

CSE/ISE 332
INTRODUCTION TO VISUALIZATION
VISUAL DESIGN & AESTHETICS

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Lecture	Topic	Projects
1	Intro and logistics	
2	Basic visualizations and tasks, data types, examples, ethical considerations	
3	Data preparation (cleaning, imputation, data set integration)	Project #1 out
4	AI-assisted coding for VIS applications (design, debugging, refactoring)	
5	Big data and data reduction (distance/sim metrics, intro to clustering)	
6	High-D data: concept, subspaces, dimension reduction, PCA	
7	Cluster analysis: hierarchical, density, model, embedding, temporal	Project #2(a) out
8	Perception and cognition (human visual system, color, contrast)	
9	Visual design and aesthetics	
10	Visualization of multivariate and high-D data: linear methods, projections	
11	Vis. of multivariate and high-D data: non-linear methods, embeddings	Project #2(b) out
12	Visualization and AI: mutual support and capabilities (VIS4AI, AI4VIS)	
13	Principles of interaction: drive what is visualized, analyzed & how (HCI4VIS)	
14	Midterm recap	
15	Midterm	
16	Visual analytics, human-centered AI, mixed-initiative & collaborative VA	Capstone proposal due
17	Visualization system design & evaluation: nested model, study designs	
18	Visualization of hierarchical data	
19	Visualization of maps and data with geo-reference	
20	Vis. of time-varying, time-series, streaming data, progressive visualization	
21	Critiquing visualization: Tufte's views, integrity, uncertainty, responsibility	Capstone prelim report due
22	Design of effective infographics	
23	Foundations scientific & medical visualization, computer graphics	
24	Intro to volume rendering	
25	Scientific visualization	
26	Capstone project demos (4-5 minutes + 2 minutes Q&A)	All capstone materials due
27	Capstone project demos (4-5 minutes + 2 minutes Q&A)	
28	Capstone project demos (4-5 minutes + 2 minutes Q&A)	
Final	Final exam	

FOUR KEY VISUAL REPRESENTATIONS

Gestalt Principles:

- the tendency to perceive elements as belonging to a group, based on certain visual properties (top-down attention)

Saliency Map:

- pay attention to interesting detail first and then integrate these features into a scene (bottom-up attention)

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



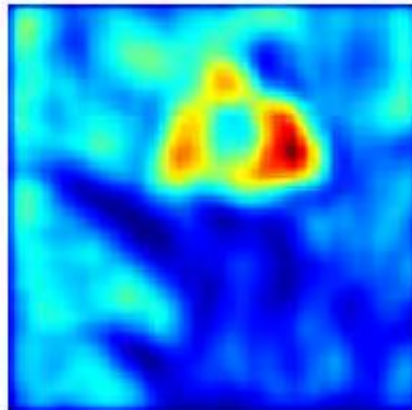
SALIENCY MAP

Red: high saliency
Blue: low saliency

Butterfly



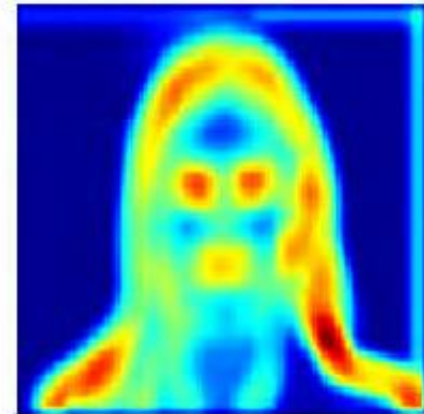
Butterfly Saliency Map



Person

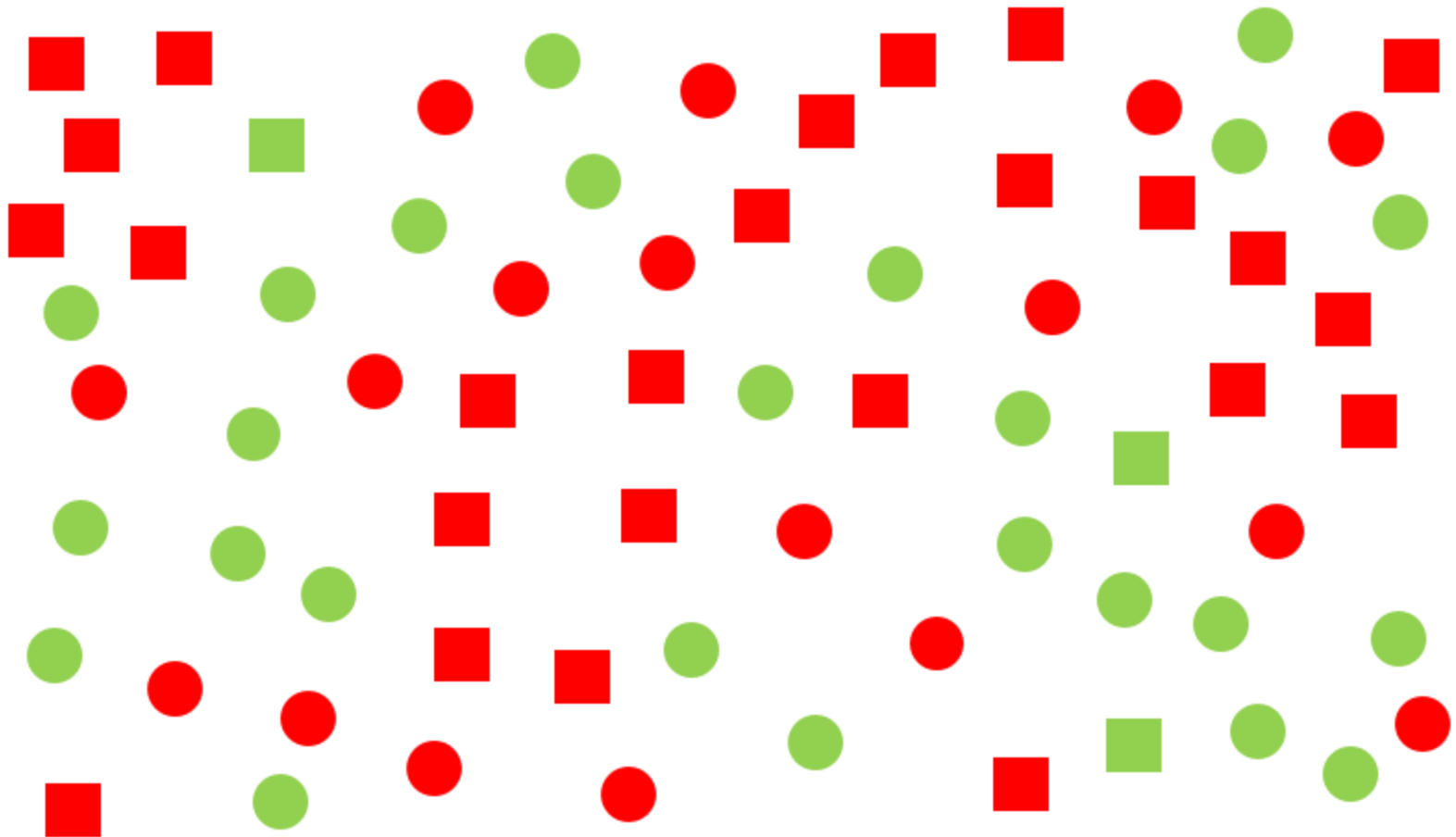


Person Saliency Map



PRE-ATTENTIVENESS

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



WHICH POPPED-OUT FASTER

Color (red vs. green)

Shape (circle vs. square)

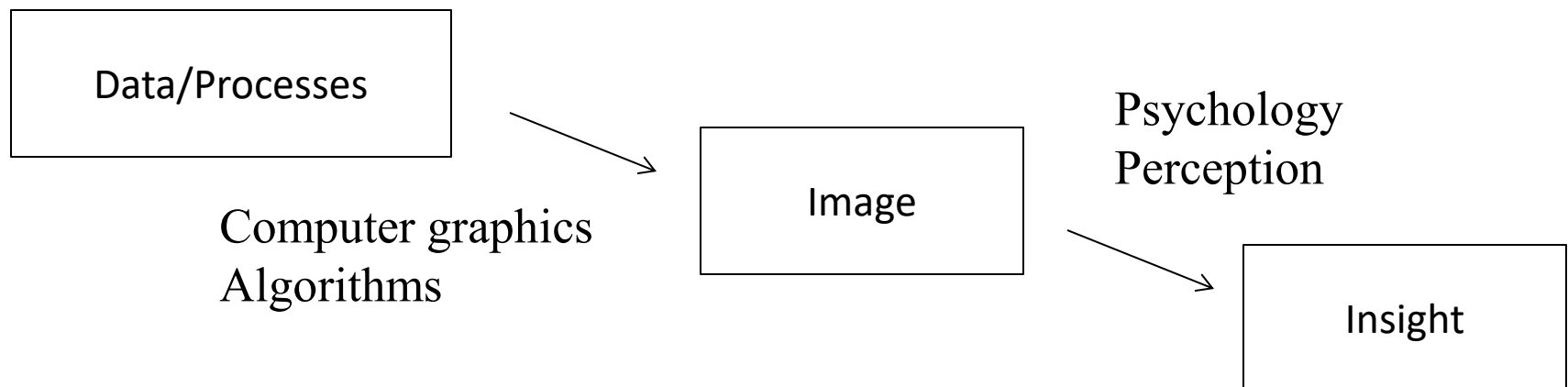
VISUAL VARIABLES

VISUAL VARIABLES

Formal theory linking perception to visualization

Established by Jacques Bertin (1967)

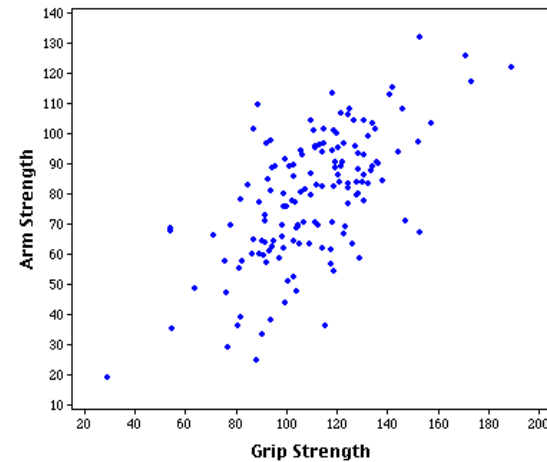
- he called it 'Image Theory'
- original book in French (*Sémiologie Graphique*) translated into English by W. Berg (1983)
- not formally linked to vision research more based on intuition
- but has been shown later by M. Green to be quite accurate



VISUAL VARIABLES

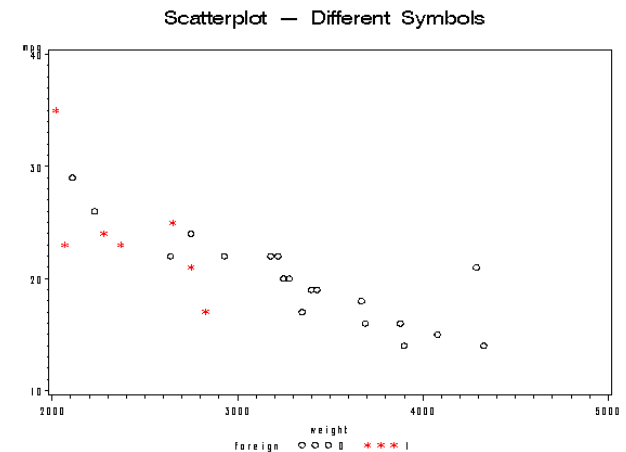
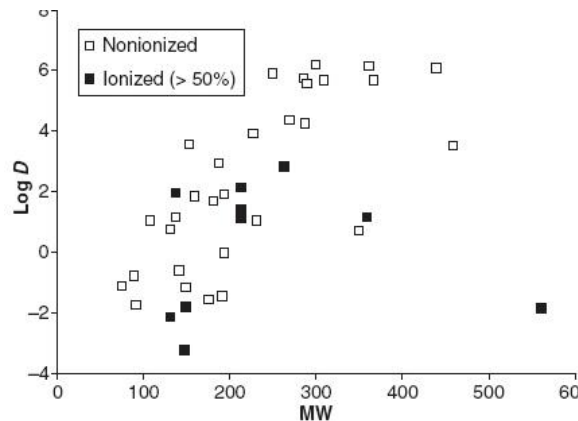
Two planar variables

- 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

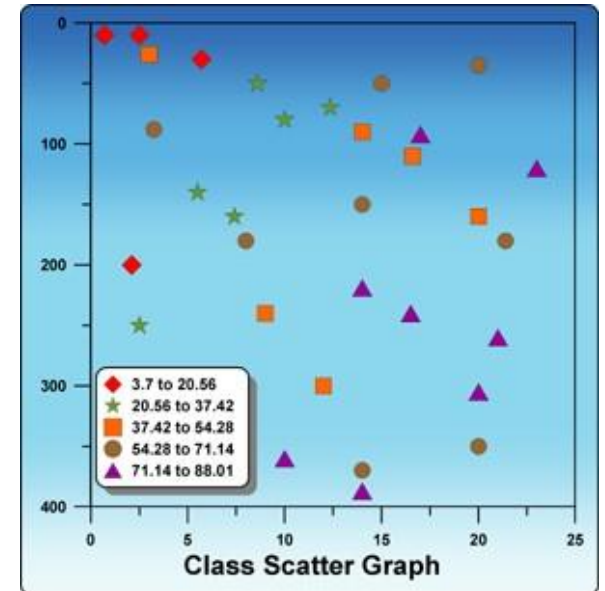
- more than three variables will hamper efficient visual search
- recall low decoding speed of conjunctions

