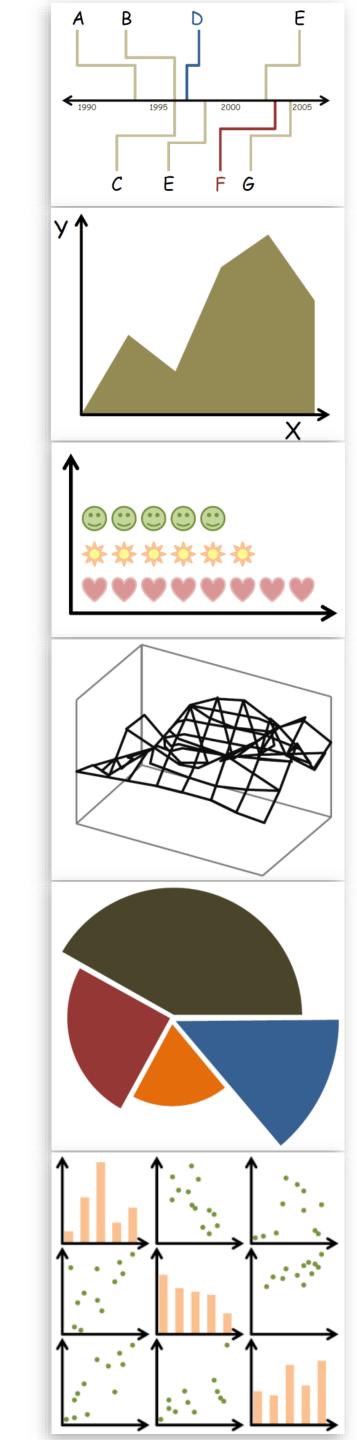


Color, Popout, Illusions

CS 7250 SPRING 2020 *Prof. Cody Dunne Northeastern University*

Slides and inspiration from Michelle Borkin, Krzysztof Gajos, Hanspeter Pfister, Miriah Meyer, Jonathan Schwabish, and David Sprague



BURNING QUESTIONS?



PREVIOUSLY, ON CS 7250...



"...avoiding catastrophe becomes the first principle in bringing color

to information: above all, do no harm." -Edward Tufte

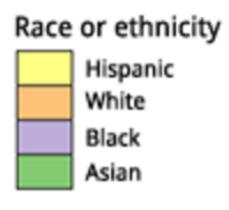
Tufte, "Envisioning Information"





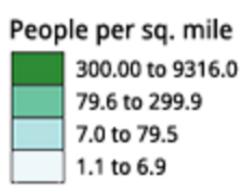
THREE MAIN TYPES:

Categorical



(categorical/nominal data)

Sequential



Diverging

Percent of population under 18 by state 28.0 to 32.2 25.7 to 27.9 Critical Value - Nat'1 Avg 24.0 to 25.6 20.1 to 23.9

(quantitative data)

- Does not imply magnitude differences
- Distinct hues with similar emphasis
- Best for ordered data that progresses from low to high (ordinal, quantitative data)
- Darkness (lightness) channel effectively employed
- For data with a "diverging" (mid) point
- Equal emphasis on mid-range critical values and extremes at both ends of the data range





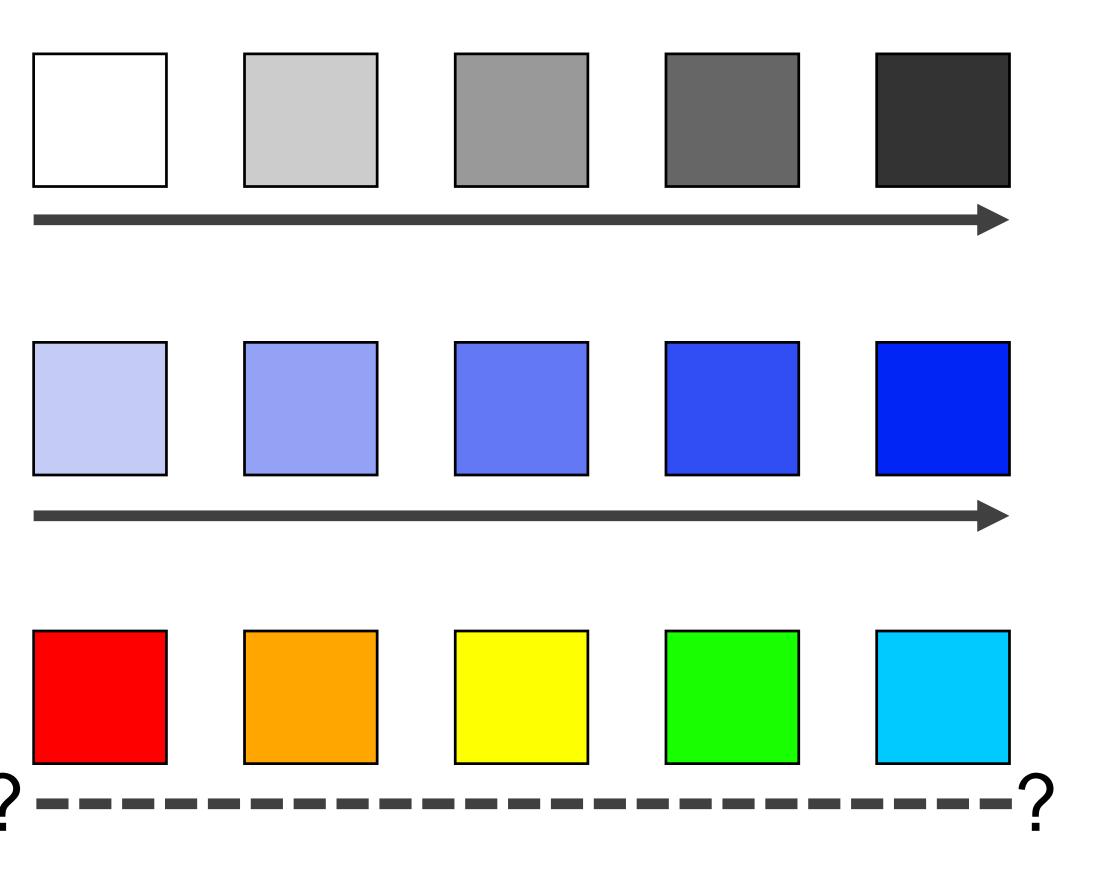


Color Vocabulary and Perceptual Ordering

Darkness (Lightness)

Saturation

Hue



Based on Slides by Miriah Meyer, Tamara Munzner⁶



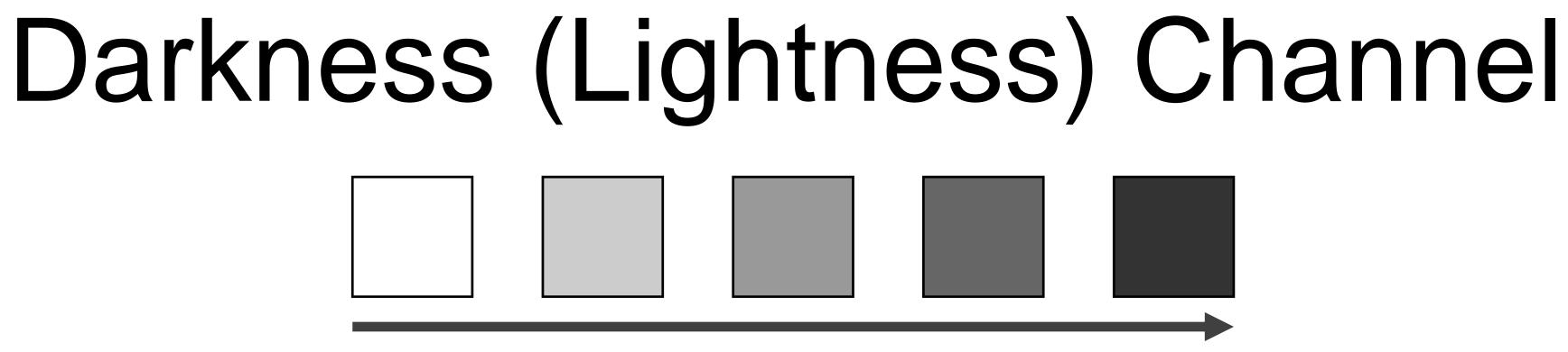


"Get it right in black and white." -Maureen Stone





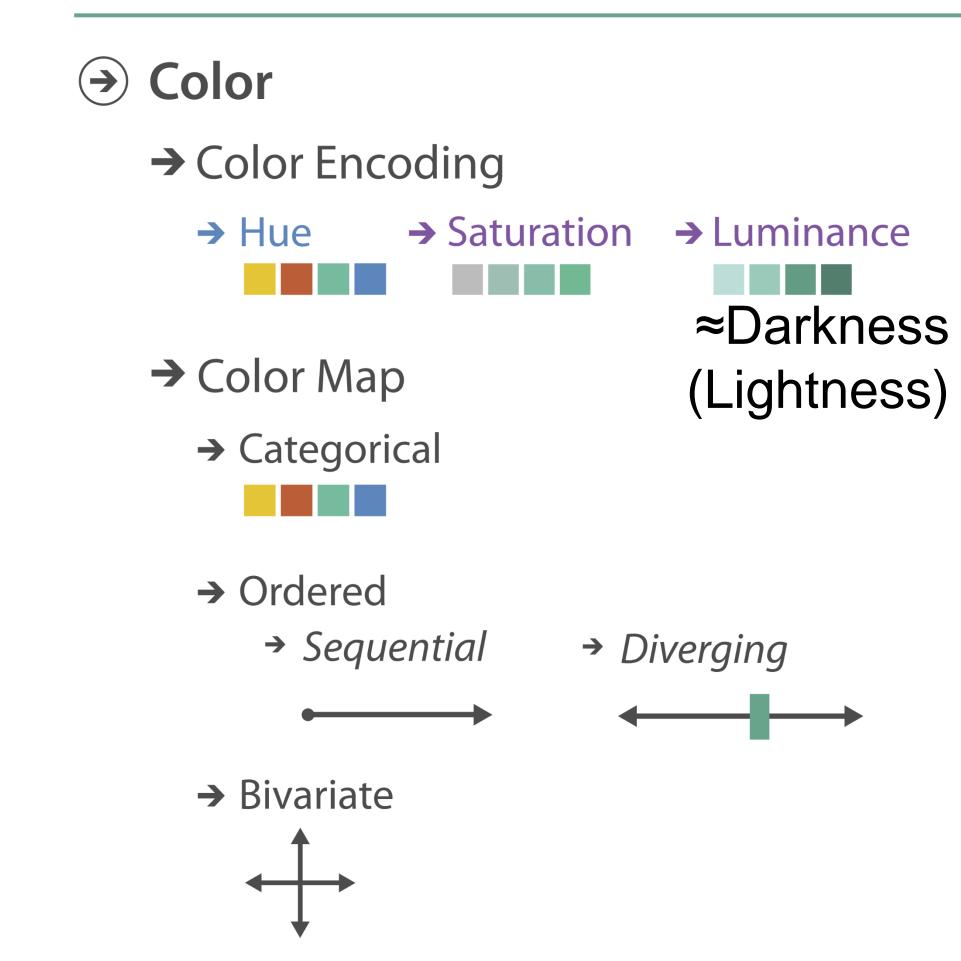
- No edges without darkness difference
- No shading without darkness variation
- Has higher spatial sensitivity than color channels
- Contrast defines legibility, attention, layering
- Controlling darkness is primary rule of design



