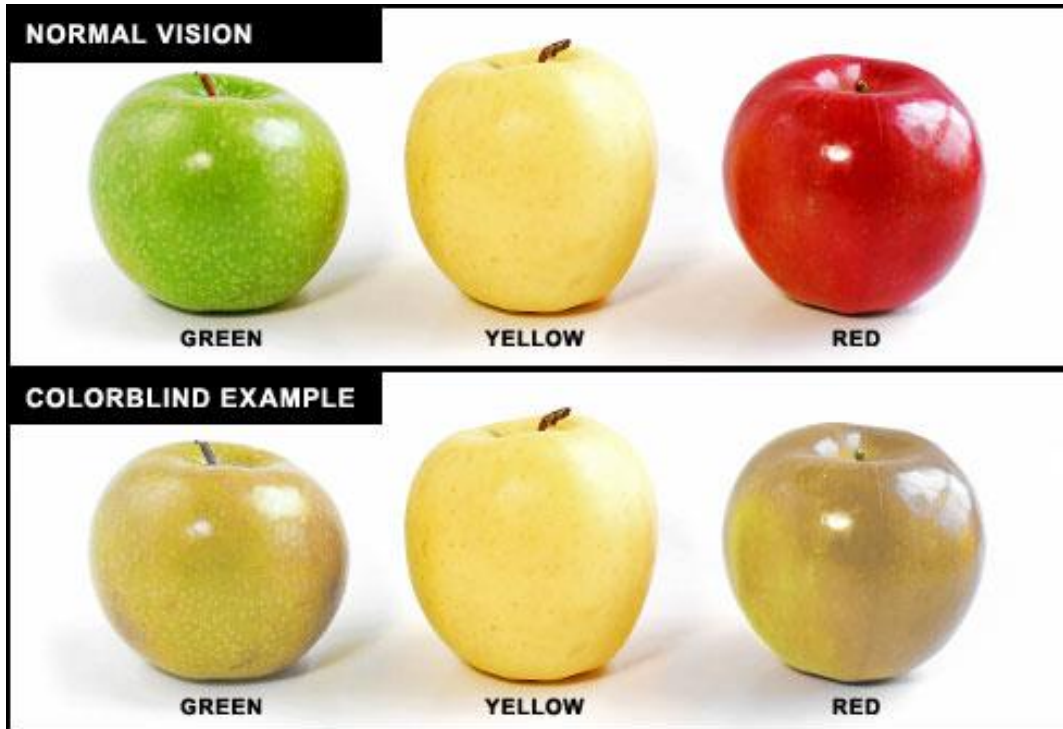
These samples will have both light/dark and hue contrast

## Opponent colors do not mix

- can only see one of the opponents
- there is no blueish yellow
- there is no reddish green



# COLOR BLINDNESS



Most common is deficiency in distinguishing red and green

# FORMS OF COLOR BLINDNESS

normal



The colors of the rainbow as viewed by a person with no color vision deficiencies.

green missing



The colors of the rainbow as viewed by a person with deuteranopia.

red missing



The colors of the rainbow as viewed by a person with protanopia.

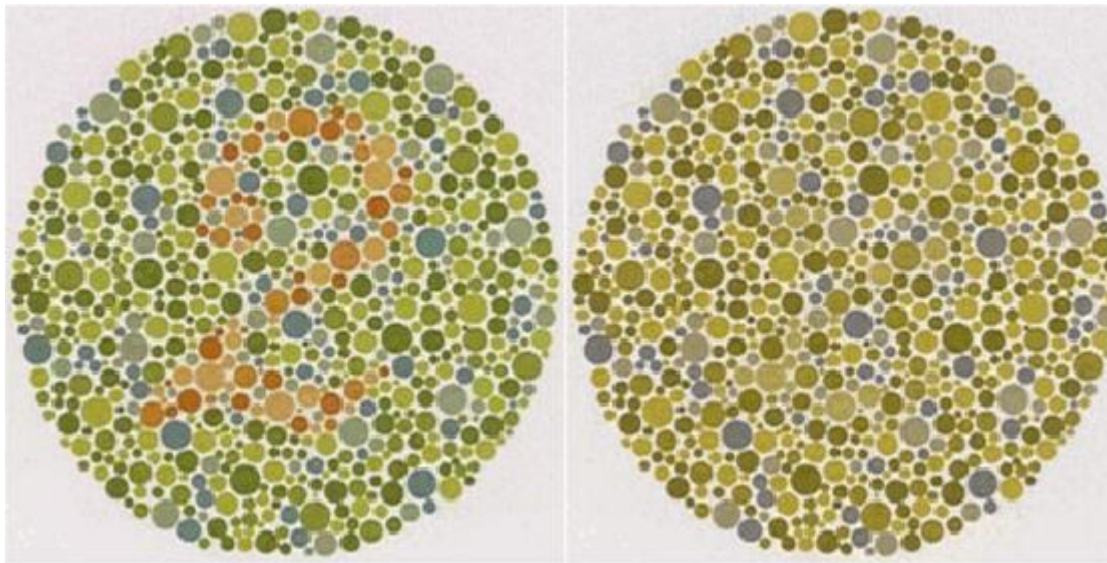
blue missing  
(rare)



The colors of the rainbow as viewed by a person with tritanopia.