ASSOCIATIVE VS. SELECTIVE

Both are nominal qualities

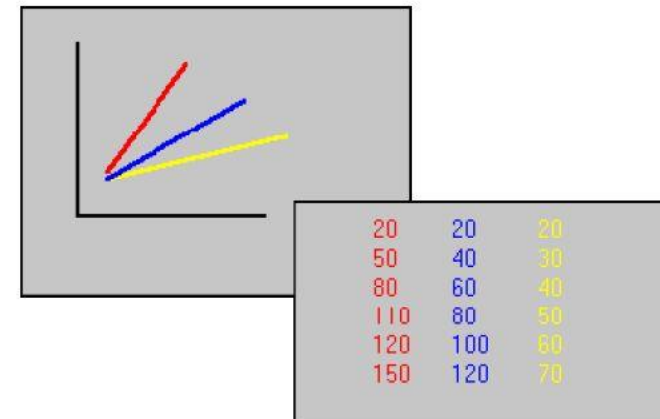
Associative

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



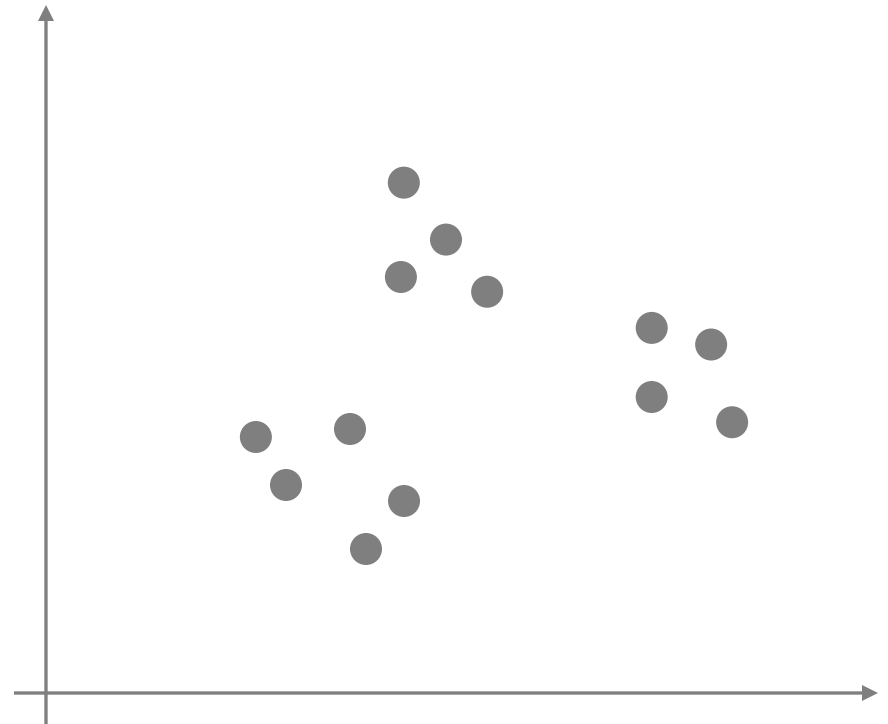
Selective

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



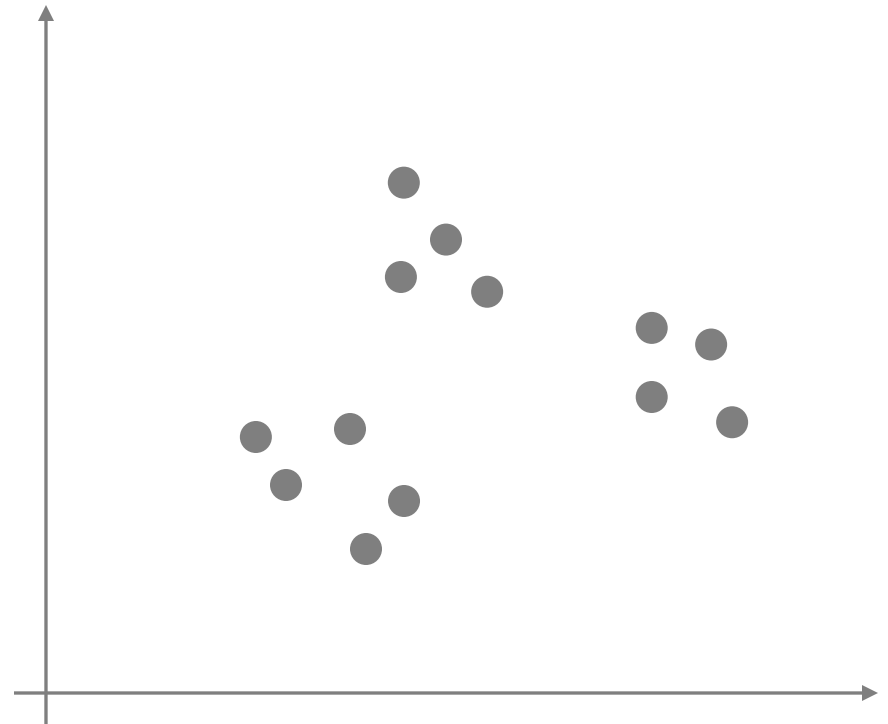
VISUAL VARIABLE #1 – PLANAR

Visual property	Can convey
Associative	
Selective	
Ordered	
Quantitative	



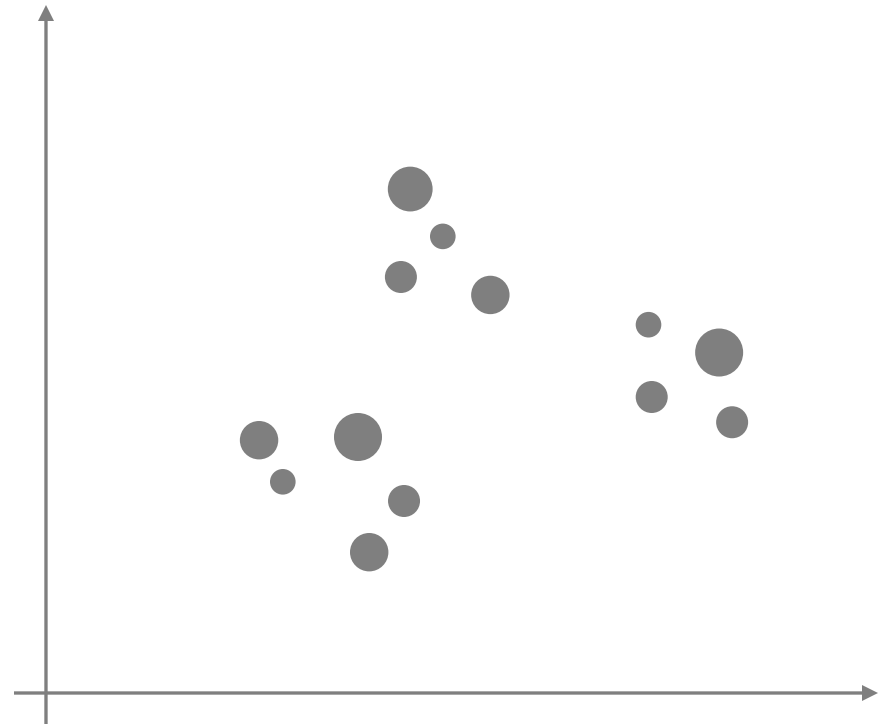
VISUAL VARIABLE #1 – PLANAR

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



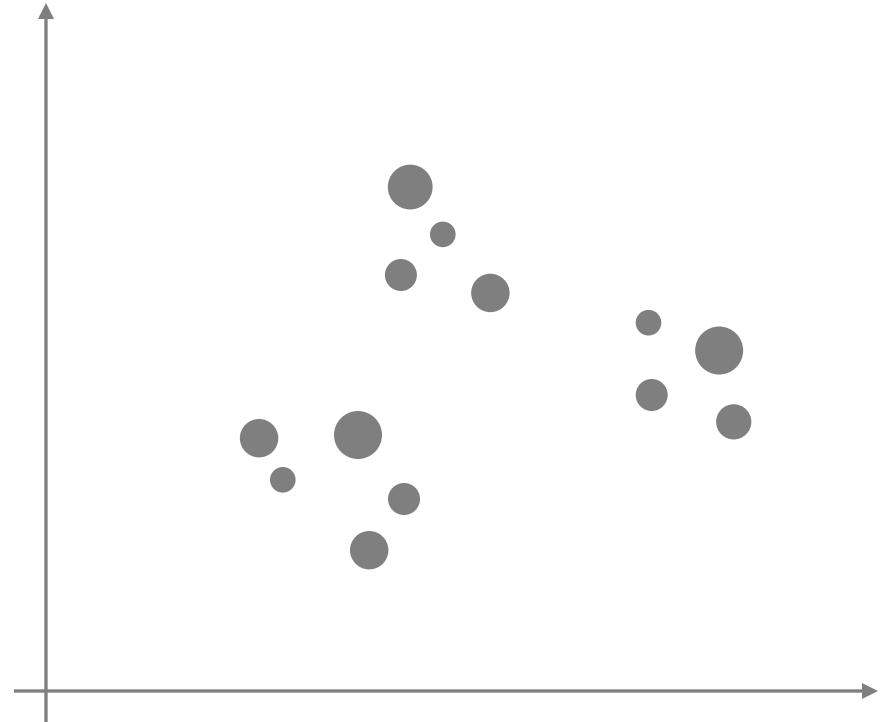
VISUAL VARIABLE #2 – SIZE

Visual property	Can convey
Associative	
Selective	
Ordered	
Quantitative	



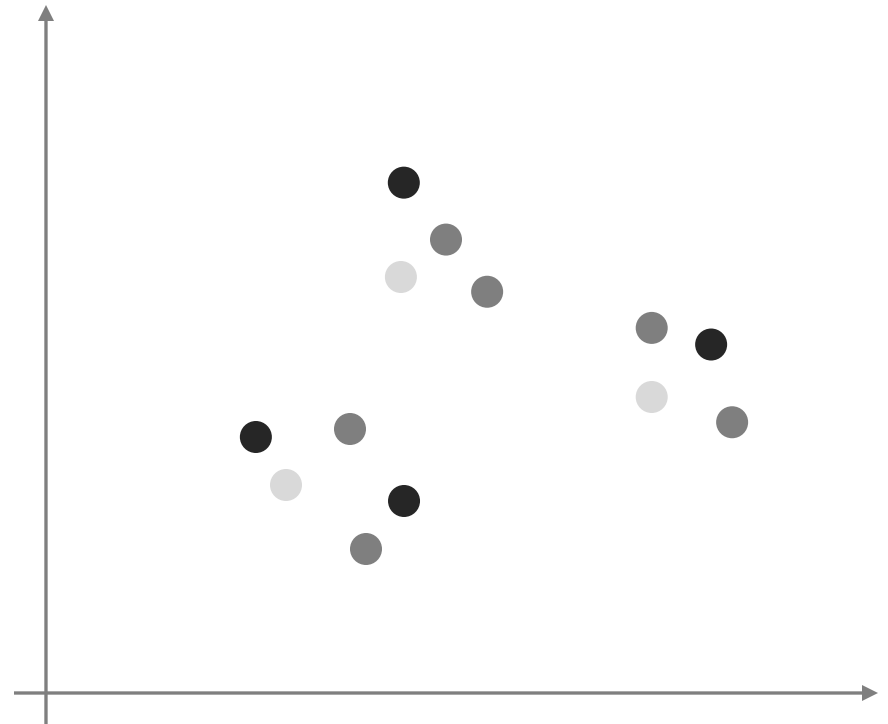
VISUAL VARIABLE #2 – SIZE

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



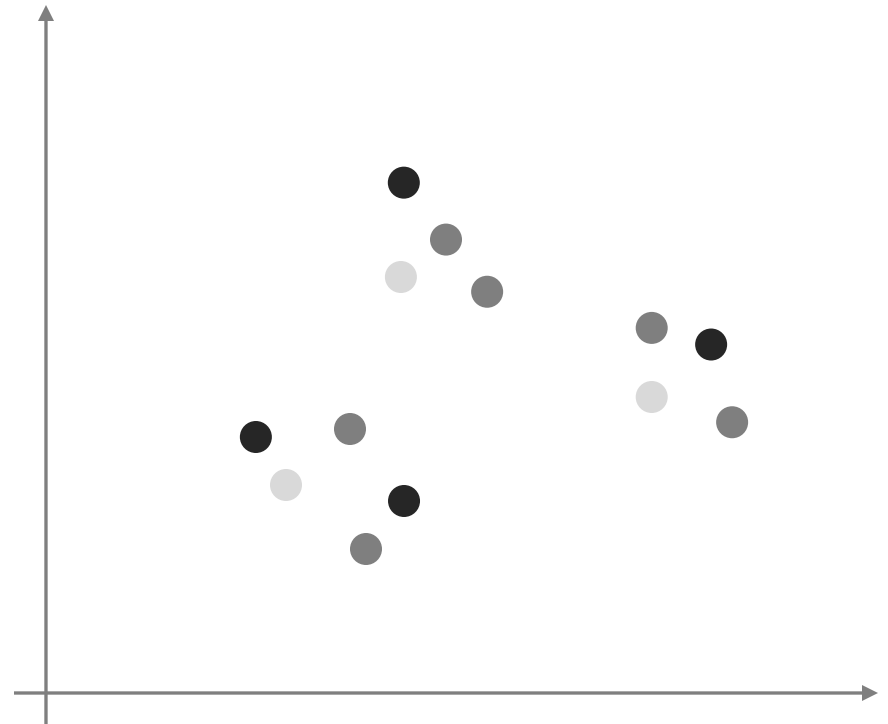
VISUAL VARIABLE #3 – BRIGHTNESS

Visual property	Can convey
Associative	
Selective	
Ordered	
Quantitative	



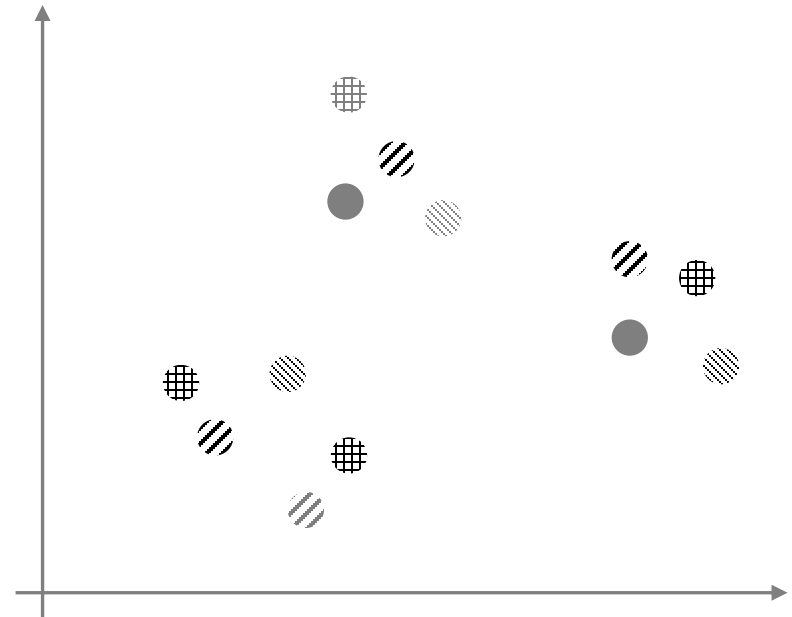
VISUAL VARIABLE #3 – BRIGHTNESS

Visual property	Can convey
Associative	Y
Selective	Y
Ordered	Y
Quantitative	



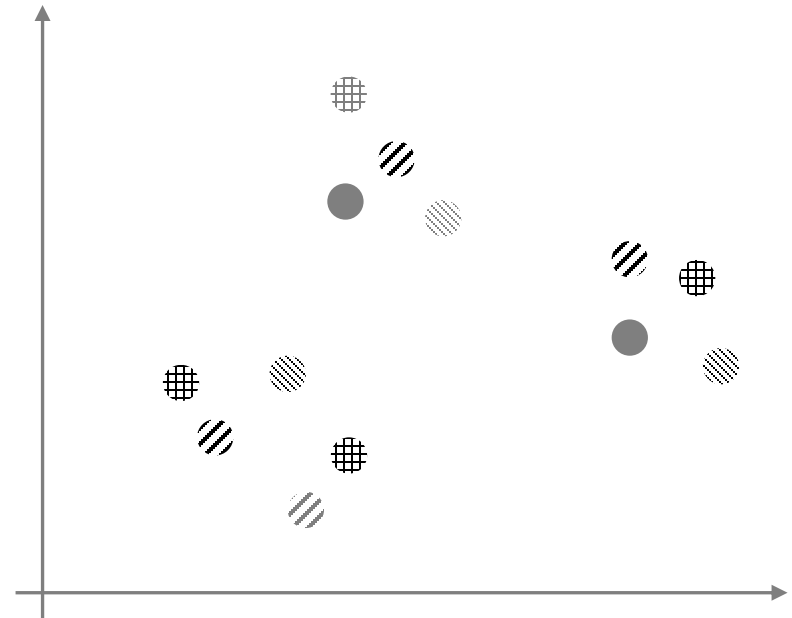
VISUAL VARIABLE #4 – TEXTURE

Visual property	Can convey