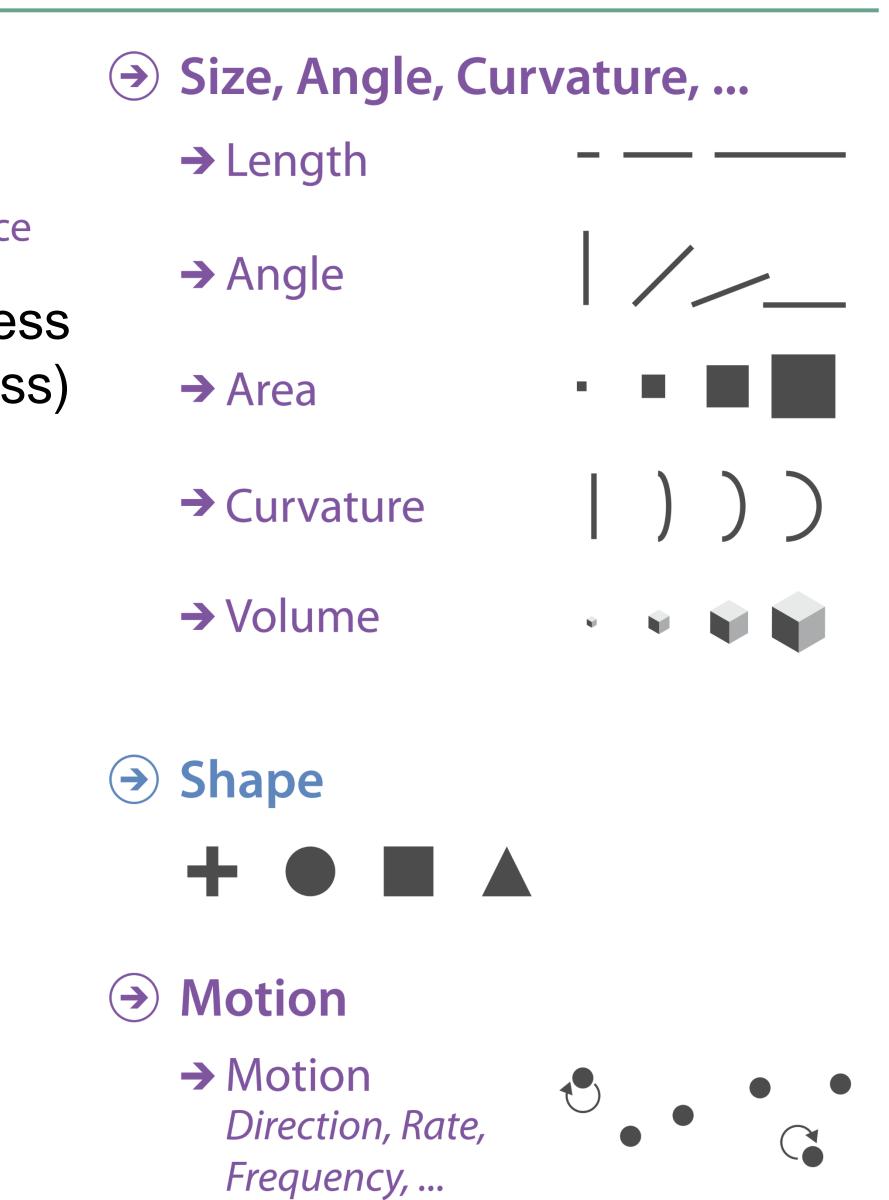
Based on Slide by Hanpseter Pfister 8







Encode > Map



VAD Chapter 10 9





NOW, ON CS 7250...



COLOR

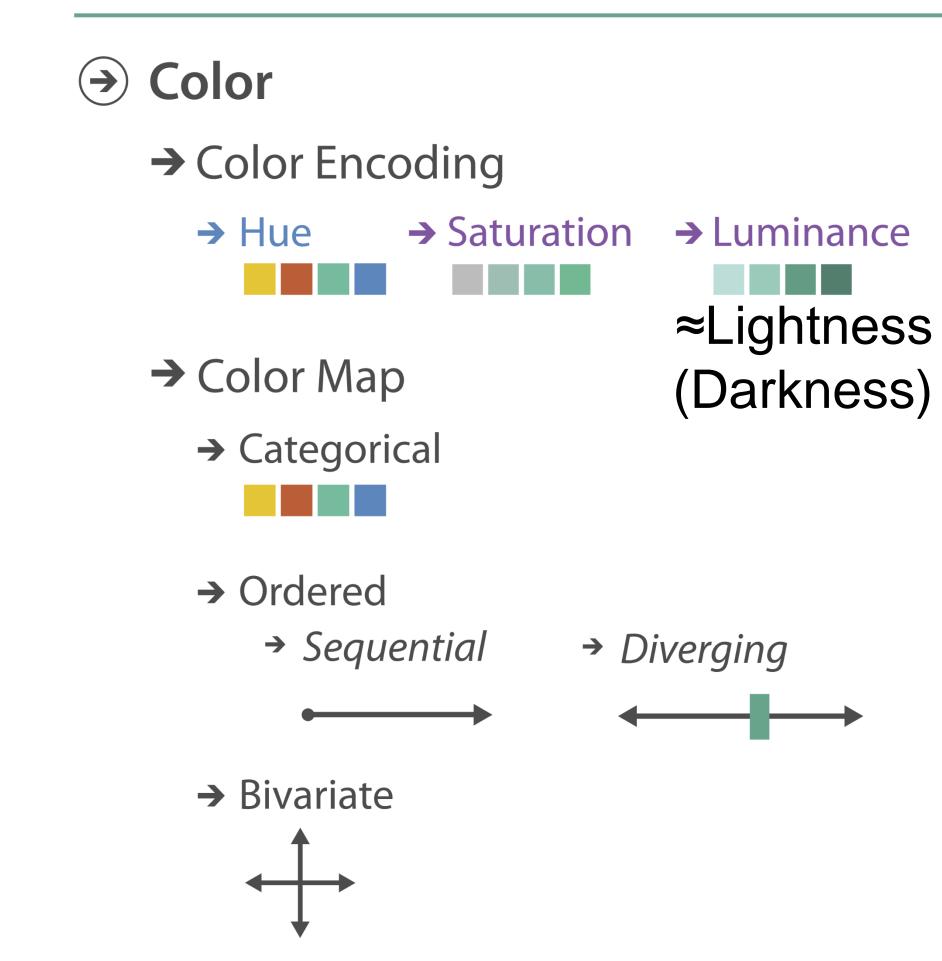


11

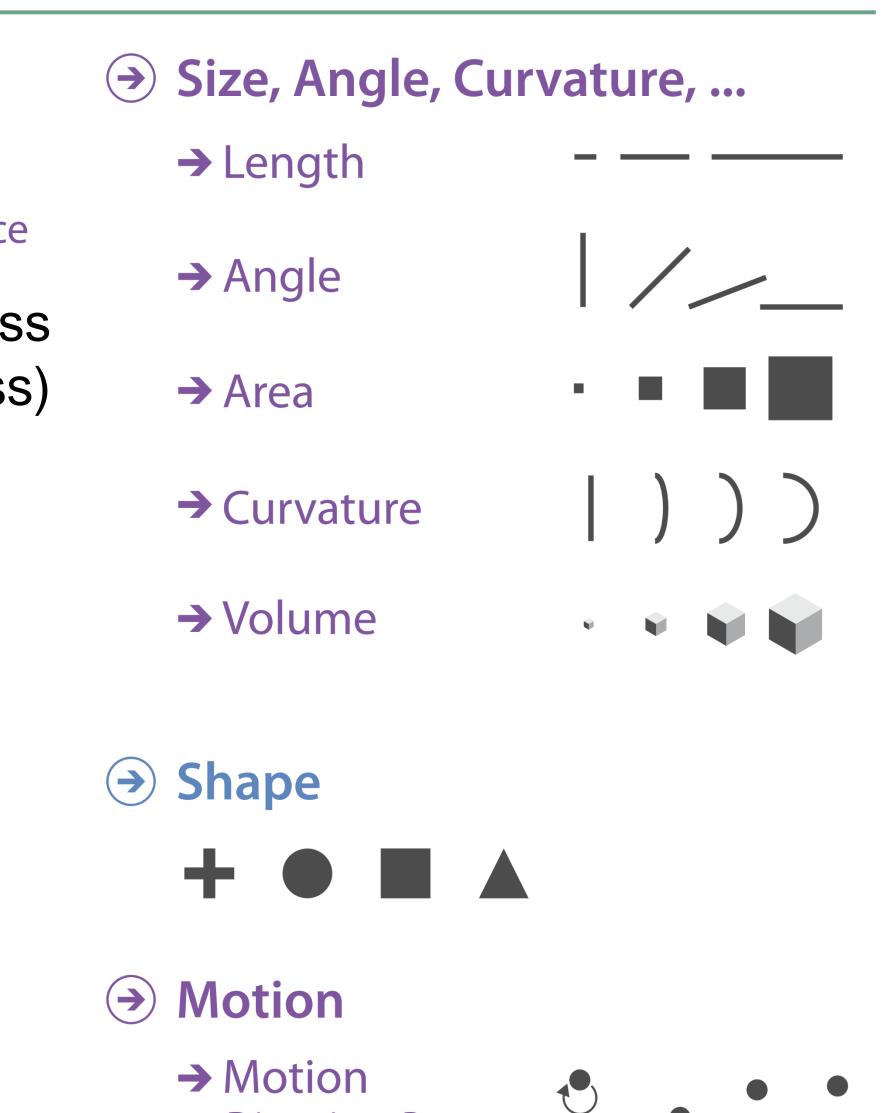
GOALS FOR TODAY: LEARN HOW...