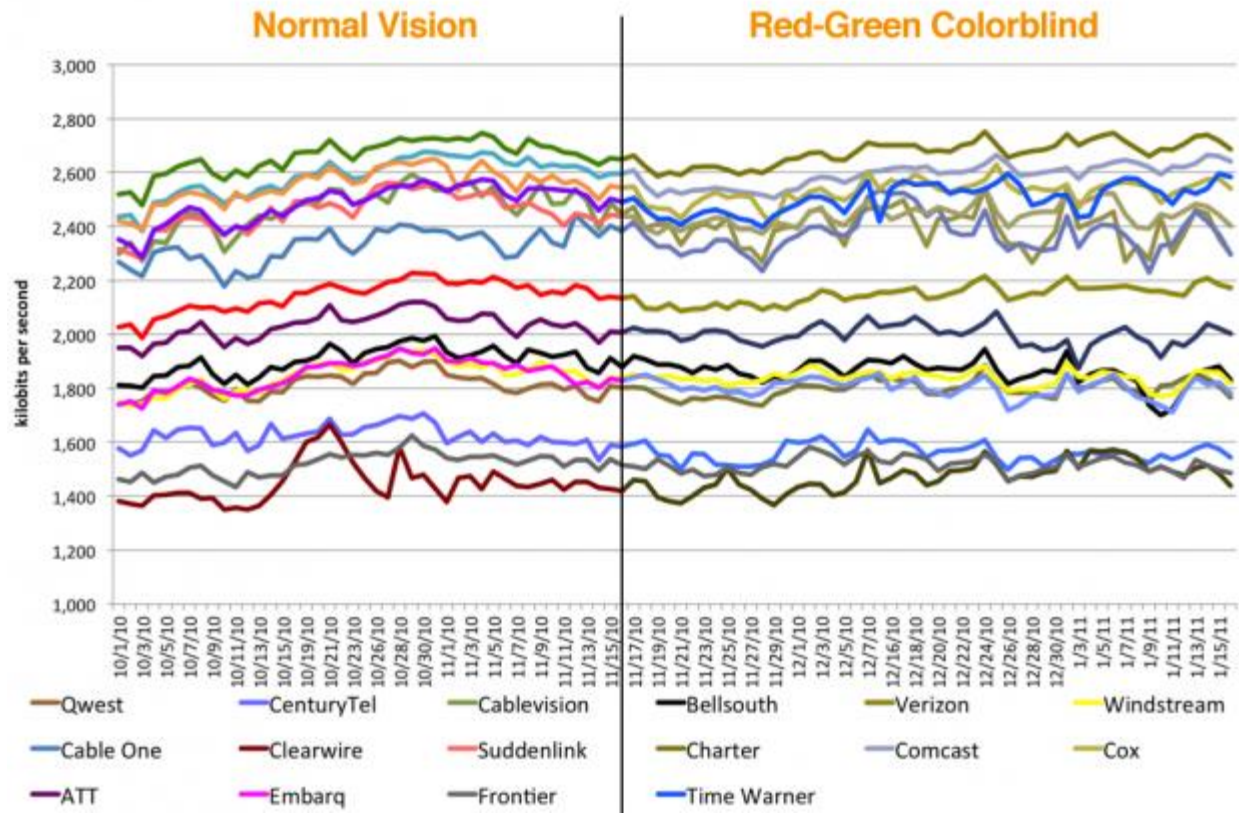
# ISHIHARA TEST



normal

protanopia

# LINE CHARTS



# DESIGNING FOR COLOR DEFICIENT USERS

8% (0.5%) of US males (females) are color deficient

- so be careful when designing visualizations

What to do?

- use different intensities for red-green (e.g. light green, dark red)
- space red and green colored colors dots far apart or make large
- add symbols to line charts
- avoid using gradient colors to indicate data value

# SUMMING UP

Use Luminance for detail, shape, and form

Use color for coding – few colors

Use strong colors for small areas

Use subtle colors to code large areas

Visualization artistry:

- Use of luminance to indicate direction