Associative	
Selective	
Ordered	
Quantitative	



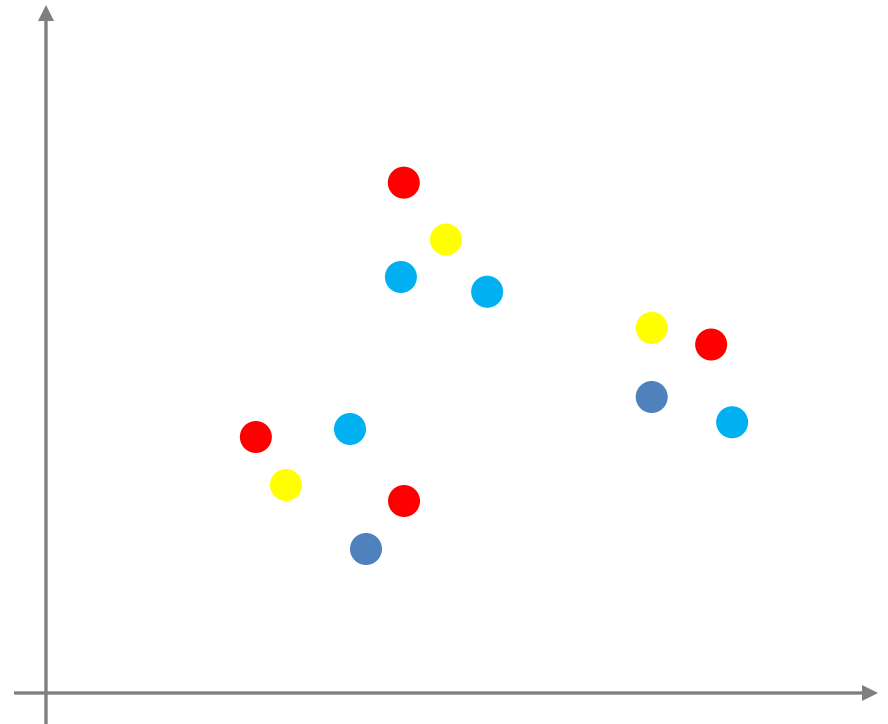
VISUAL VARIABLE #4 – TEXTURE

Visual property	Can convey
Associative	Y
Selective	Y
Ordered	
Quantitative	



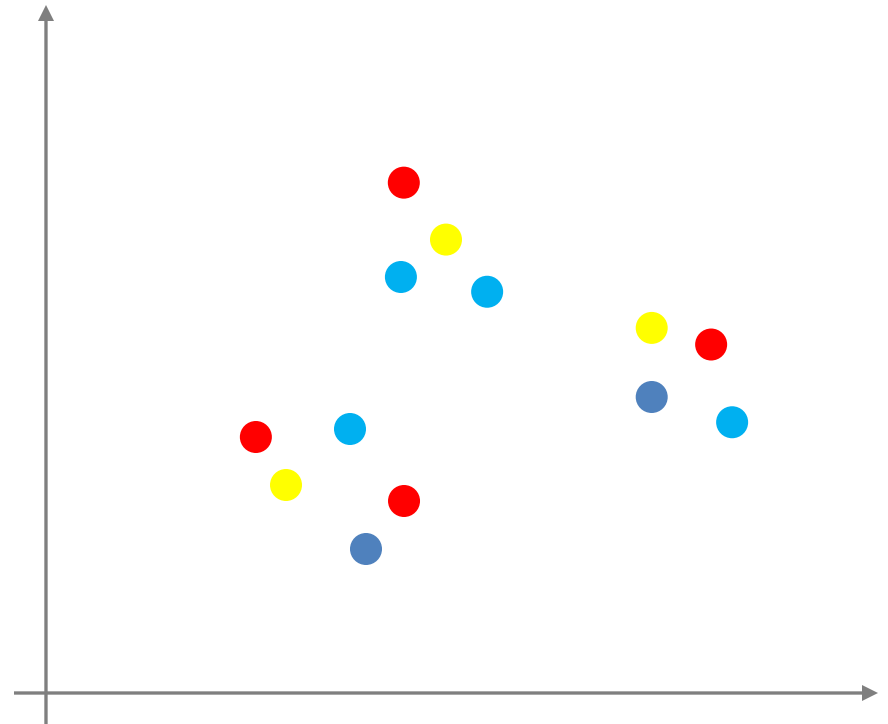
VISUAL VARIABLE #4 – COLOR

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	



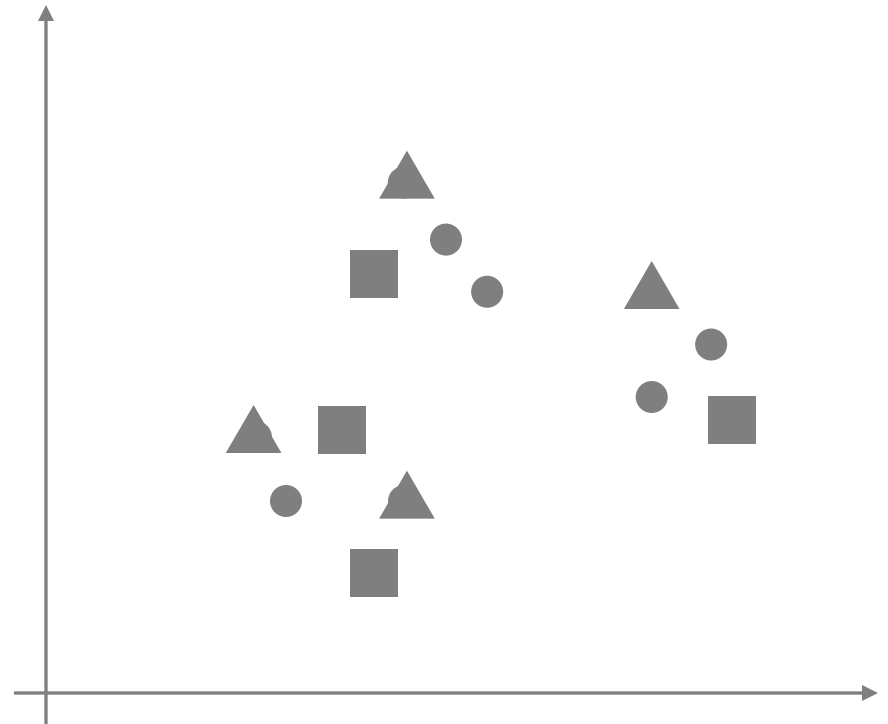
VISUAL VARIABLE #5 – ORIENTATION

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



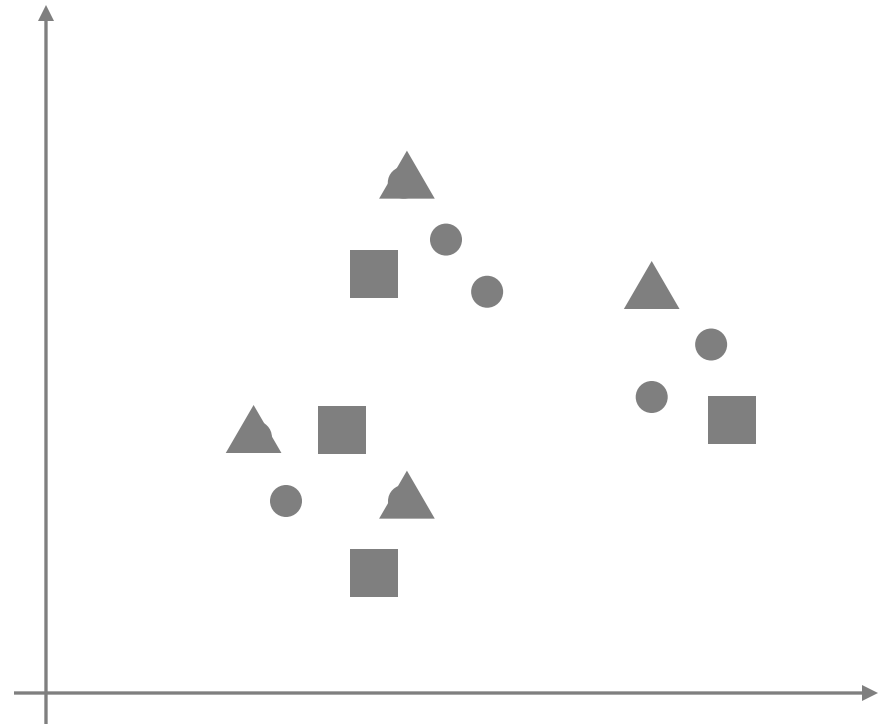
VISUAL VARIABLE #6 – SHAPE

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

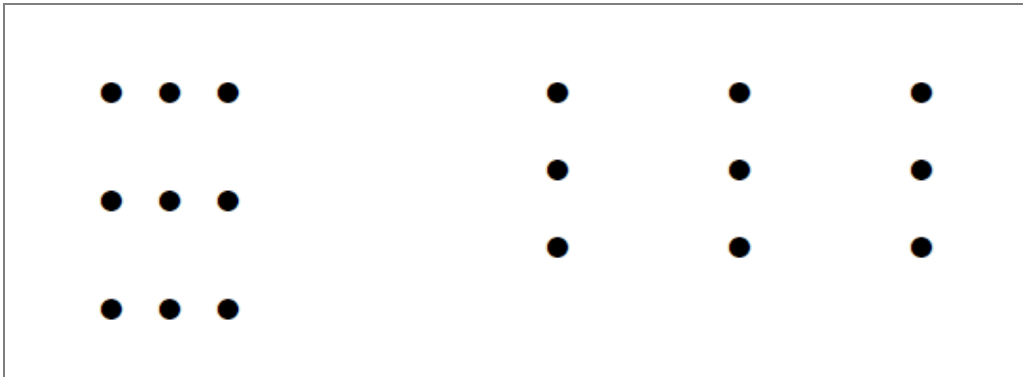
Visual variables differ in what data properties they can convey

	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

County

Post Code Country

| [Cancel](#)

PRIMARY ACTION | SECONDARY ACTION

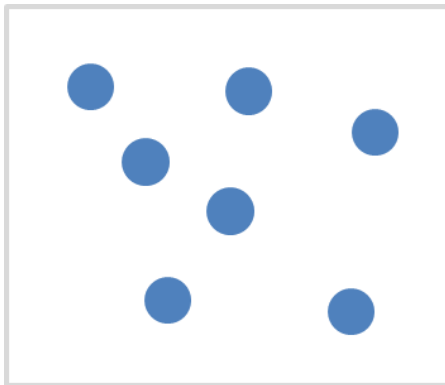
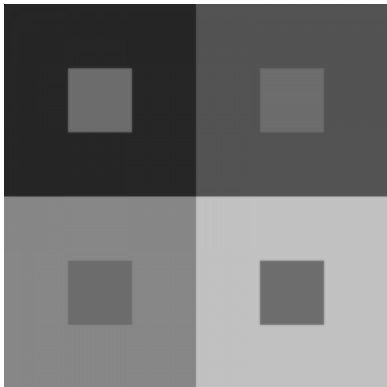
TAKE-AWAYS (2)

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

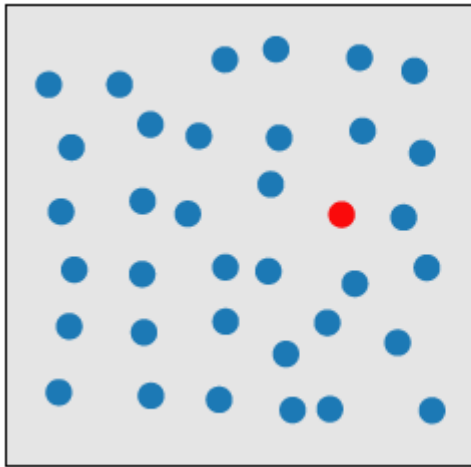
- + brightness does not consume extra space (bigger disks do)
- brightness depends on environmental lighting (size does not)
where do you view the visualization (office, outdoors, night or day?)