- ...to effectively use color as a channel for visual encodings including different colormap types.
- ...we process color in the visual system.
- ...individual color differences (i.e., colorblindness) should be accommodated in visualizations.
- …interactions can occur between colors and with lighting.
 - ...illusions and tricks can affect perception.





Encode > Map



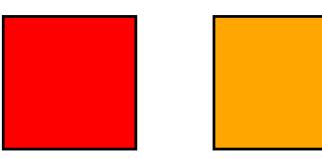
Direction, Rate,

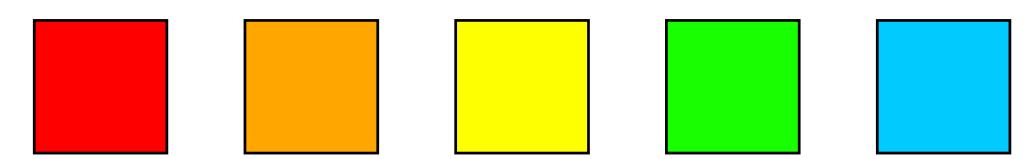
Frequency, ...

VAD Chapter 10¹³



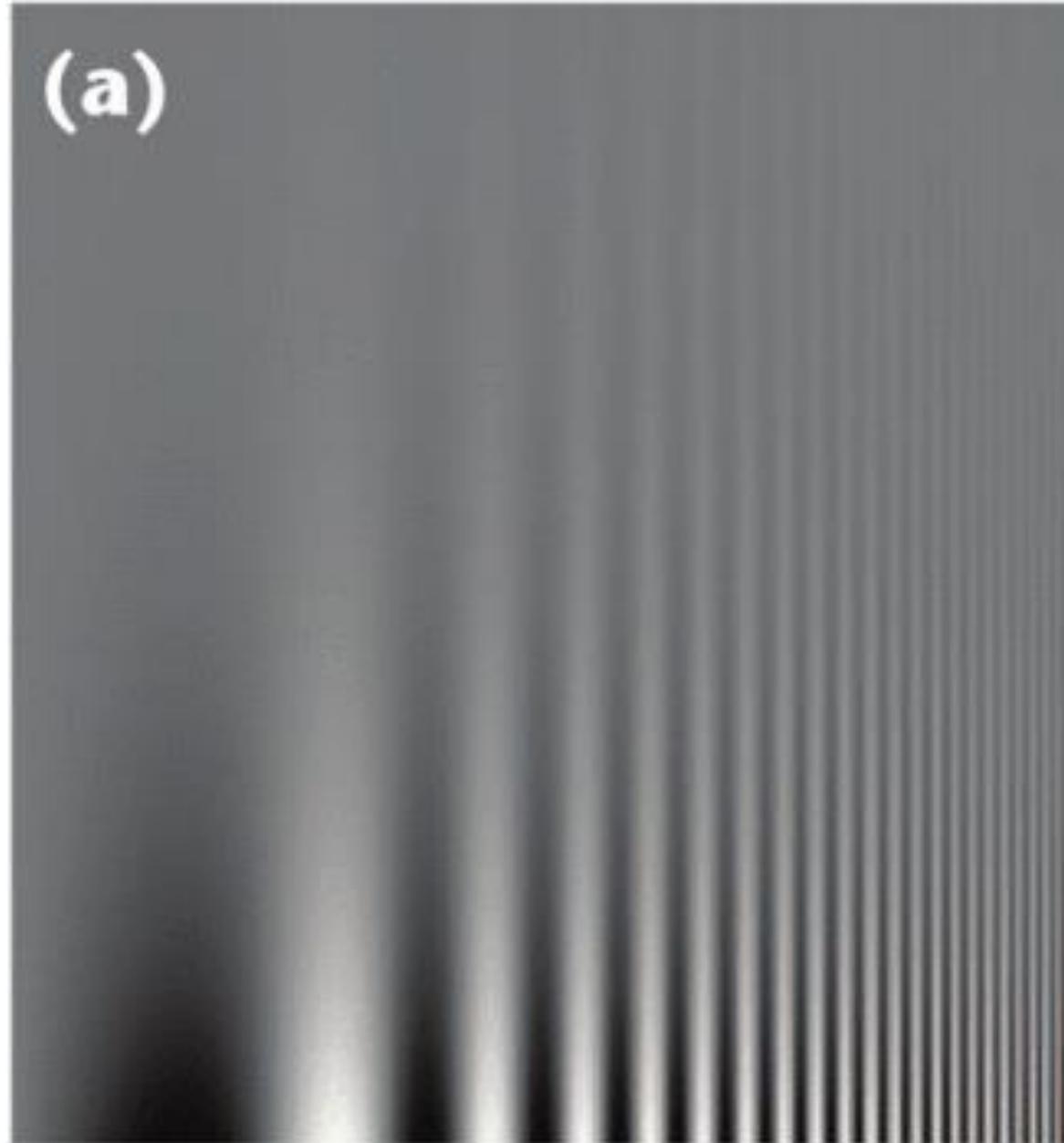
Rainbow Color Map (Hue)







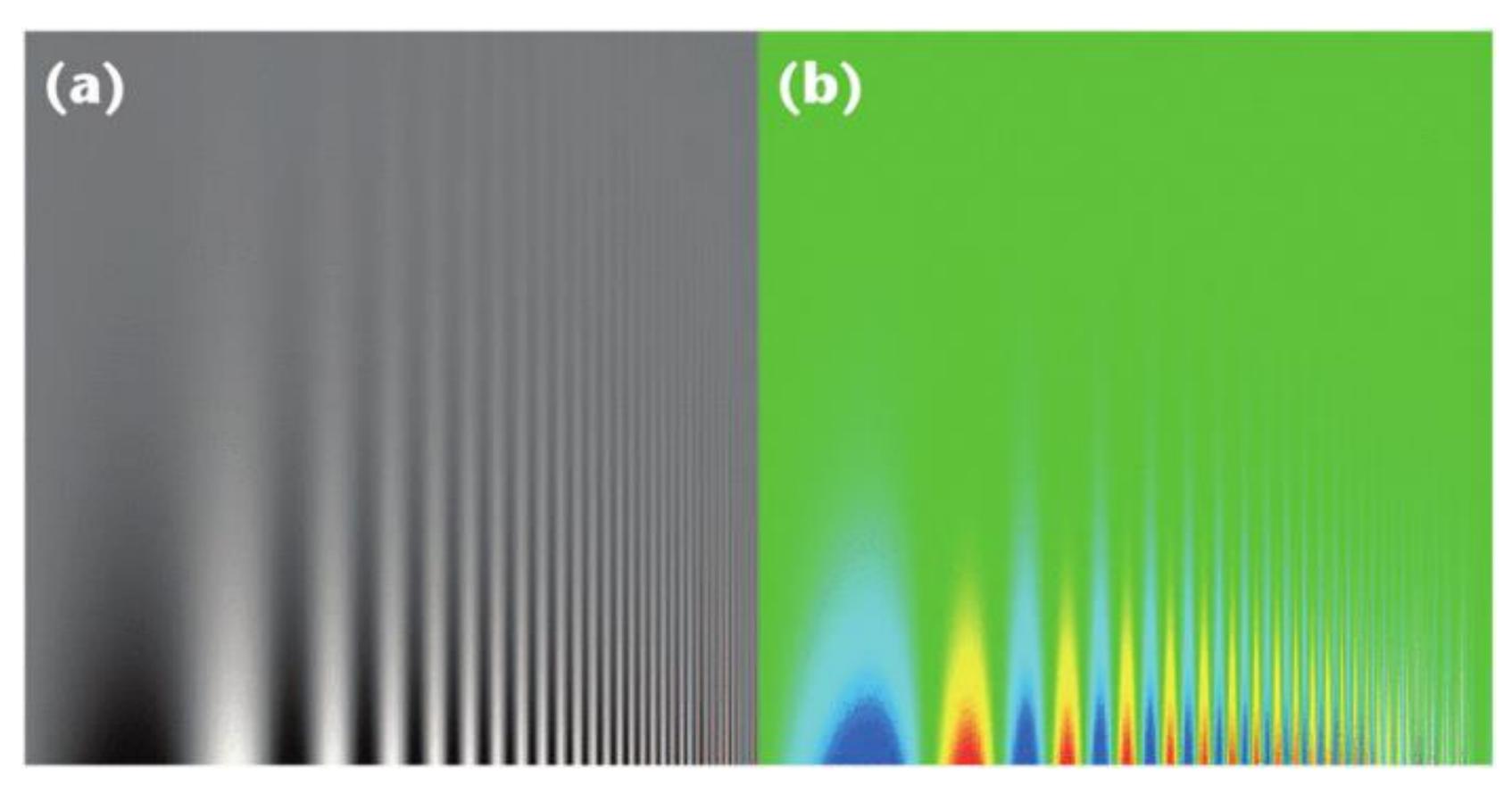
Rainbow Color Map



(b)