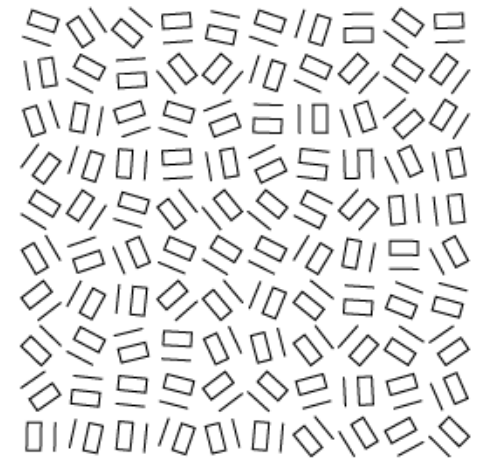
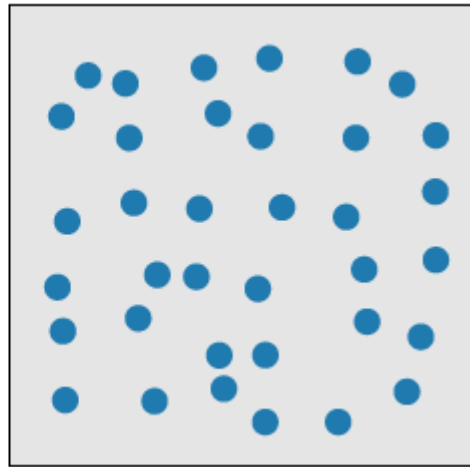
TAKE-AWAYS (3)

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

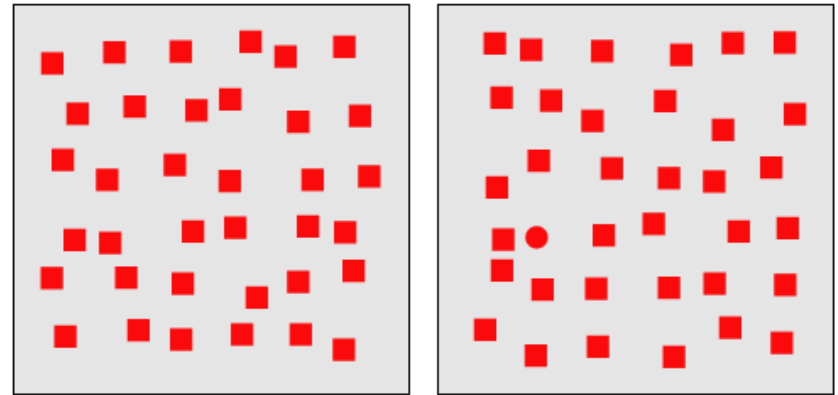


texture pop-out?

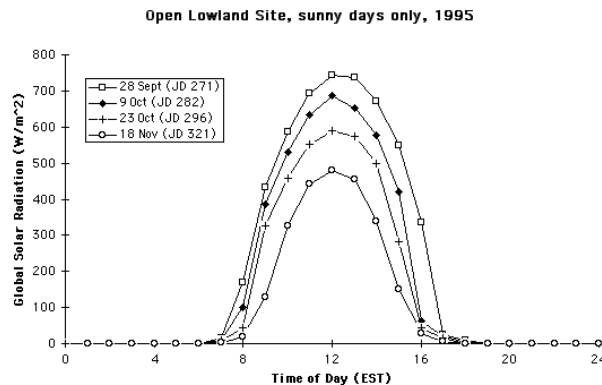


TAKE AWAYS (4)

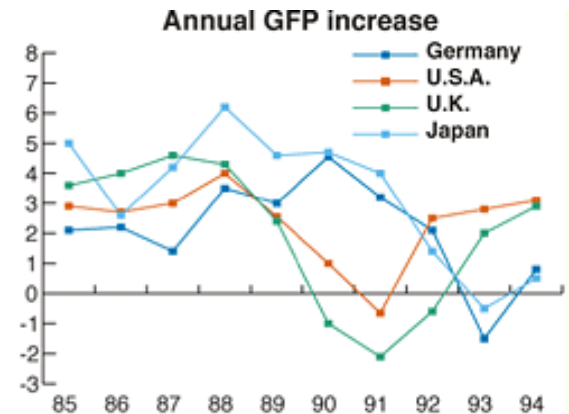
Shape provides only limited pop-out



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



VS.



COLOR REVISITED

COLOR AND CONTRAST



Background with same-colored object at the same brightness

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

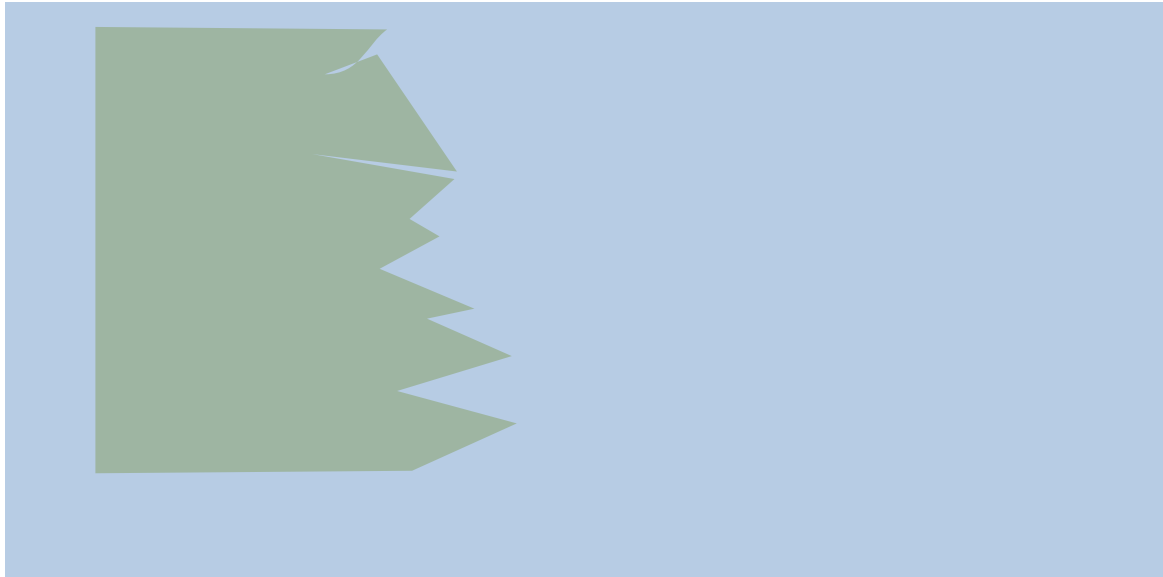
COLOR AND CONTRAST



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 ...

WHAT DID WE LEARN FROM THAT EXPERIMENT?

Color is for ... labeling

Brightness (intensity, luminance) is for ... fine detail contrast

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

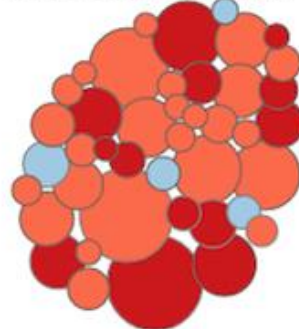
Share 1161 Tweet 558

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

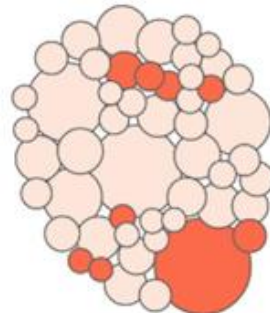


Argentina



ASIA

China

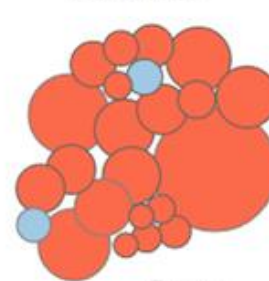


Japan

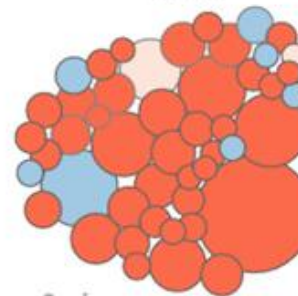


EUROPA

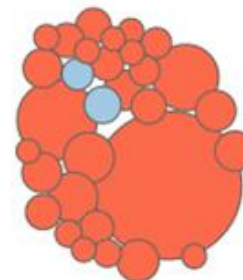
Great Britain



France



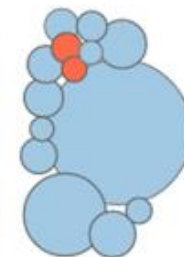
Spain



Netherlands - Belgium



Switzerland



Italy



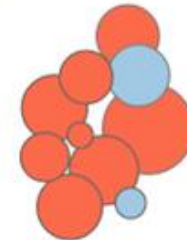
Russia



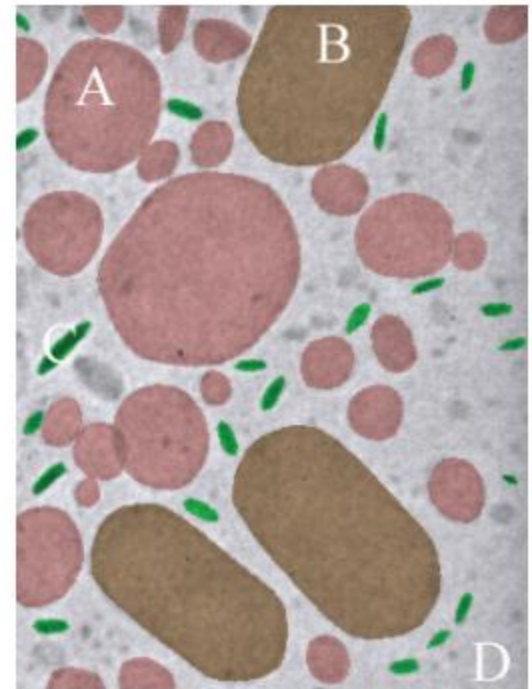
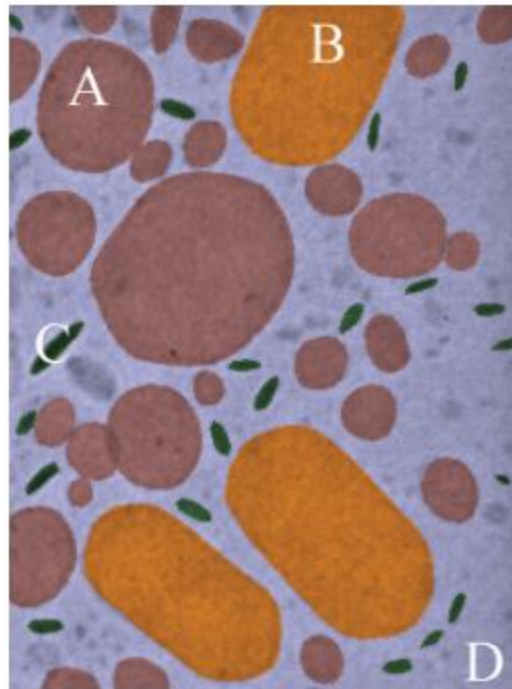
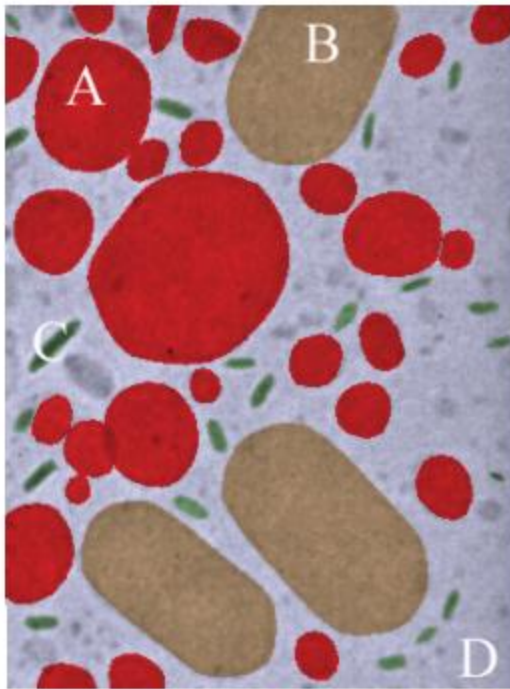
Germany



Others



COLOR TAGGING FOR IMPORTANCE

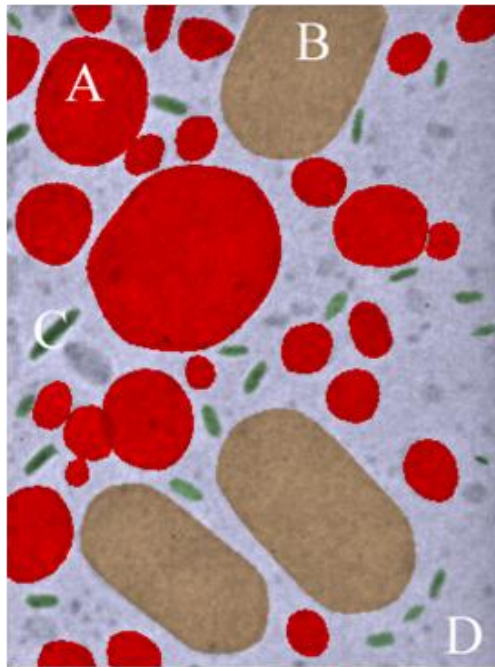


Which is the most important structure in each (as intended by the author)

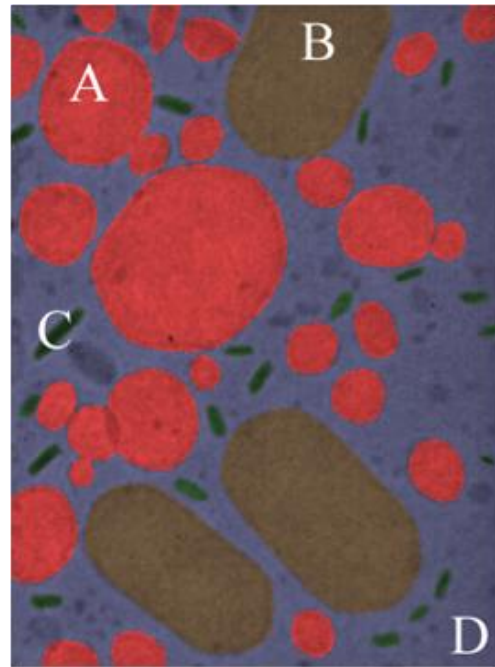
HOW ABOUT AESTHETICS?

Which one do people like better?

- perceived importance level of red object is the same



Vis 1

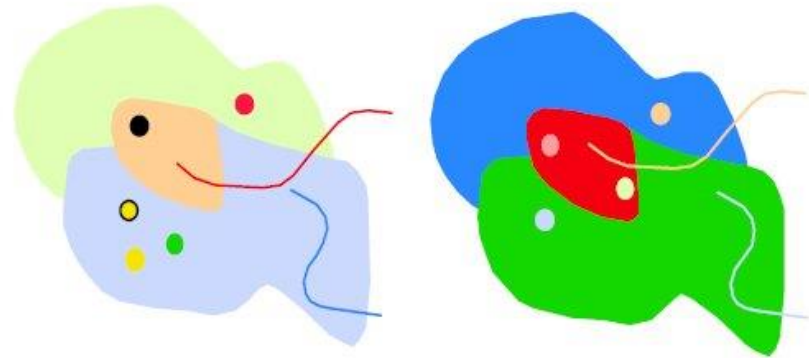


Vis 2



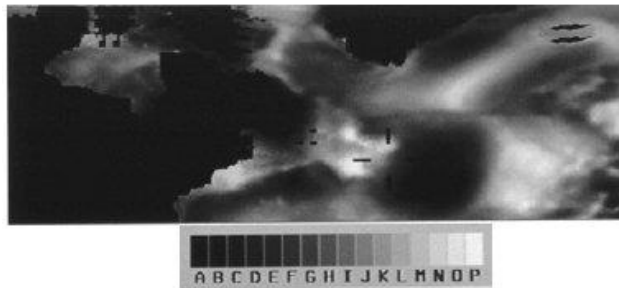
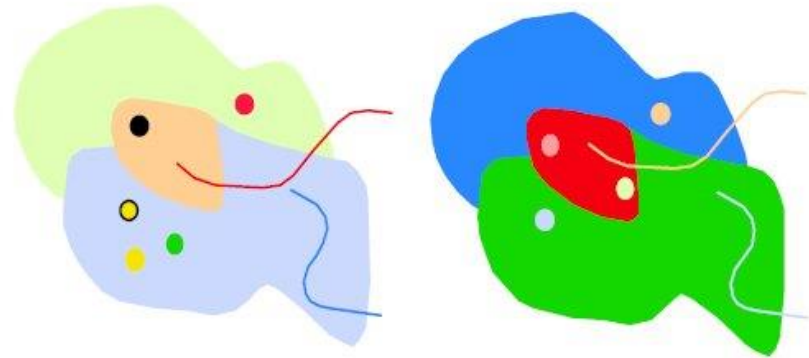
COLOR CODING AND COLORMAPS

- 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

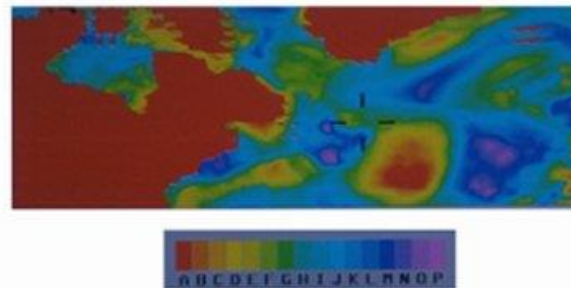


COLOR CODING AND COLORMAPS

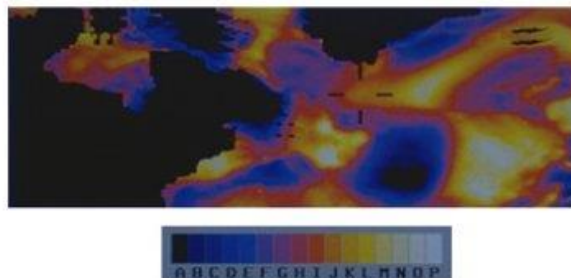
- Color coding
 - large areas: low saturation
 - small areas: high saturation
 - maintain luminance contrast
 - break iso-luminances with borders
- Pseudo-coloring: assign colors to grey levels by indexing the grey levels into a color map



original greylevel map



simple spectrum sequence
with iso-luminance

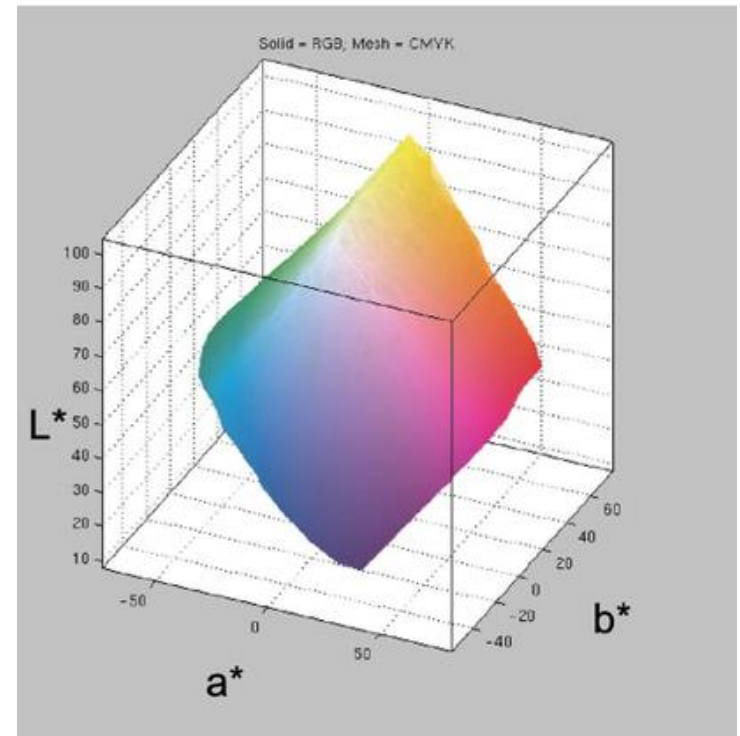
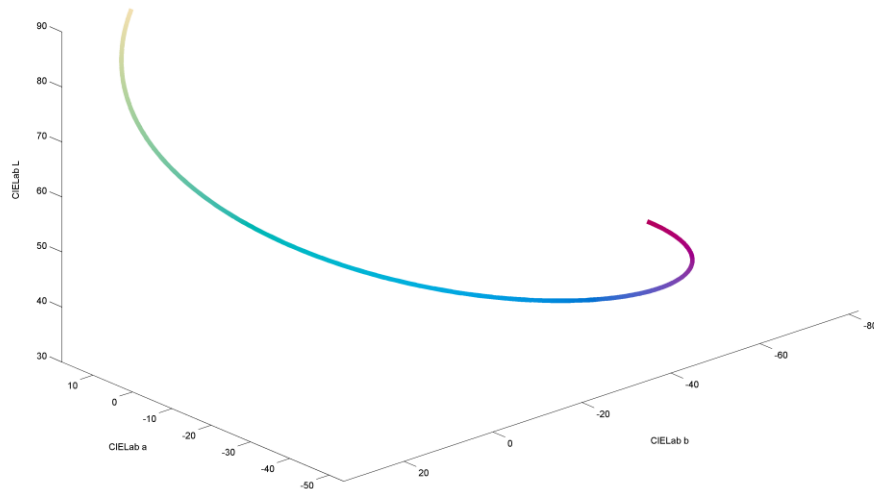


more effective:
spiral sequence through
color space
luminance increases with
hue

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

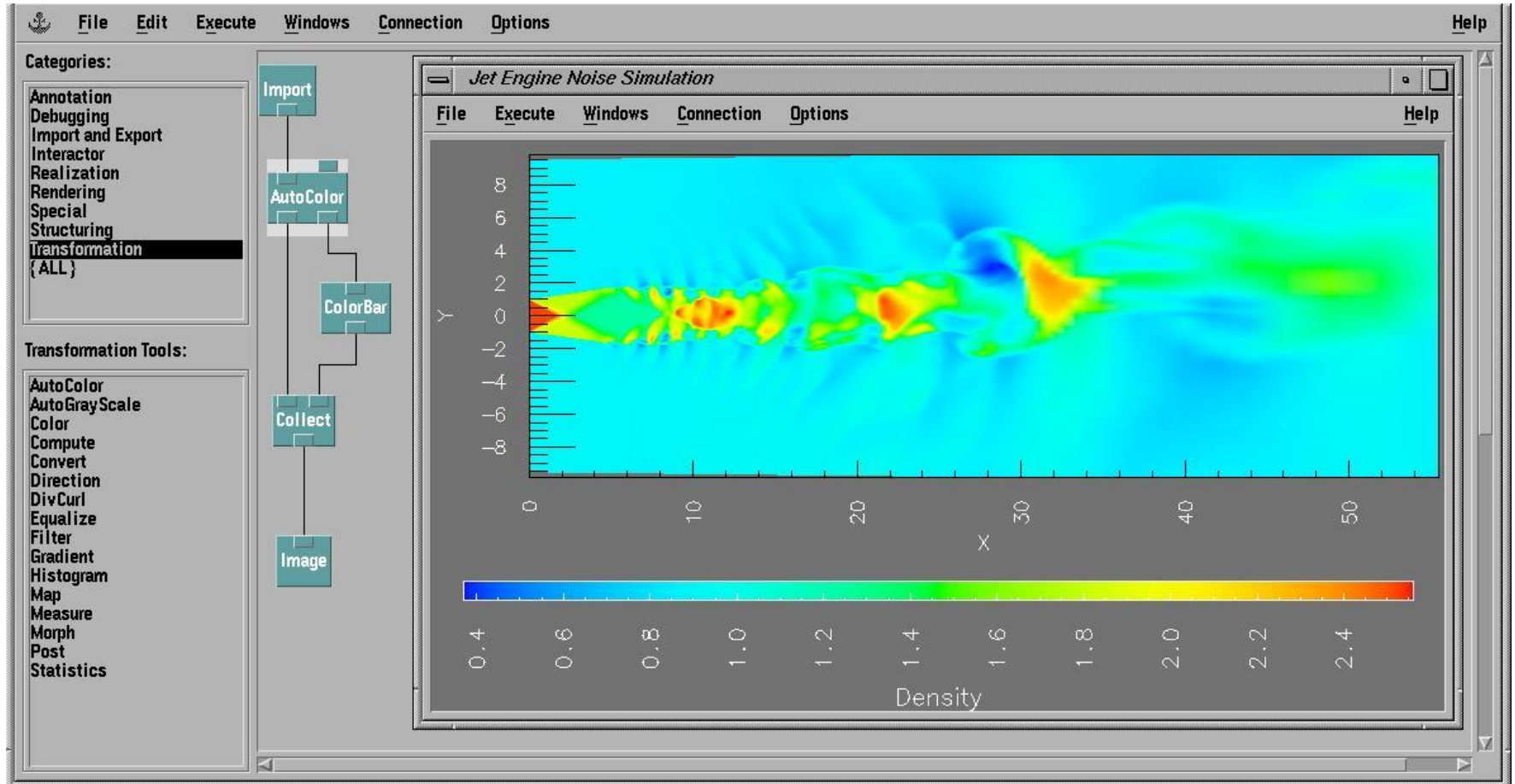
Solution 1:

- map to hue → the rainbow colormap

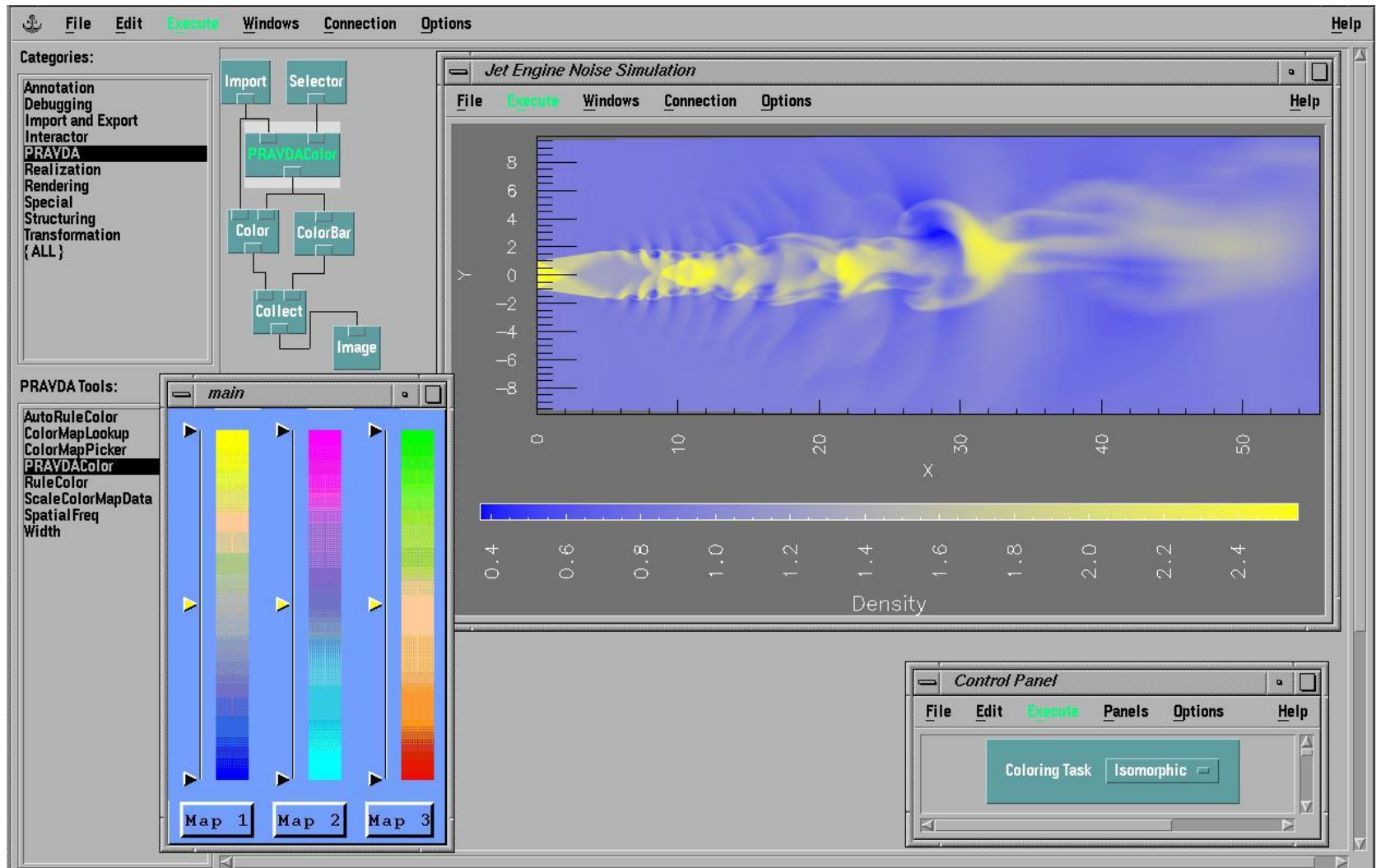


- can you see all adjacent colors at the same contrast?

AVOID RAINBOW COLORMAPS



BETTER: LINEAR HUE



EFFECTIVE USE OF RAINBOW COLOR MAPS

Wait, did I not tell you that rainbow color maps are bad?