Rainbow Color Map



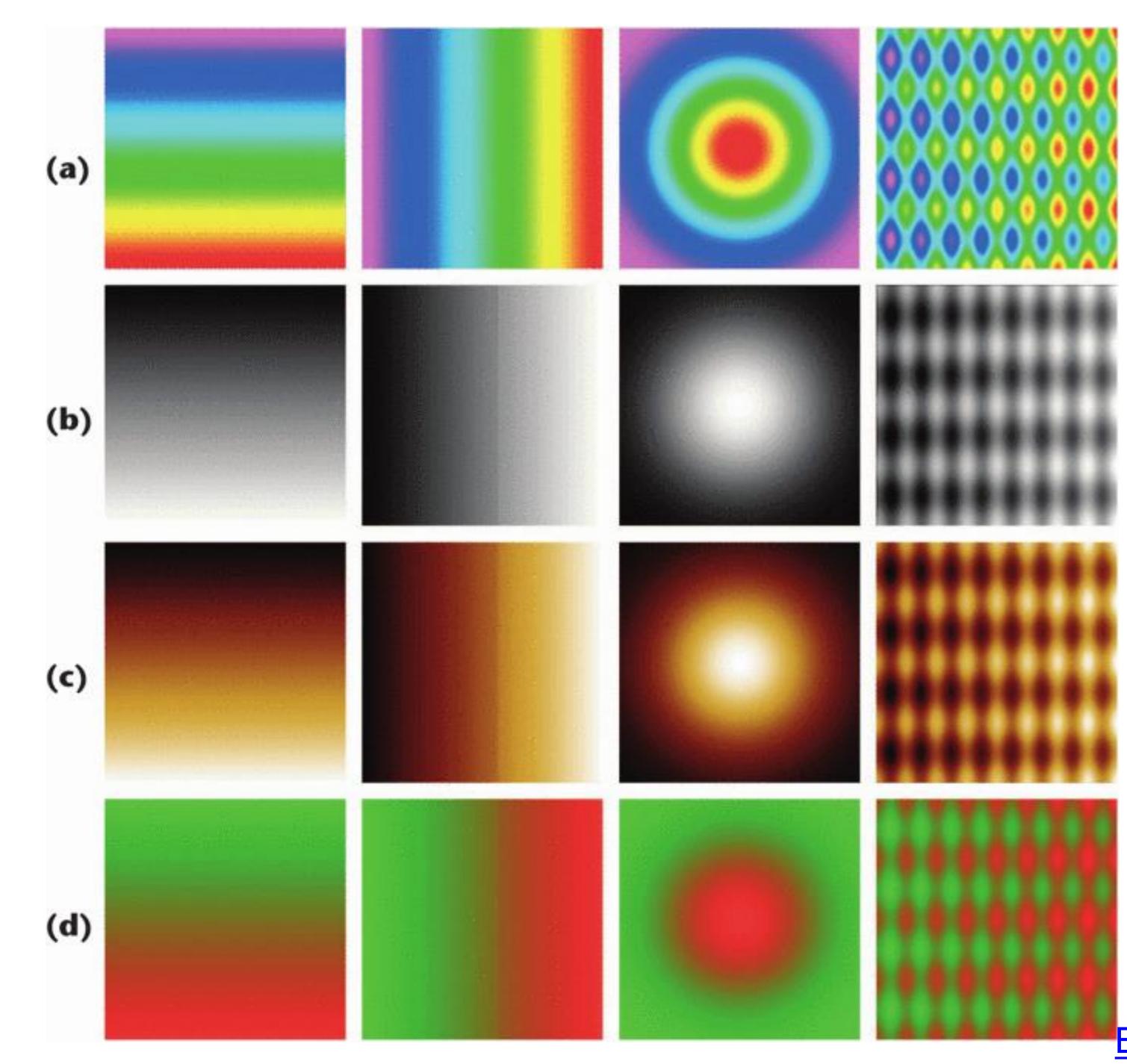
- No darkness variation (obscures details)
- data, even when this is not the case (misleading)

Viewers perceive sharp transitions in color as sharp transitions in the

Borkin et al., 2011 ¹⁶







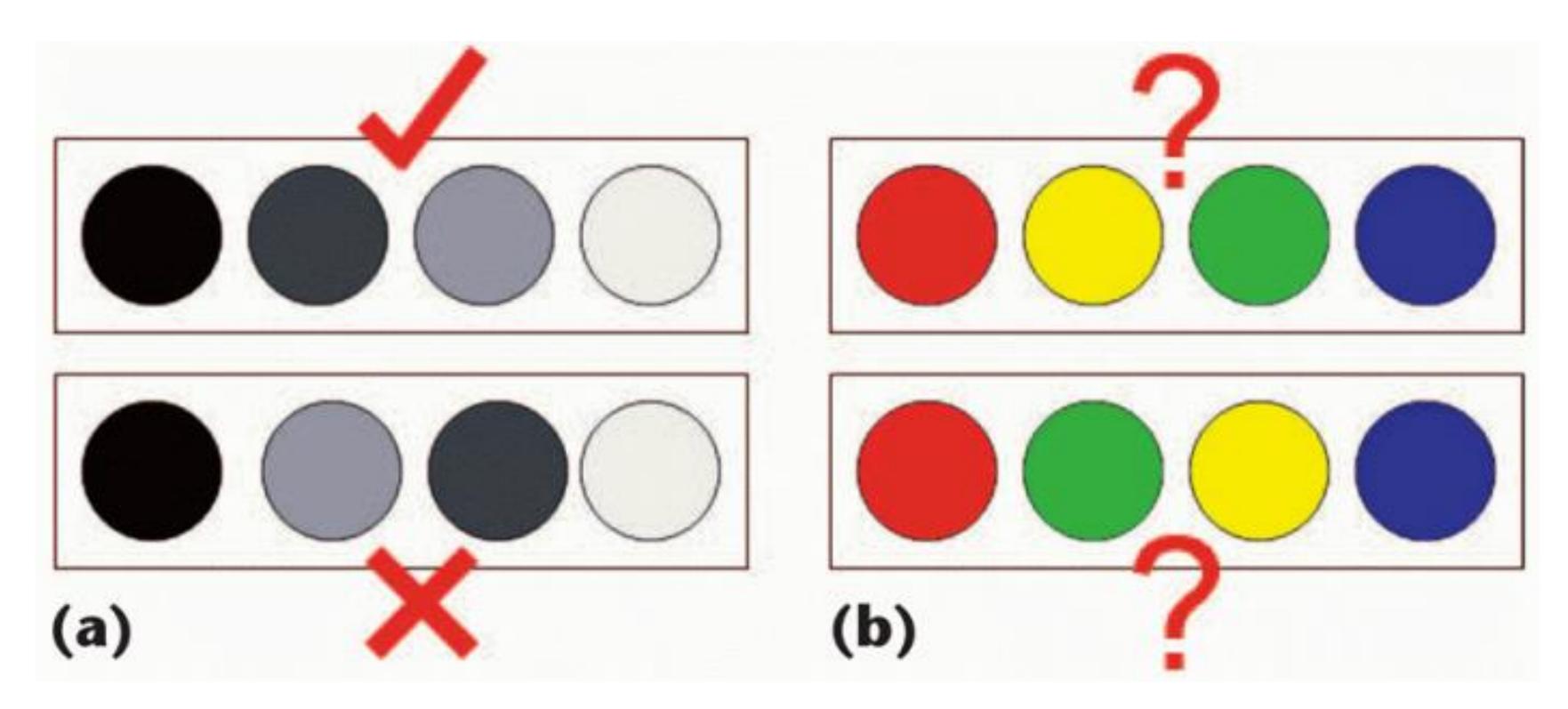
Borland & Russell, 2007 17





Rainbow Color Map (Hue)

No perceptual ordering (confusing)