- actually, they can be useful if the intervals are carefully chosen

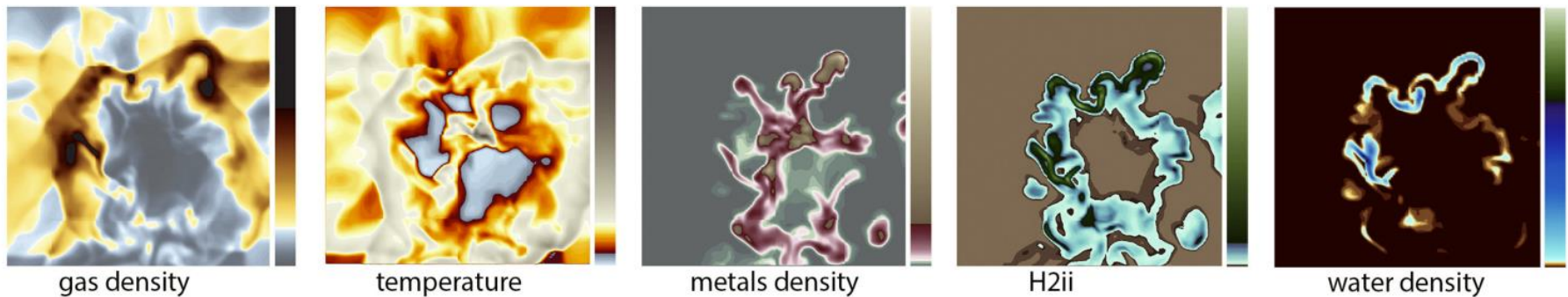
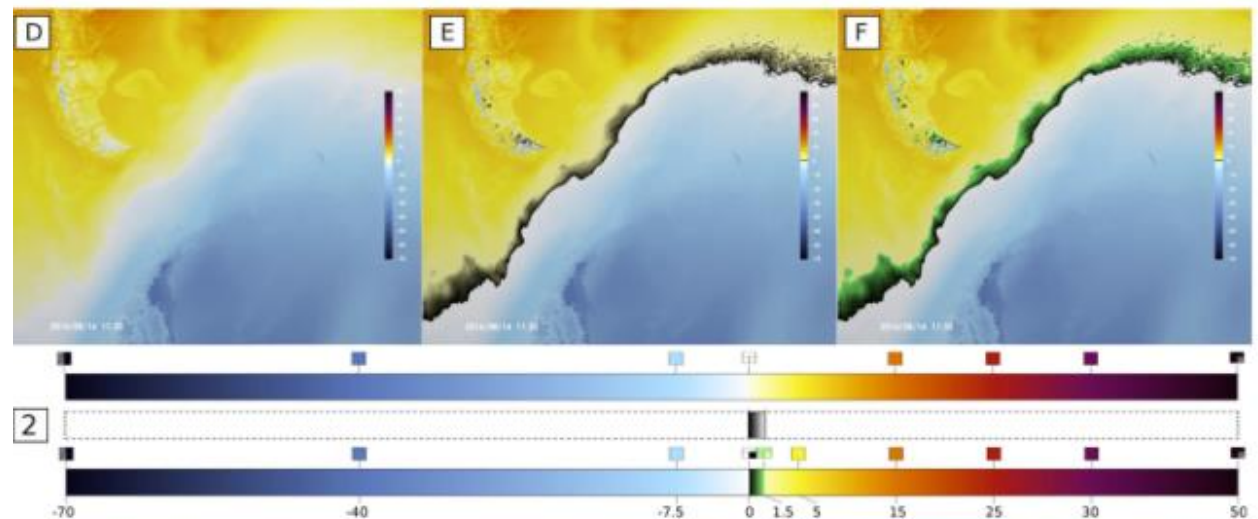
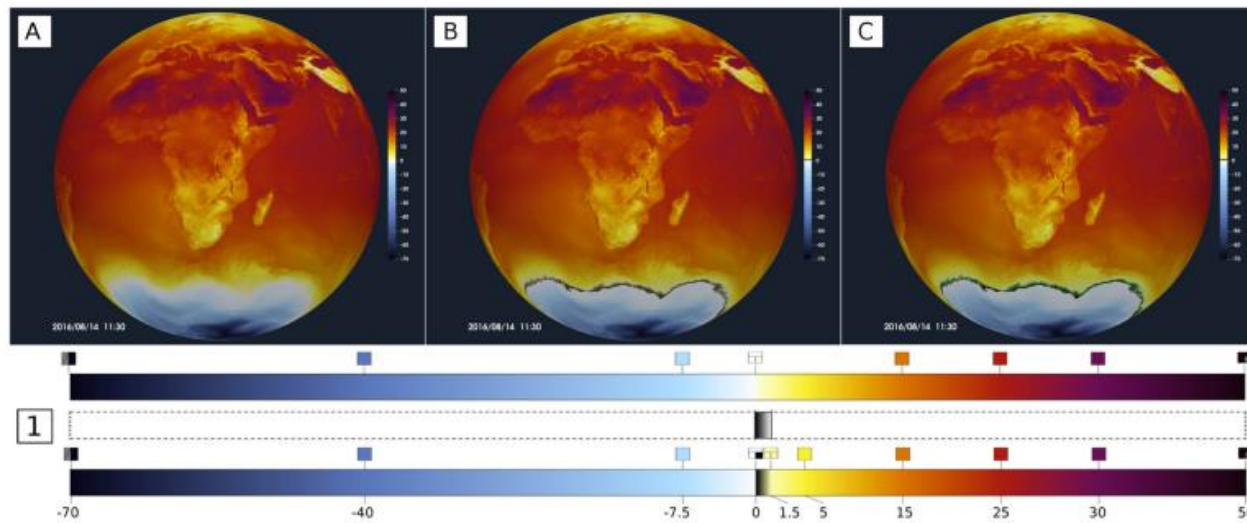


Fig. 15. Scientists examine multiple variables in order to gain an understanding into the locations and quantities where ancient water was likely to have formed. CCC-Tool color bar locations are crafted to highlight the data ranges for each variable that is conducive to water formation, enabling scientists to easily recognize and compare the locations over multiple variables and time steps.

MORE PURPOSEFUL RAINBOW COLORMAPS



also Nardini et al.

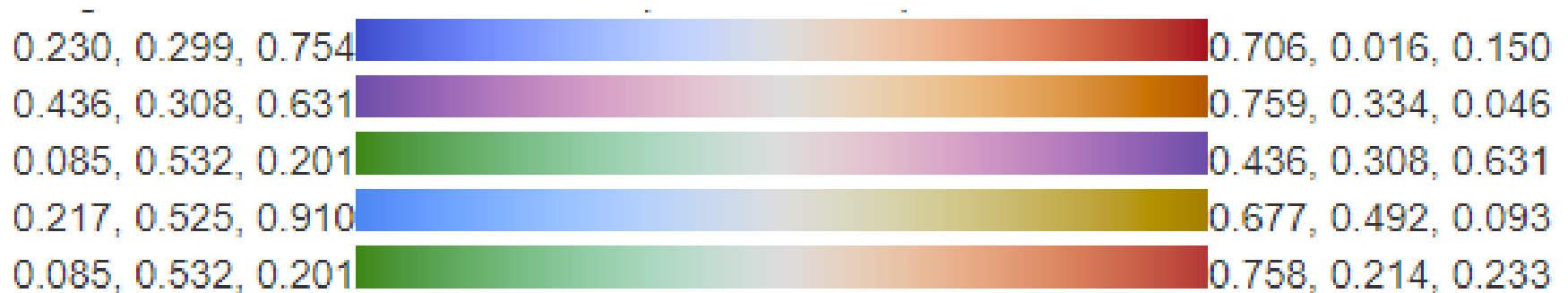
EXPLANATION FOR LAST SLIDE

At the example of the 2m-temperature of a high resolution simulation with the global atmosphere model ICON, the figure illustrates the use of probes to inspect small sub-ranges of the global data range. The rendering on the left (A) shows the the global temperature distribution with colormapping using a CMS (inset 1, top) that was designed to resolve the data range from -70 to 50C. However, within small sub-regions, as shown in a close-up (D), only a small section of the CMS is used and local structures are hardly visible. In order to probe the temperature range 0 - 1.5C in more detail, we added single probe at 0C to compose a CMS (1, bottom) that creates an isoline-like-structure to highlight the freezing point and the data range above. The images (B) and (E) show the result for a One-Sided-Transparent-Probe. The according colormap composition is shown in inset (1). Similarly, (C) and (F) show the according renderings for One-Sided-Probe according to the definition shown in inset (2, middle). (1: Top: Divergent CMS for the 2m-temperature. Middle: one sided transparent probe for the range 0 - 1.5C. Bottom: resulting colormap. 2: One sided probe without transparency.)

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

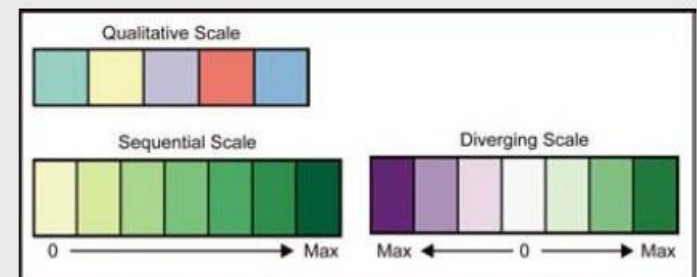
- vary in lightness and saturation
- vary slightly in hue

<http://colorbrewer2.org/>

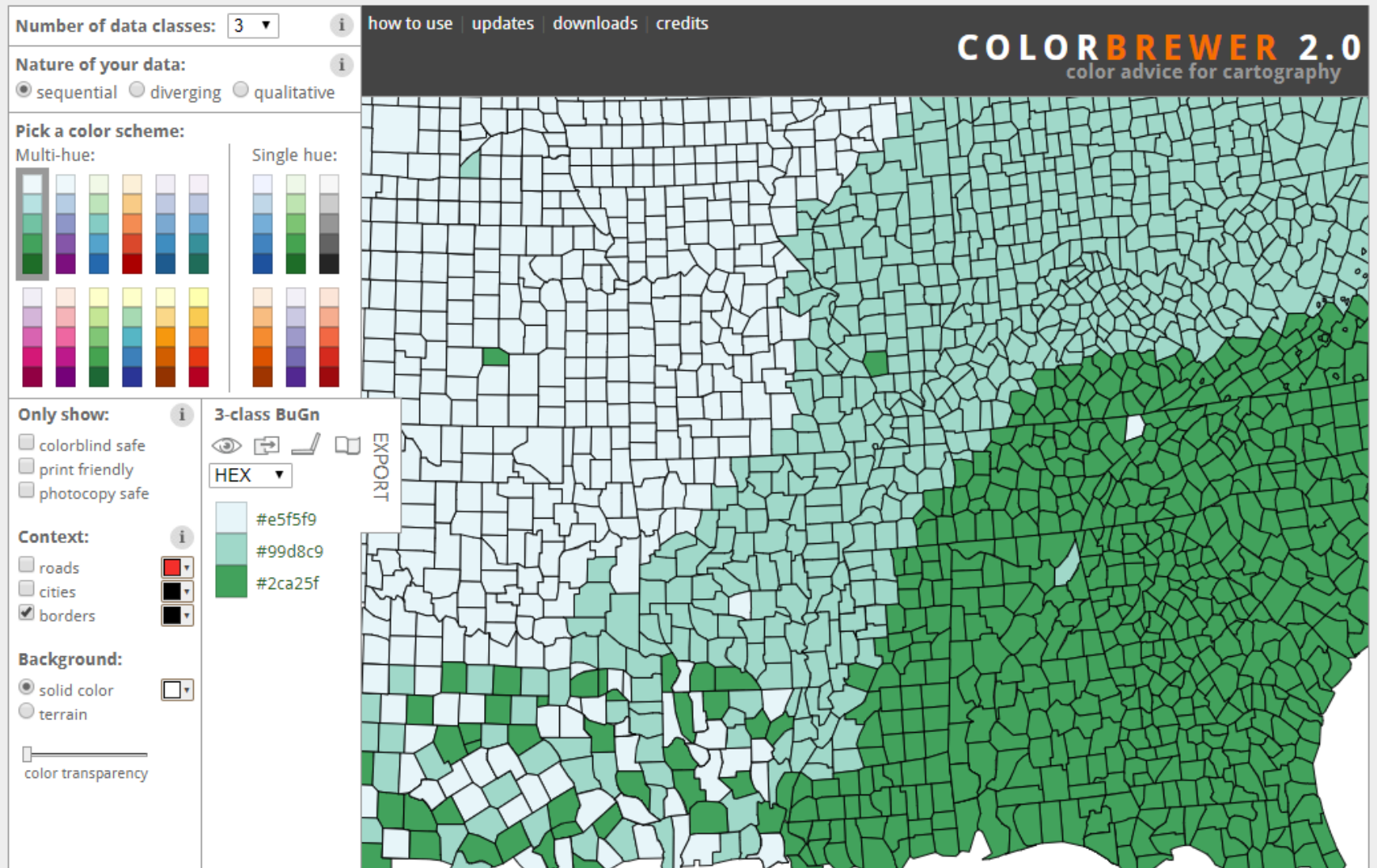
Diverging scale

- complementary sequential scales
- neutral at "zero"

Brewer's Categories



COLOR BREWER



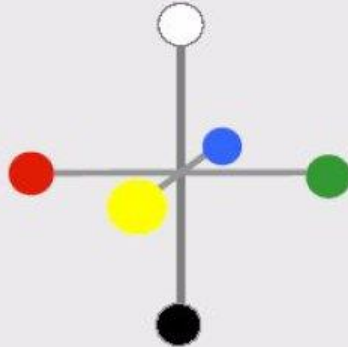
OPPONENT COLOR

Definition

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

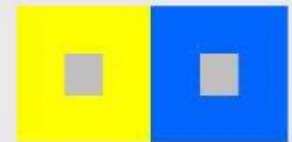
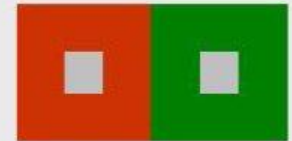
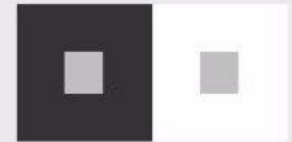
First level encoding

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



Add Opponent Color

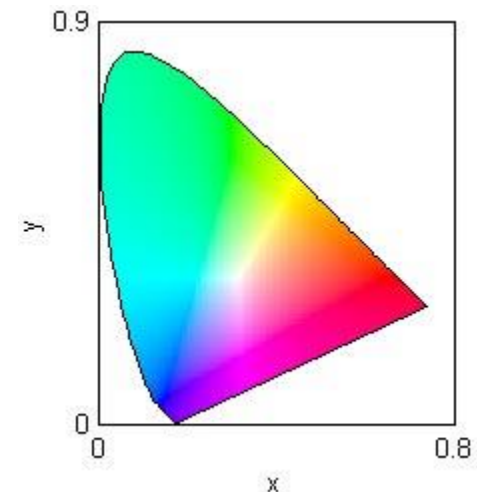
- Dark adds light
- Red adds green
- Blue adds yellow



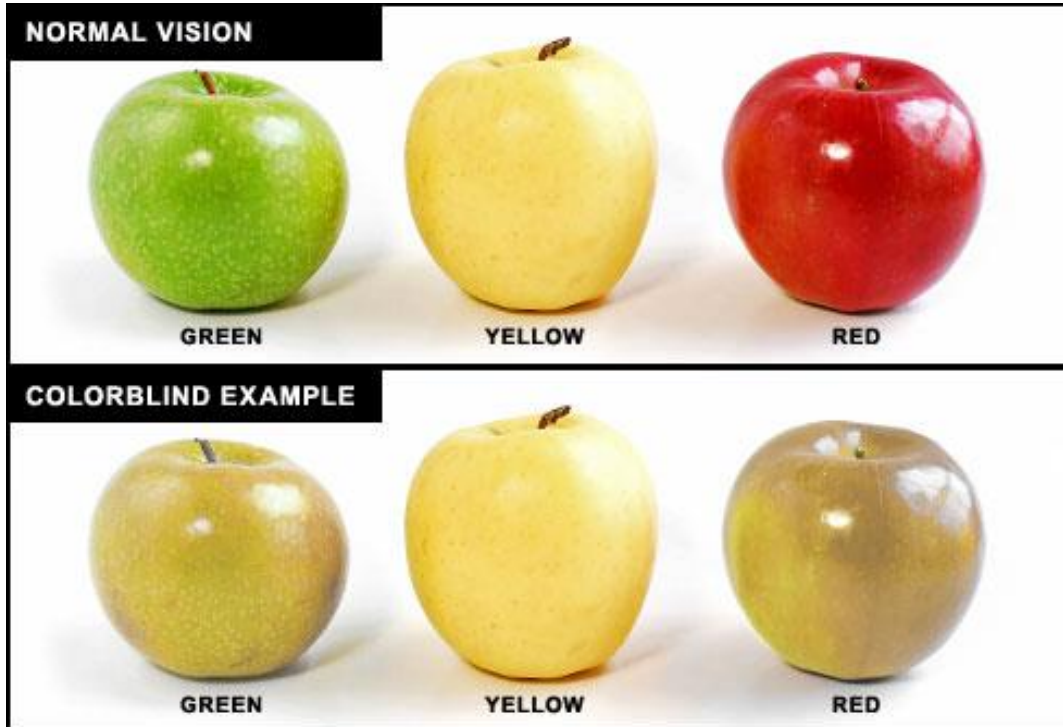
These samples will have both light/dark and hue contrast

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



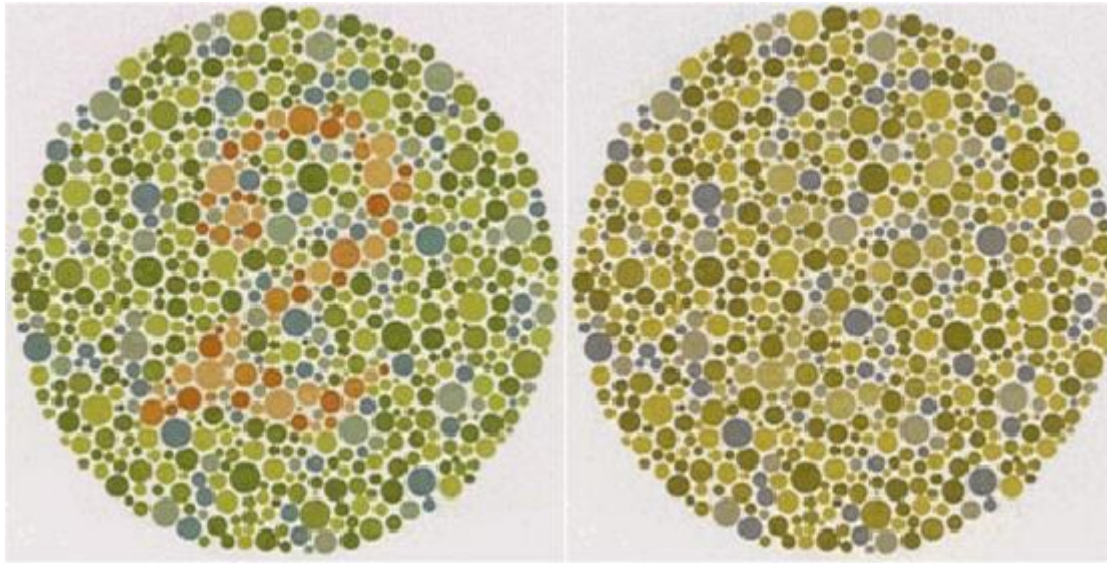
The colors of the rainbow as viewed by a person with protanopia.

blue missing
(rare)



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

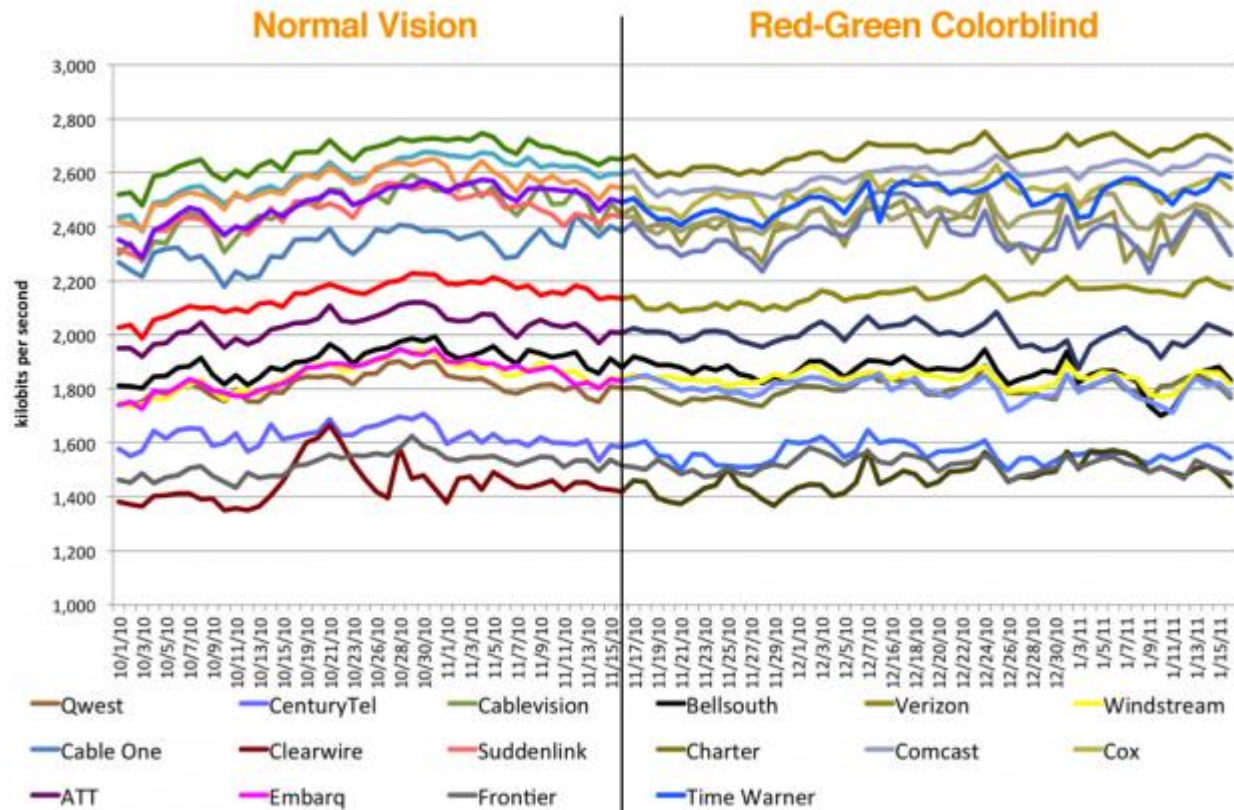
ISHIHARA TEST



normal

protanopia

LINE CHARTS



DESIGNING FOR COLOR DEFICIENT USERS

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

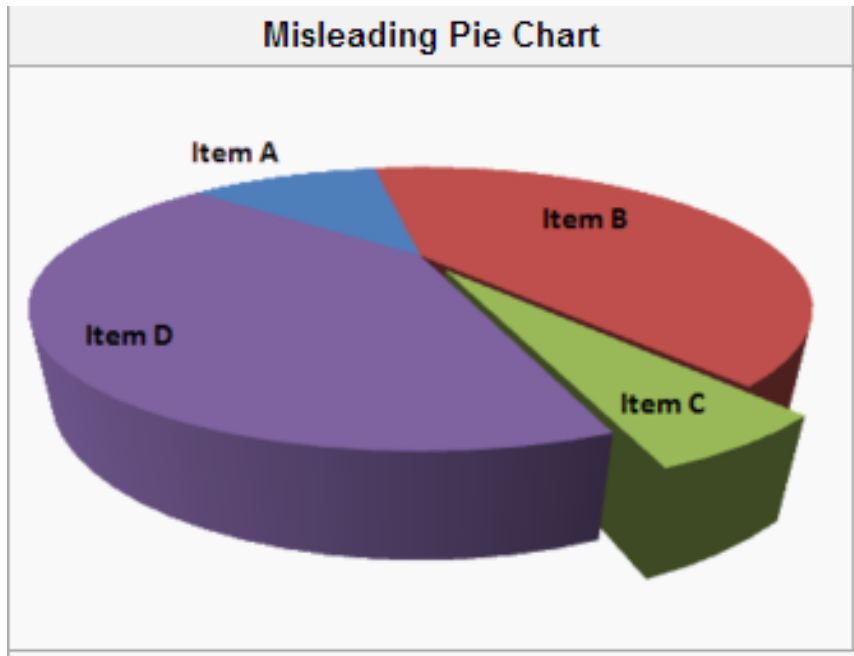
- so be careful when designing visualizations

What to do?

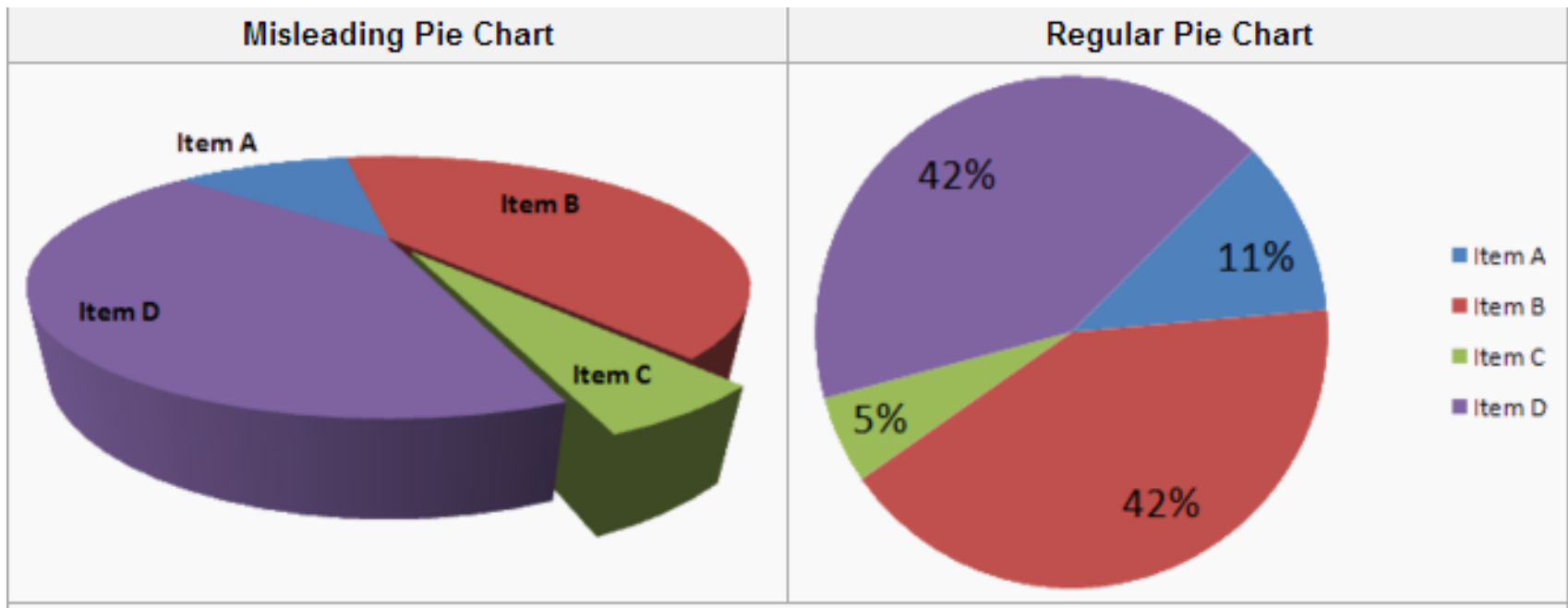
- use different intensities for red-green (e.g. light green, dark red)
- space red and green colored colors dots far apart or make large
- add symbols to line charts or vary line style
- avoid using gradient colors to indicate data value

USE OF 3D GRAPHICS

“FANCY” VISUALIZATIONS



“FANCY” VISUALIZATIONS



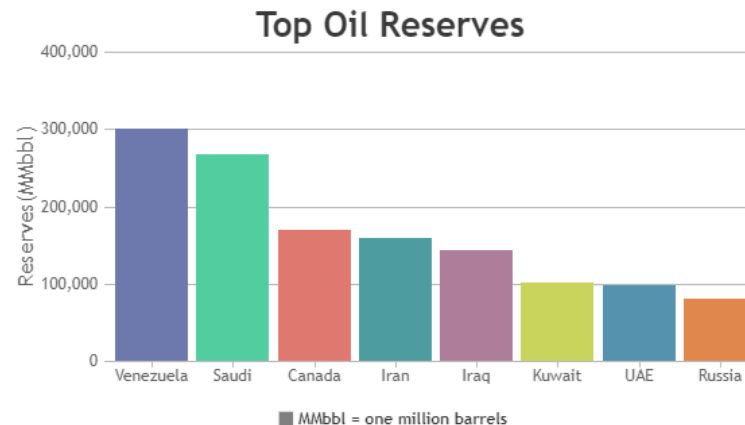
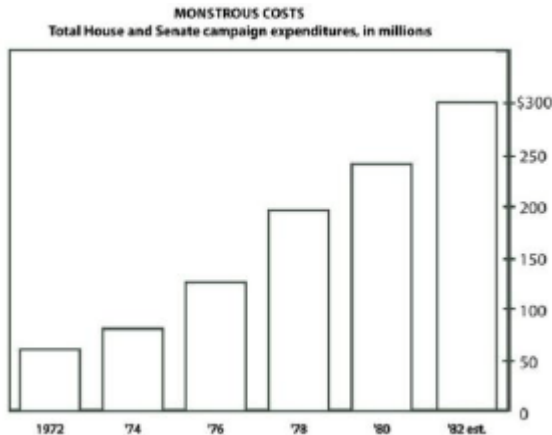
Perspective distortion in 3D rendering causes misconceptions

- in the 3D chart. item C appears to be at least as large as Item A
- whereas in actuality, it is less than half as large.