Borland & Russell, 2007¹⁸

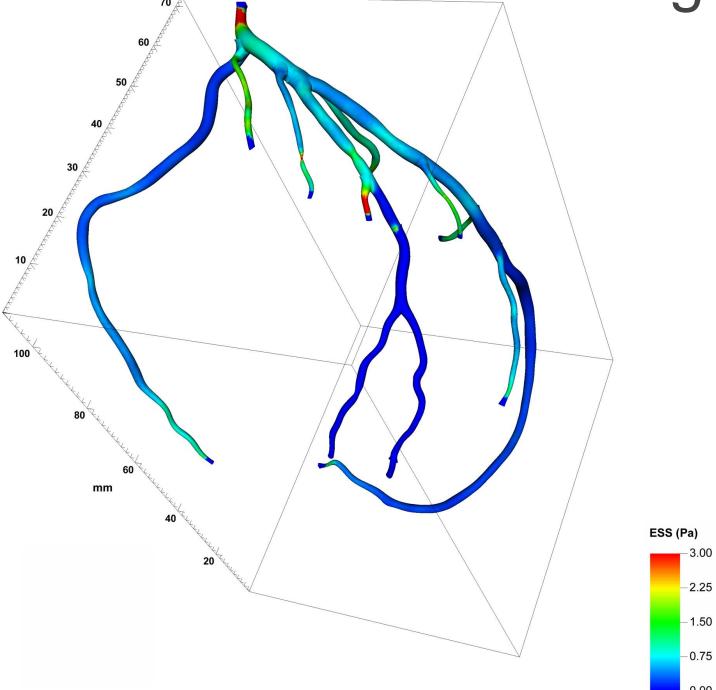




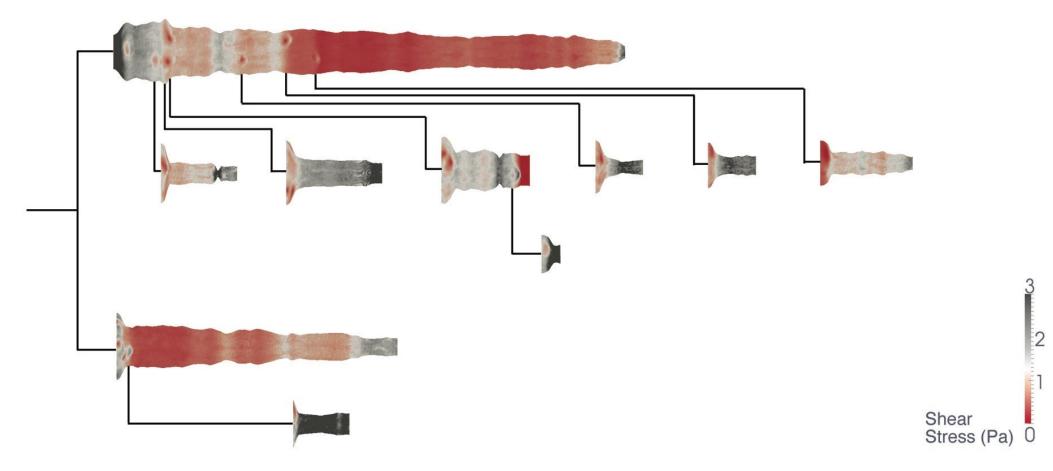
Rainbow Color Map

Rainbow: 3D: 39% 2D: 62%

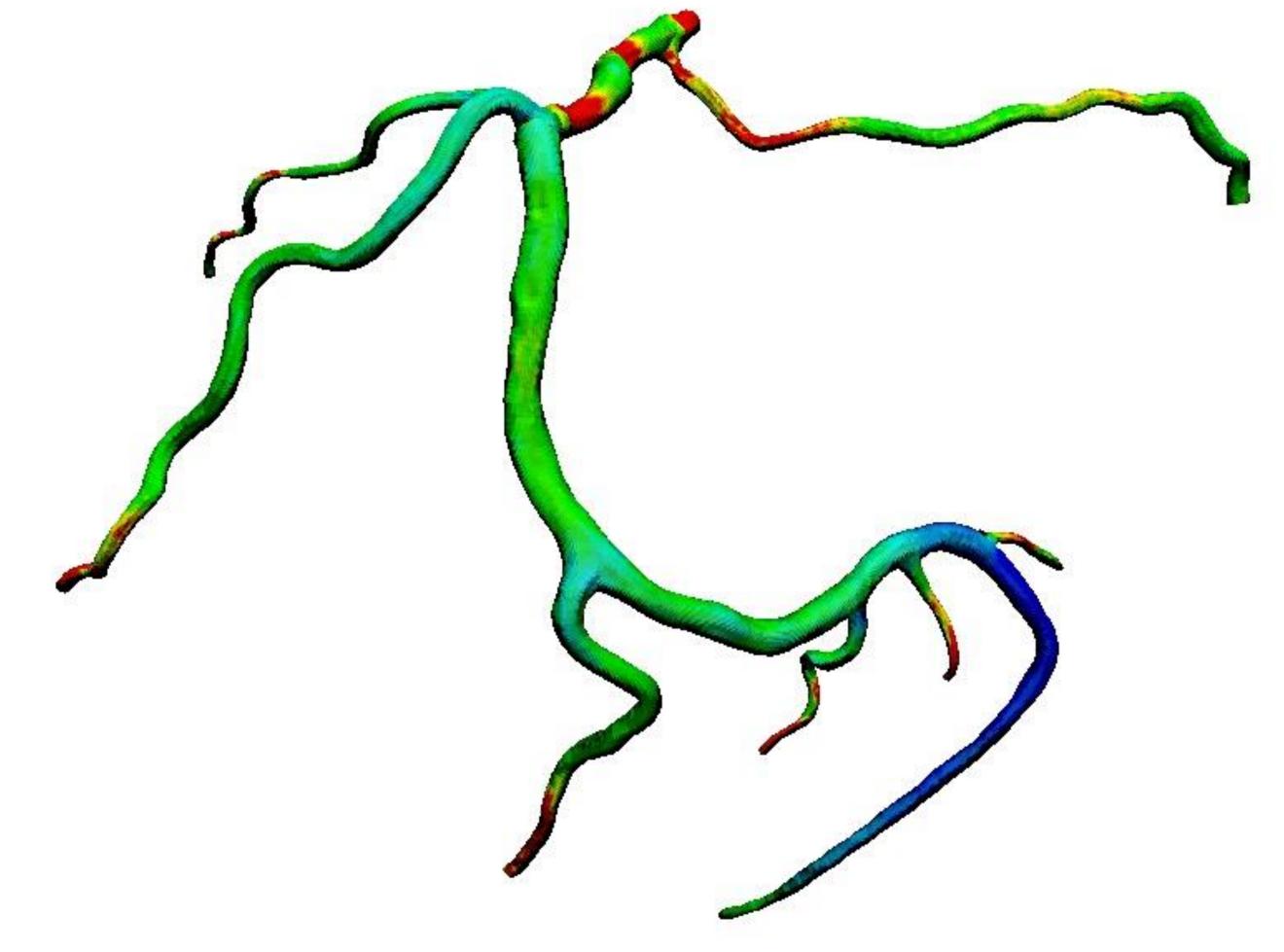
How many diseased regions found?



Diverging: 3D: 71% (Δ +31%) 2D: 91% (Δ +29%)



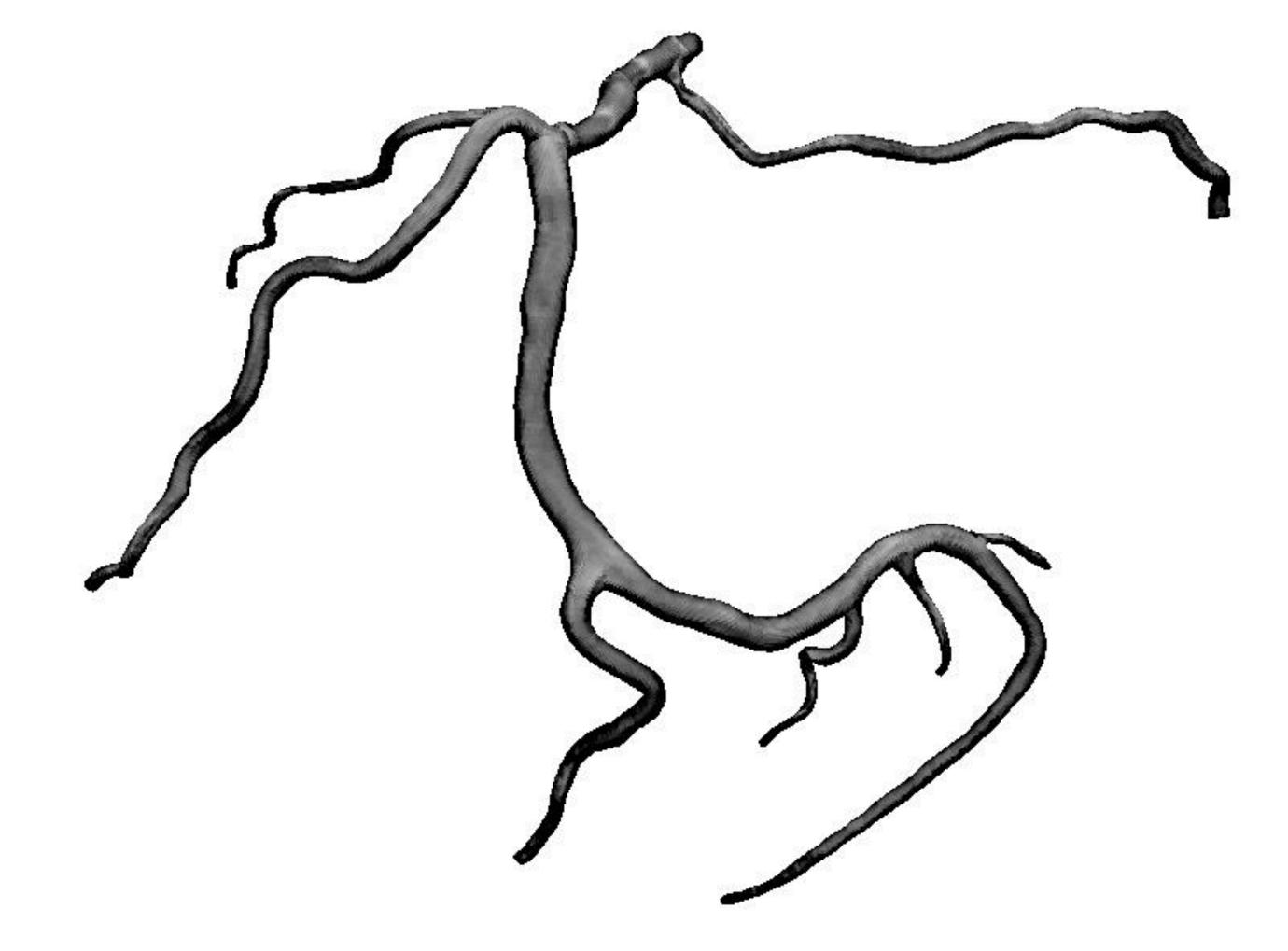




39% Diseased Regions Found

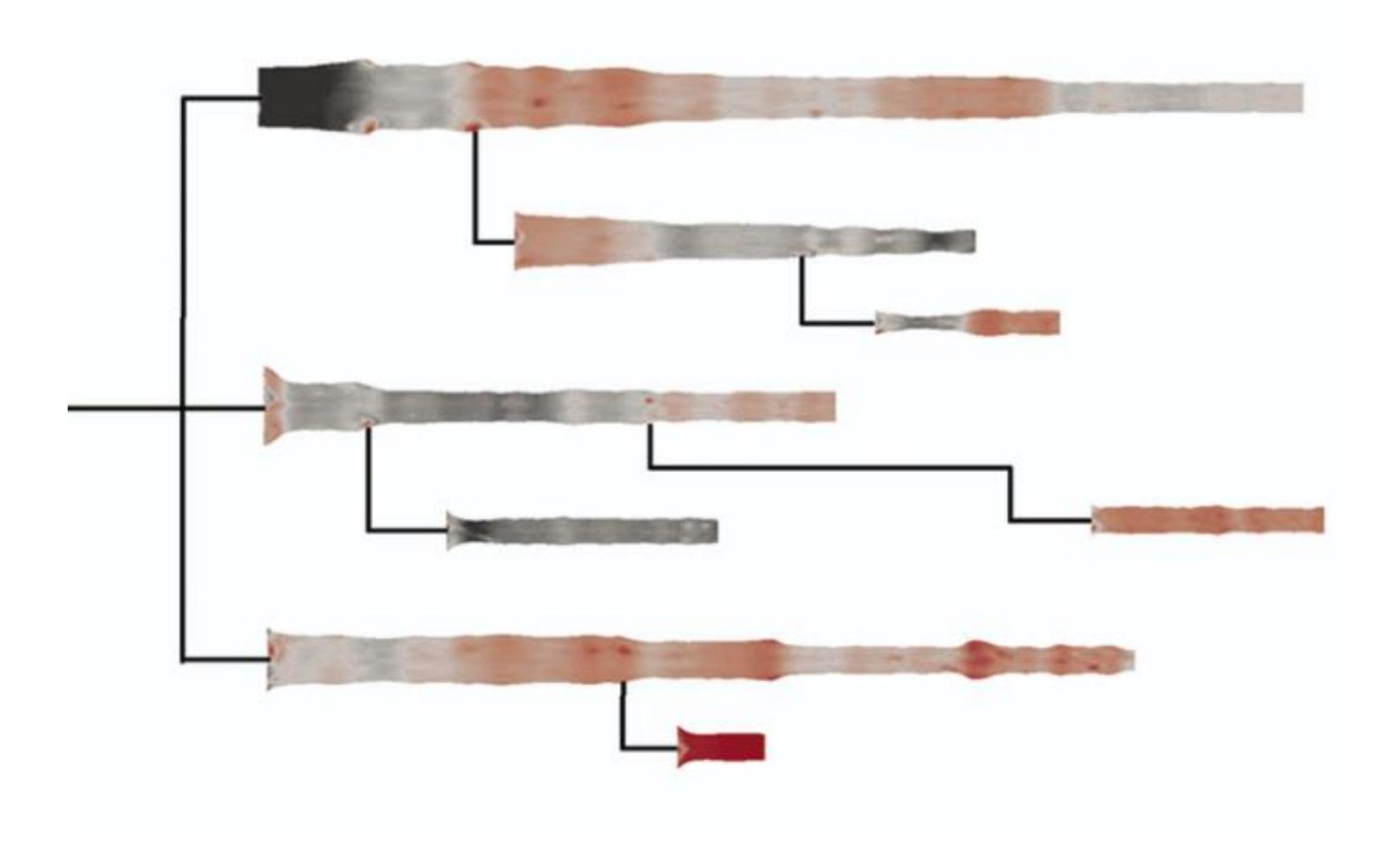
"Get it right in black and white."