THE HALO EFFECT

Also known as the "physical attractiveness stereotype" or the "what is beautiful is 'good' principle"

Plain chart vs fancy vs really fancy

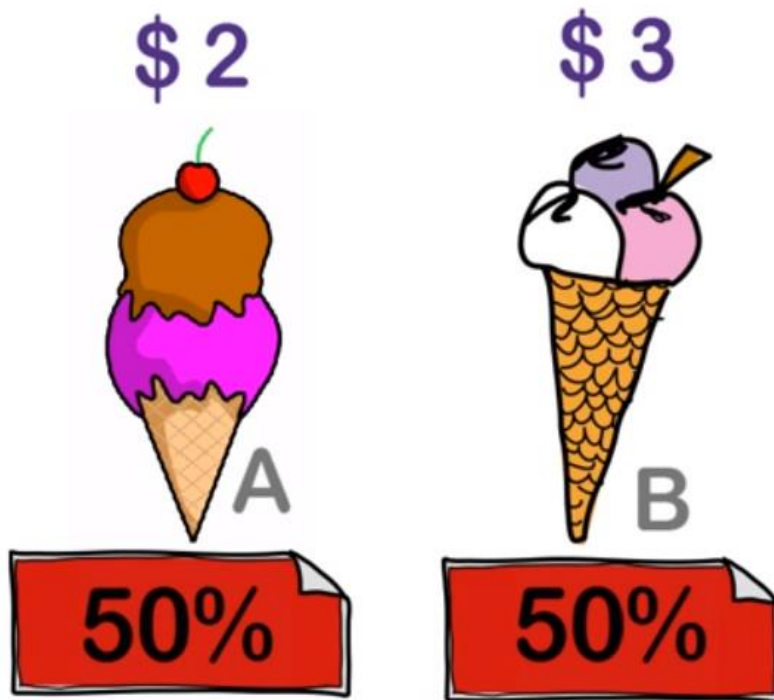


ATTRACTION EFFECT

THE ATTRACTION EFFECT (1)

Assume you can choose among two ice cream cones

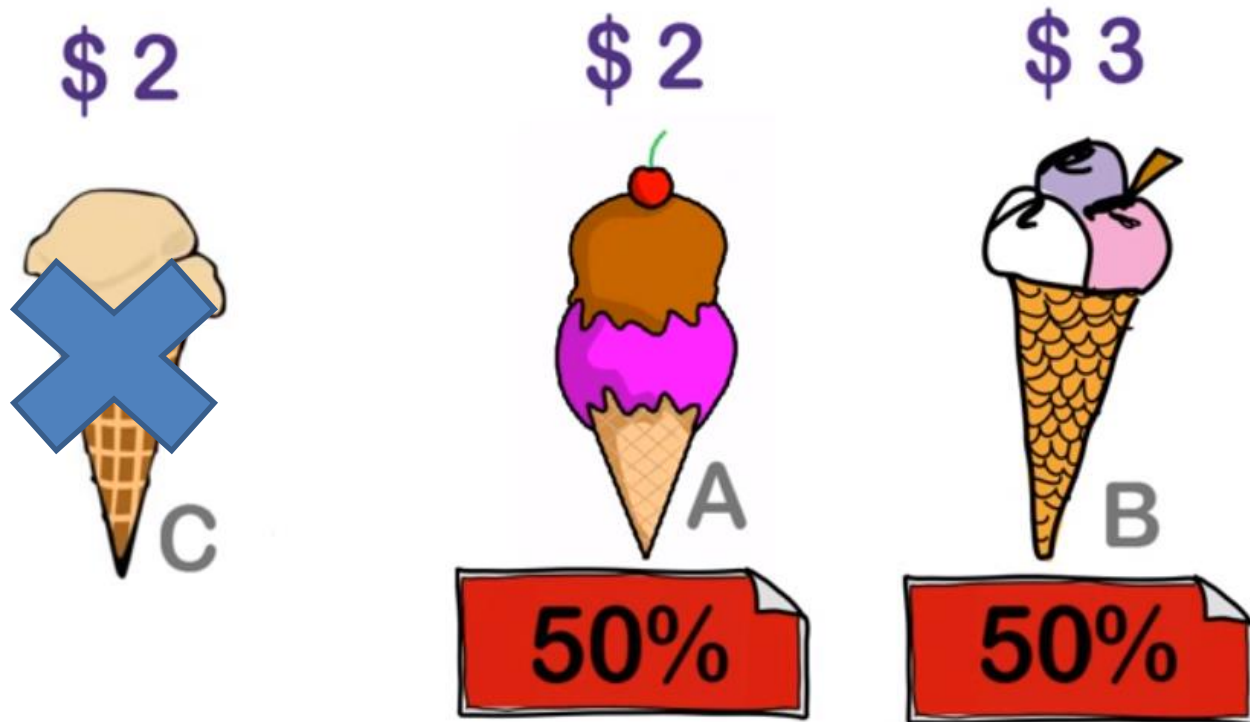
- one has a higher price but offers more scoops
- the other has fewer scoops but also a lower price
- depending on how you feel you will pick either one of them



ice cream cone
A and B have the
same market share

THE ATTRACTION EFFECT (2)

Now suppose there was a third ice cream cone available



- nobody would pick it

THE ATTRACTION EFFECT (3)

ADDING A THIRD OPTION CAN INCREASE SALES!

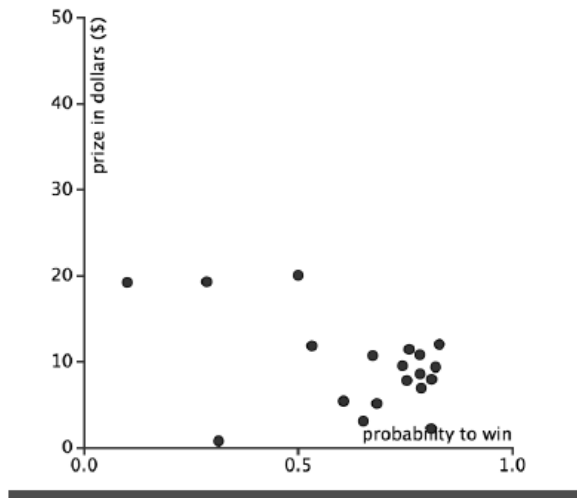


Adding the third (inferior) option stole $50\% - 33\% = 17\%$ market share from ice cream cone B and gave it to A

APPLICATION TO VISUALIZATION

Decision making with conflicting goals

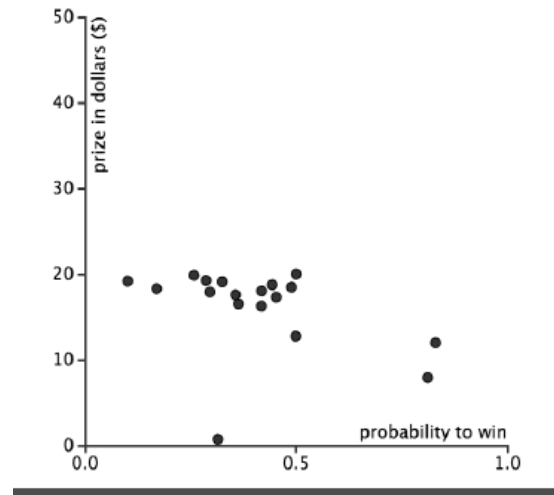
- here: lottery prize vs probability of winning – which ticket will you buy?



APPLICATION TO VISUALIZATION

Decision making with conflicting goals

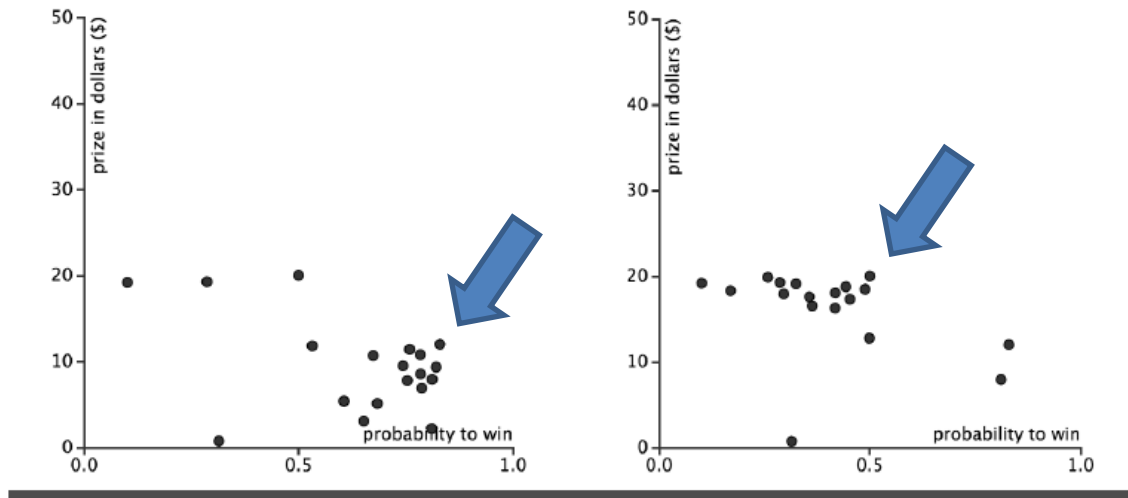
- here: lottery prize vs probability of winning – which ticket will you buy?



APPLICATION TO VISUALIZATION

Decision making with conflicting goals

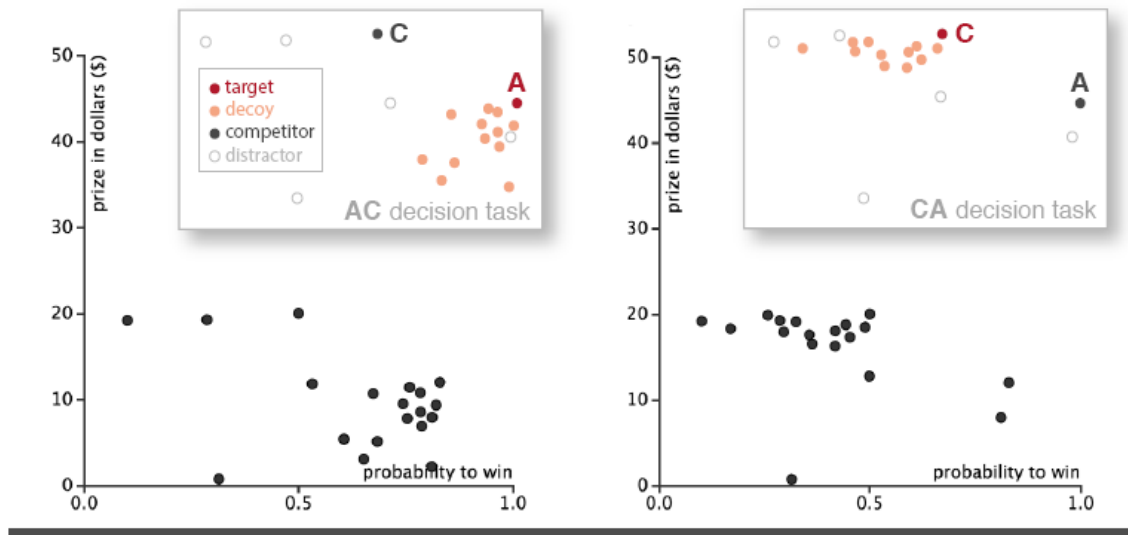
- lottery prize vs probability of winning – which ticket will you buy?



APPLICATION TO VISUALIZATION

Decision making with conflicting goals

- here: lottery prize vs probability of winning – which ticket will you buy?



Placement of decoys will always make A or C most attractive in selection and attention tasks

- note, the bottom plots were used in the experiment
- the top plots are just for illustration

A MITIGATION TECHNIQUE

Allow user to delete data points

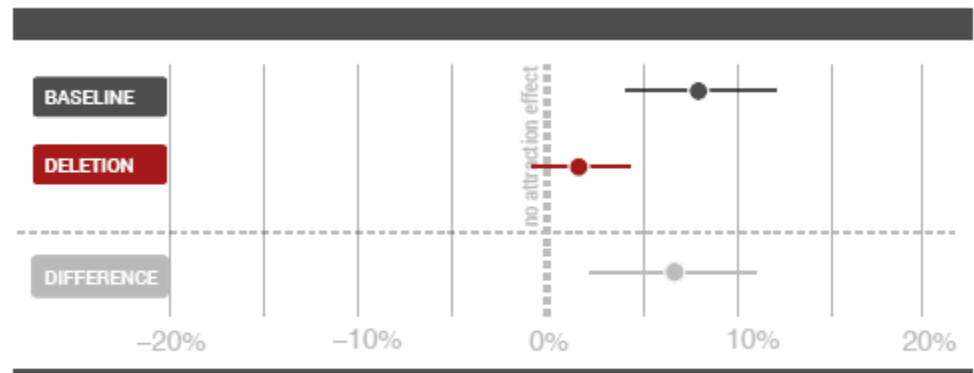
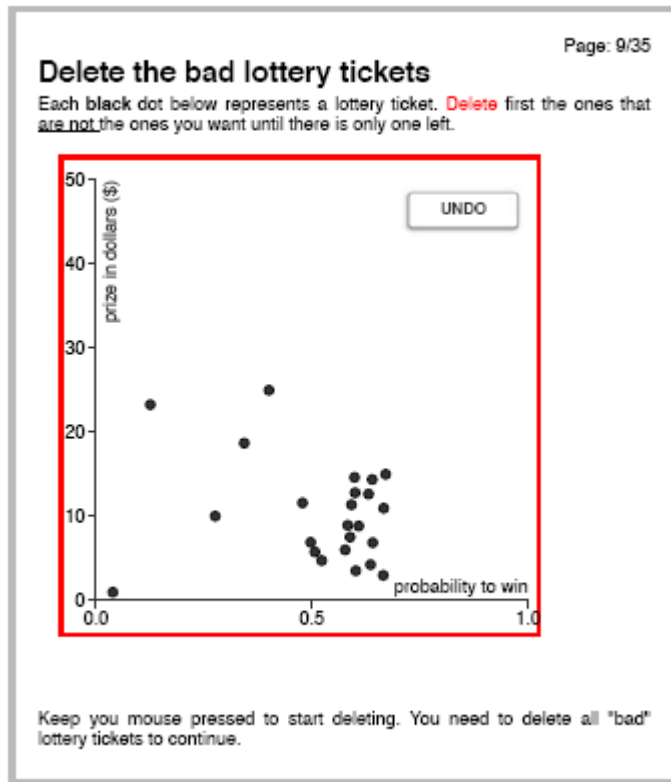


Fig. 8. Point estimates and 95% confidence intervals for the attraction effects in *baseline* and *deletion* conditions.

indeed allowed users to overcome the bias

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

Avoid 3D just for effect

Visualization artistry:

- Use of luminance to indicate direction