"Get it right in black and white."

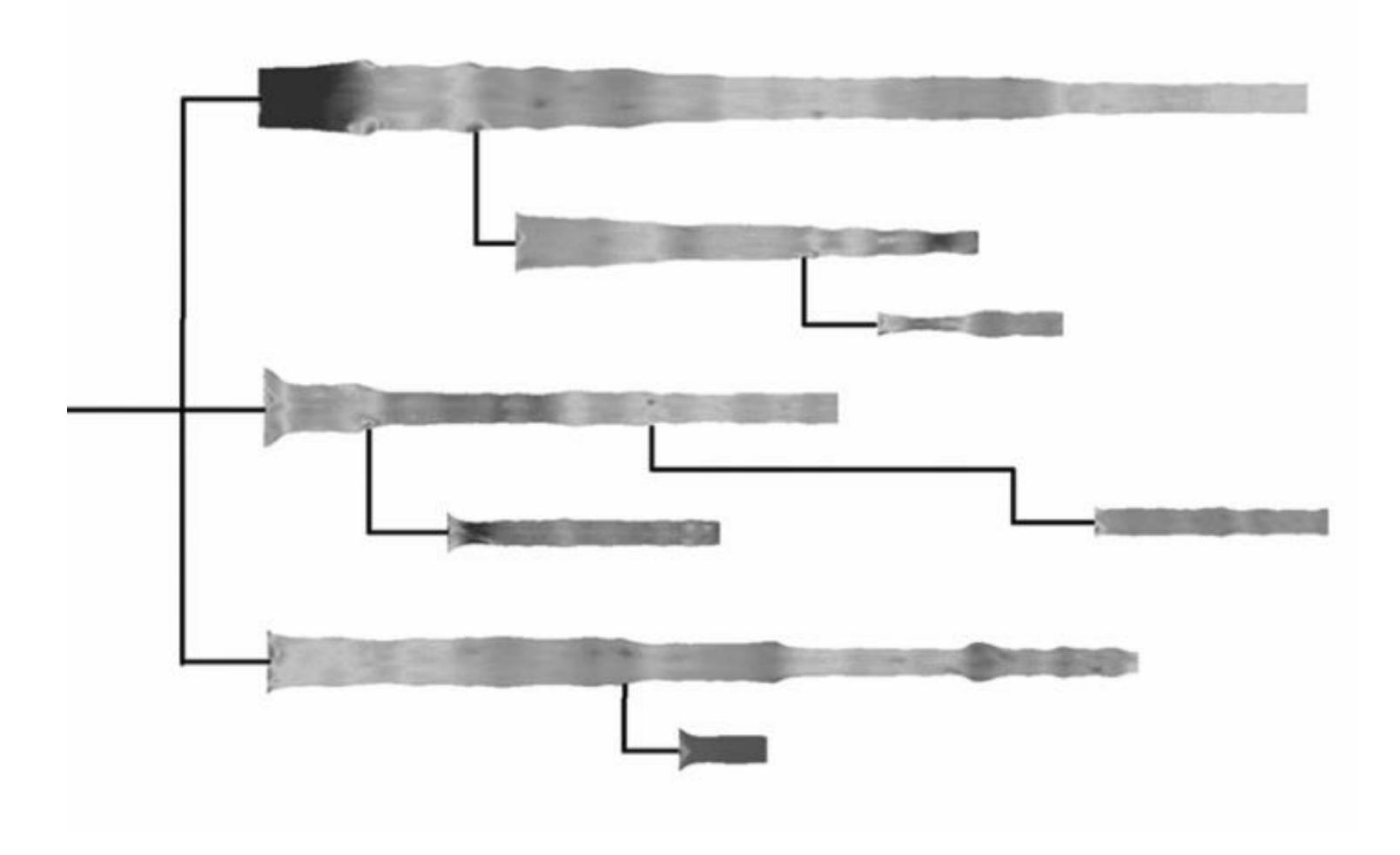




91% Diseased Regions Found

"Get it right in black and white."





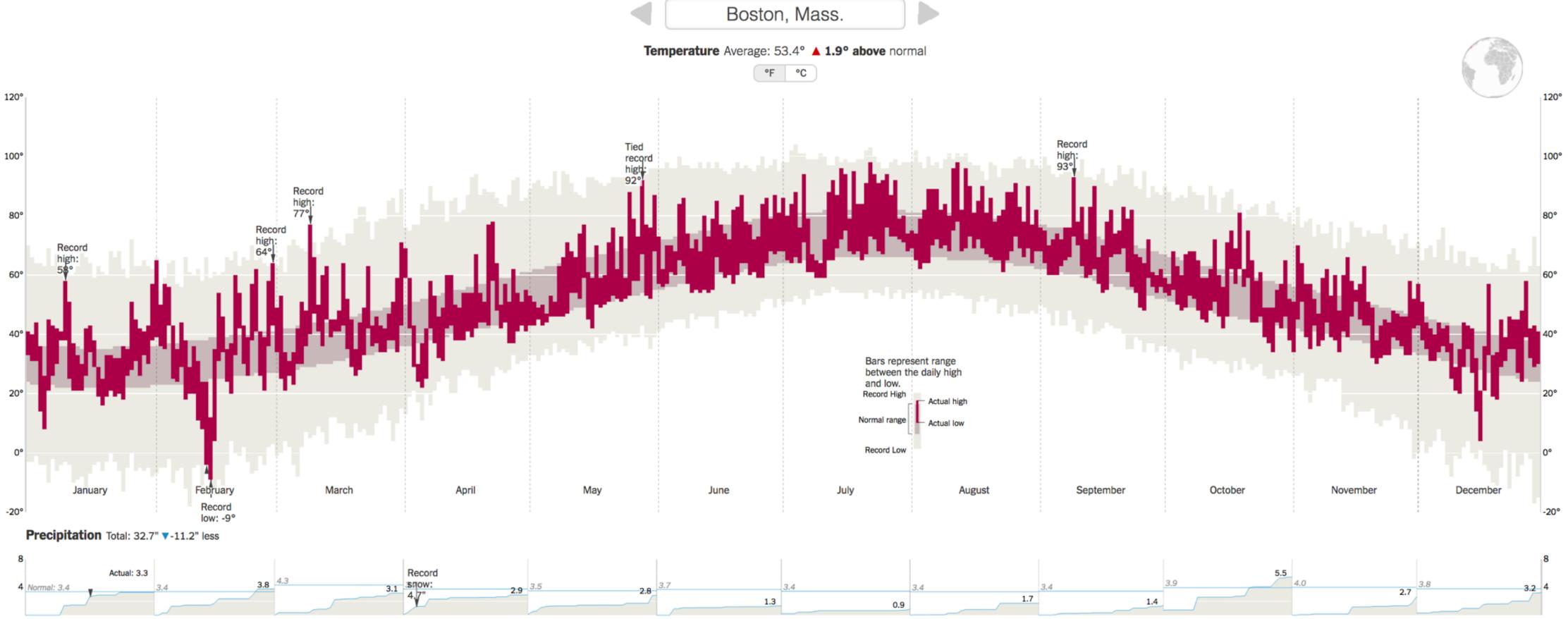
"Get it right in black and white."



"Get it right in black and white." How Much Warmer Was Your City in 2016?

Last year is the hottest year on record for the third consecutive year. In a database of more than 5,000 cities provided by AccuWeather, about 90 percent recorded annual mean temperatures higher than normal. Enter your city below to see how much warmer (or cooler) it was.





Cumulative monthly precipitation, in inches, compared with normal. Precipitation totals are rainfall plus the liquid equivalent of any frozen precipitation.

By K.K. REBECCA LAI JAN. 18, 2017

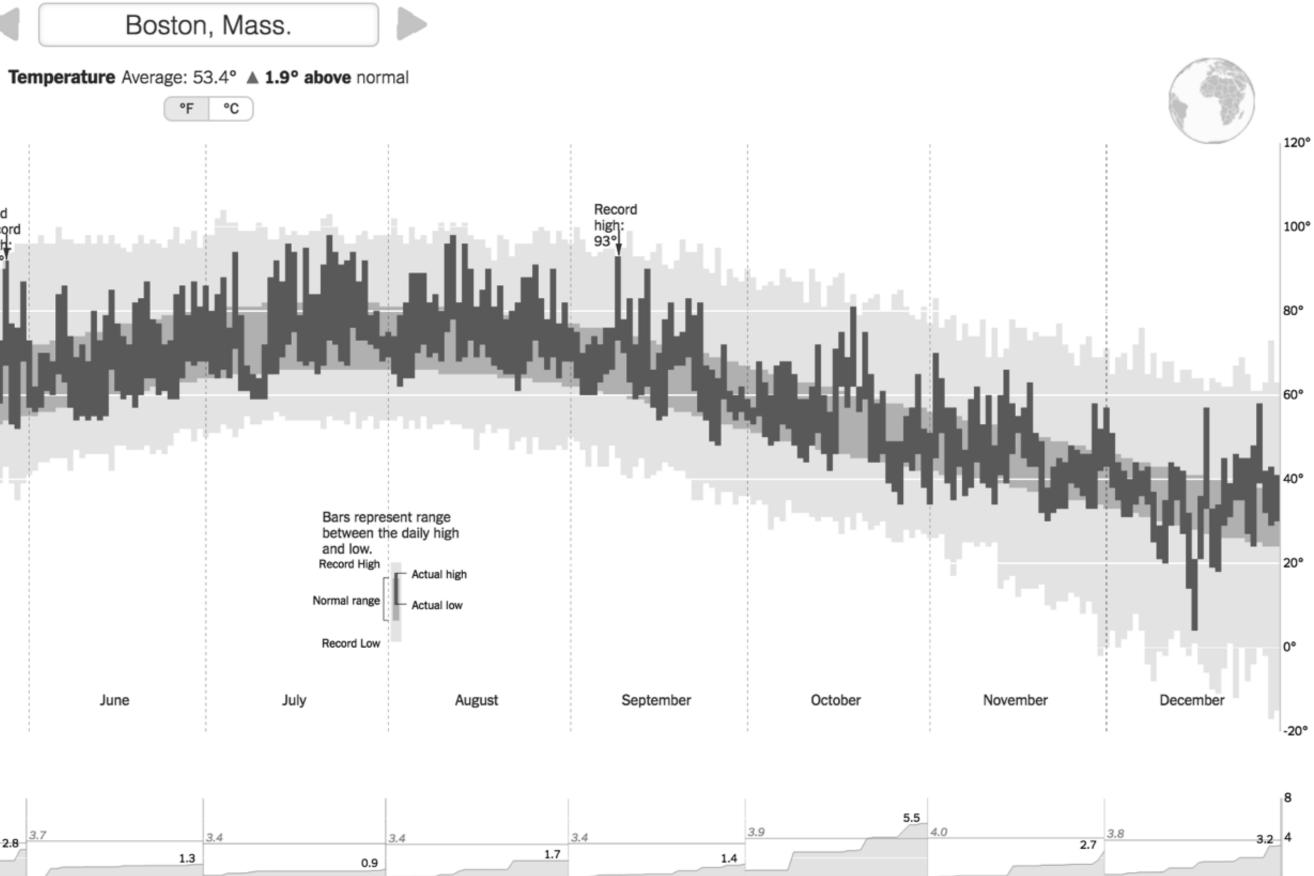
<u>NY Times, 2017</u>



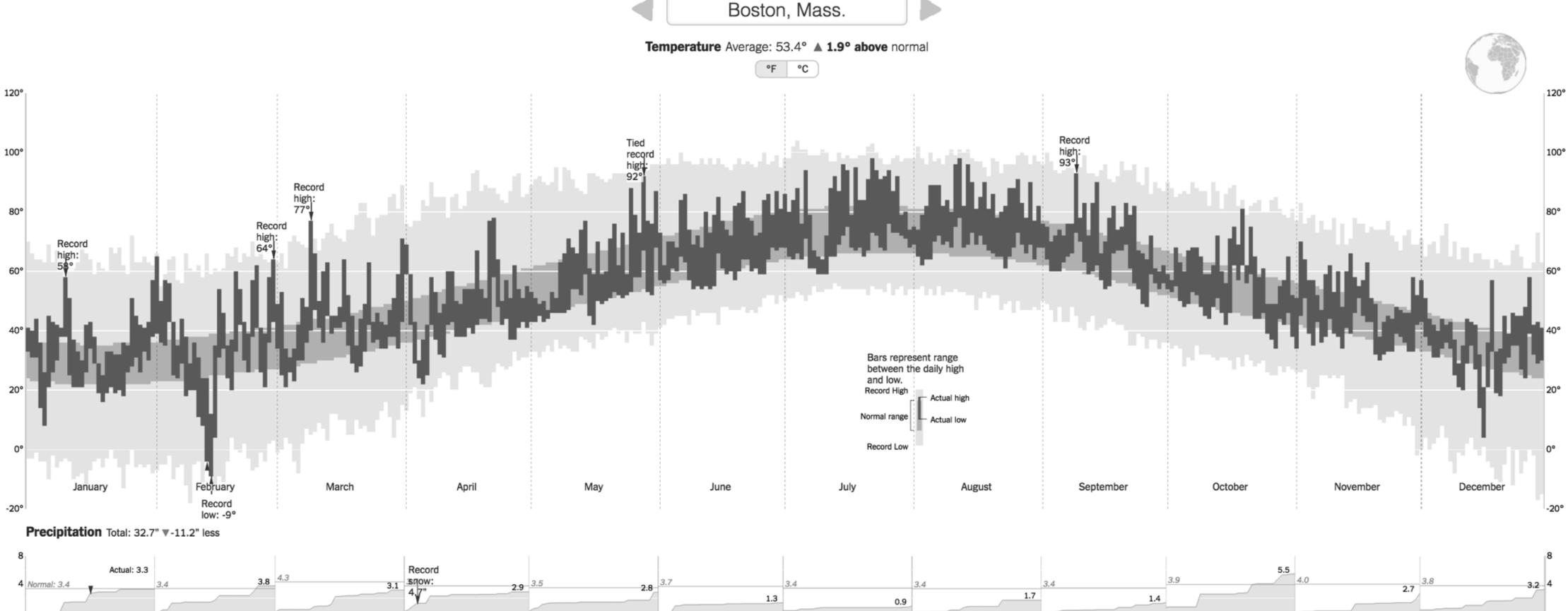


"Get it right in black and white." How Much Warmer Was Your City in 2016?

Last year is the hottest year on record for the third consecutive year. In a database of more than 5,000 cities provided by AccuWeather, about 90 percent recorded annual mean temperatures higher than normal. Enter your city below to see how much warmer (or cooler) it was.







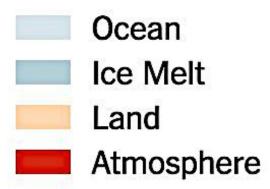
Cumulative monthly precipitation, in inches, compared with normal. Precipitation totals are rainfall plus the liquid equivalent of any frozen precipitation.

By K.K. REBECCA LAI JAN. 18, 2017

<u>NY Times, 2017</u>



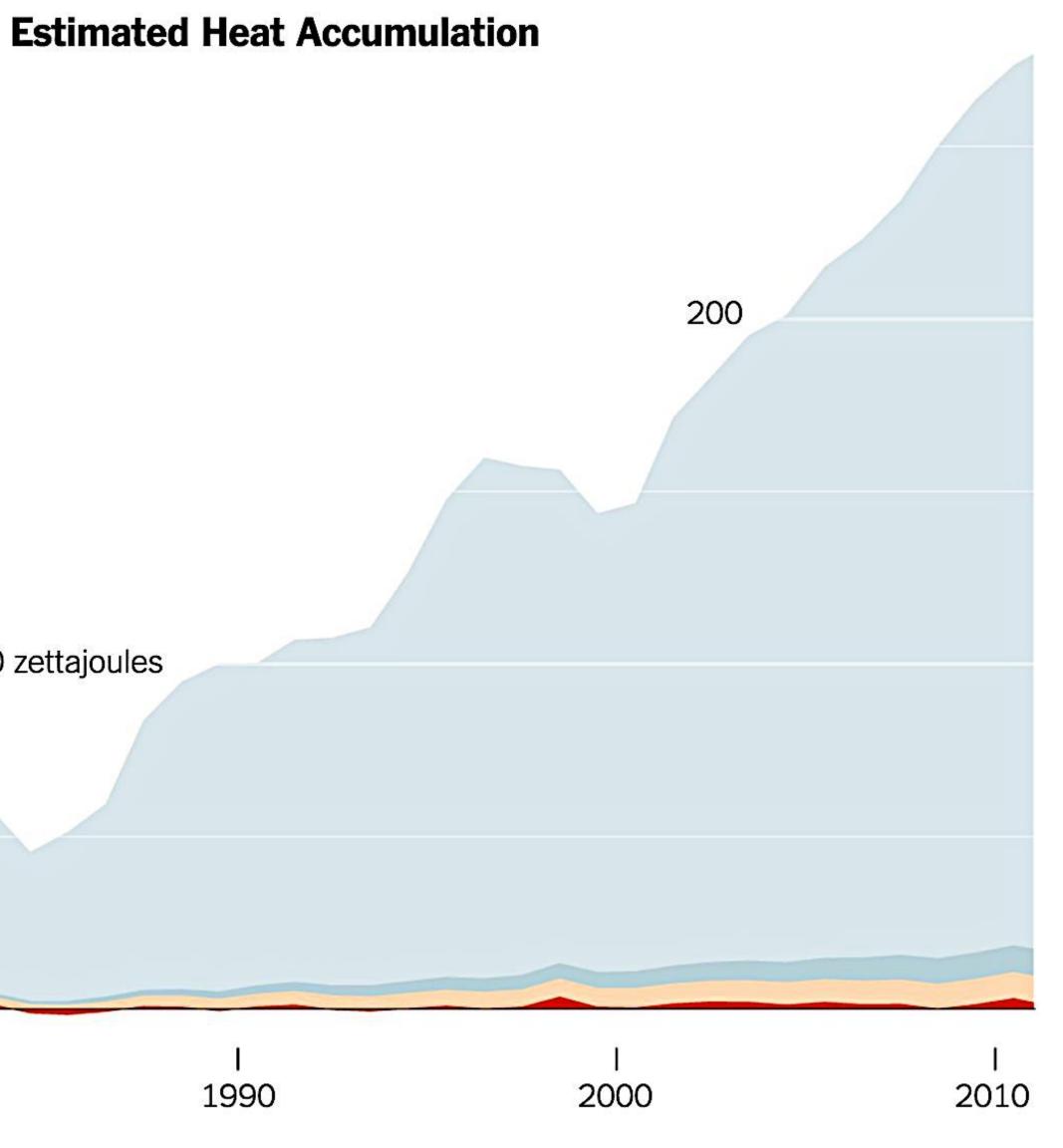






1980

"Get it right in black and white."





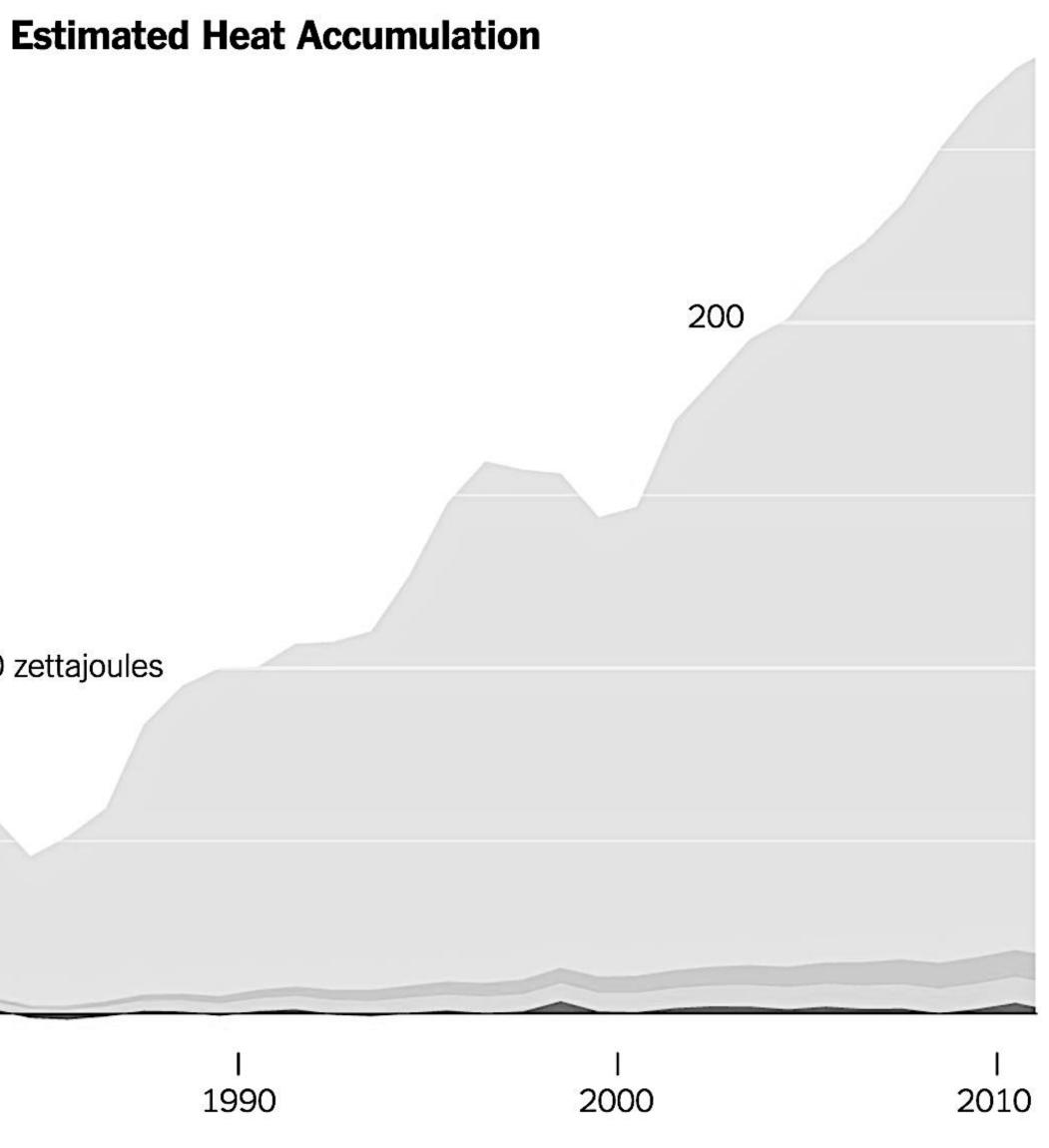
Ocean Ice Melt Land

Atmosphere

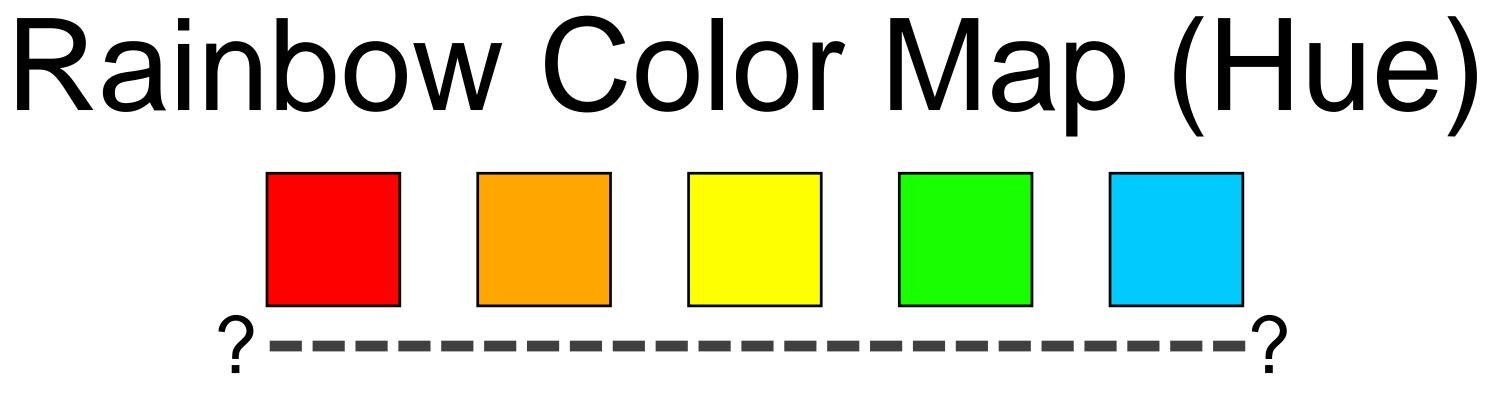
100 zettajoules

1980

"Get it right in black and white."







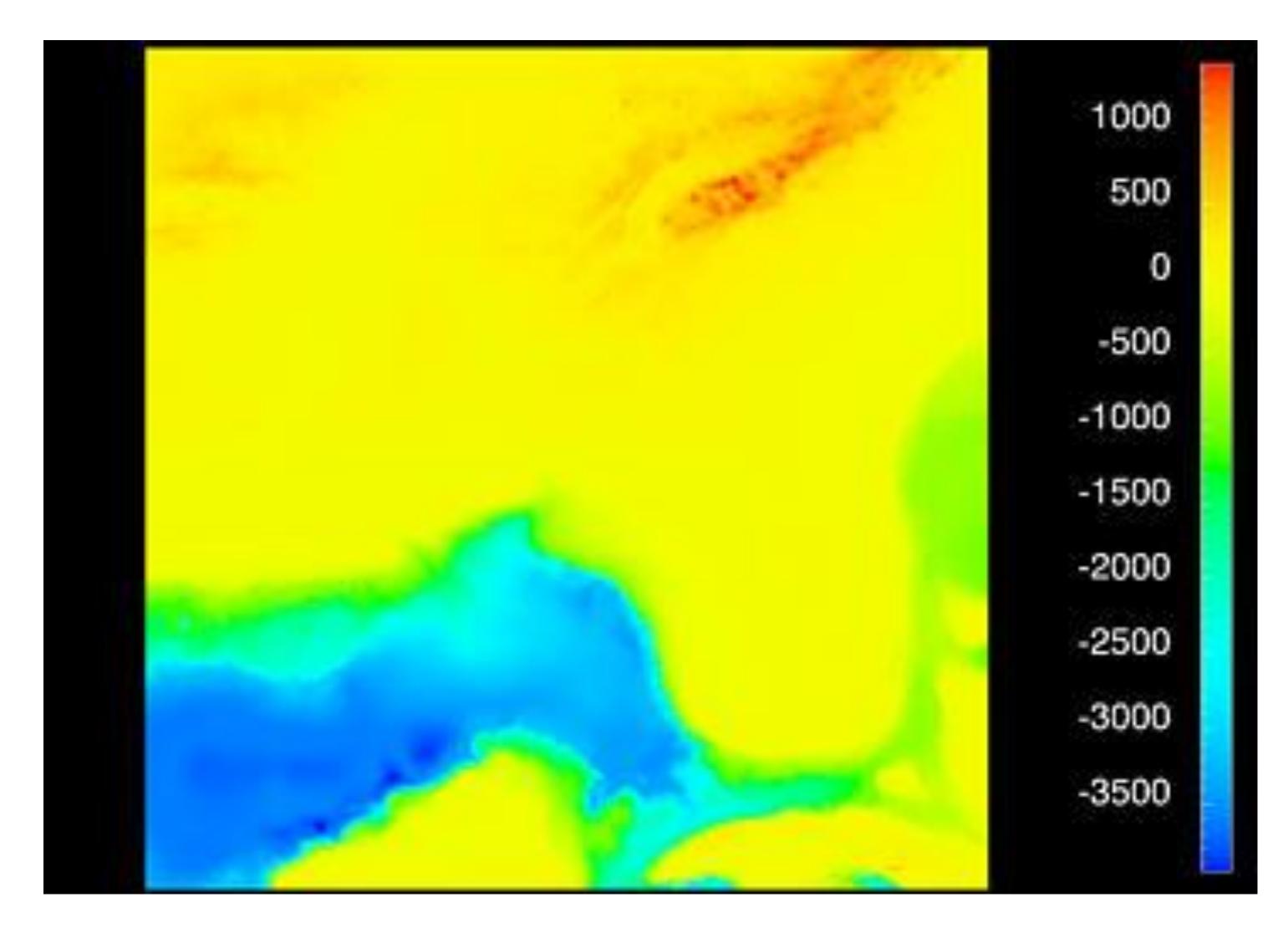
Why this color map is a poor choice for quantitative data... No perceptual ordering (confusing) No darkness variation (obscures details) Viewers perceive sharp transitions in color as sharp transitions in the data, even when this is not the

- case (misleading)





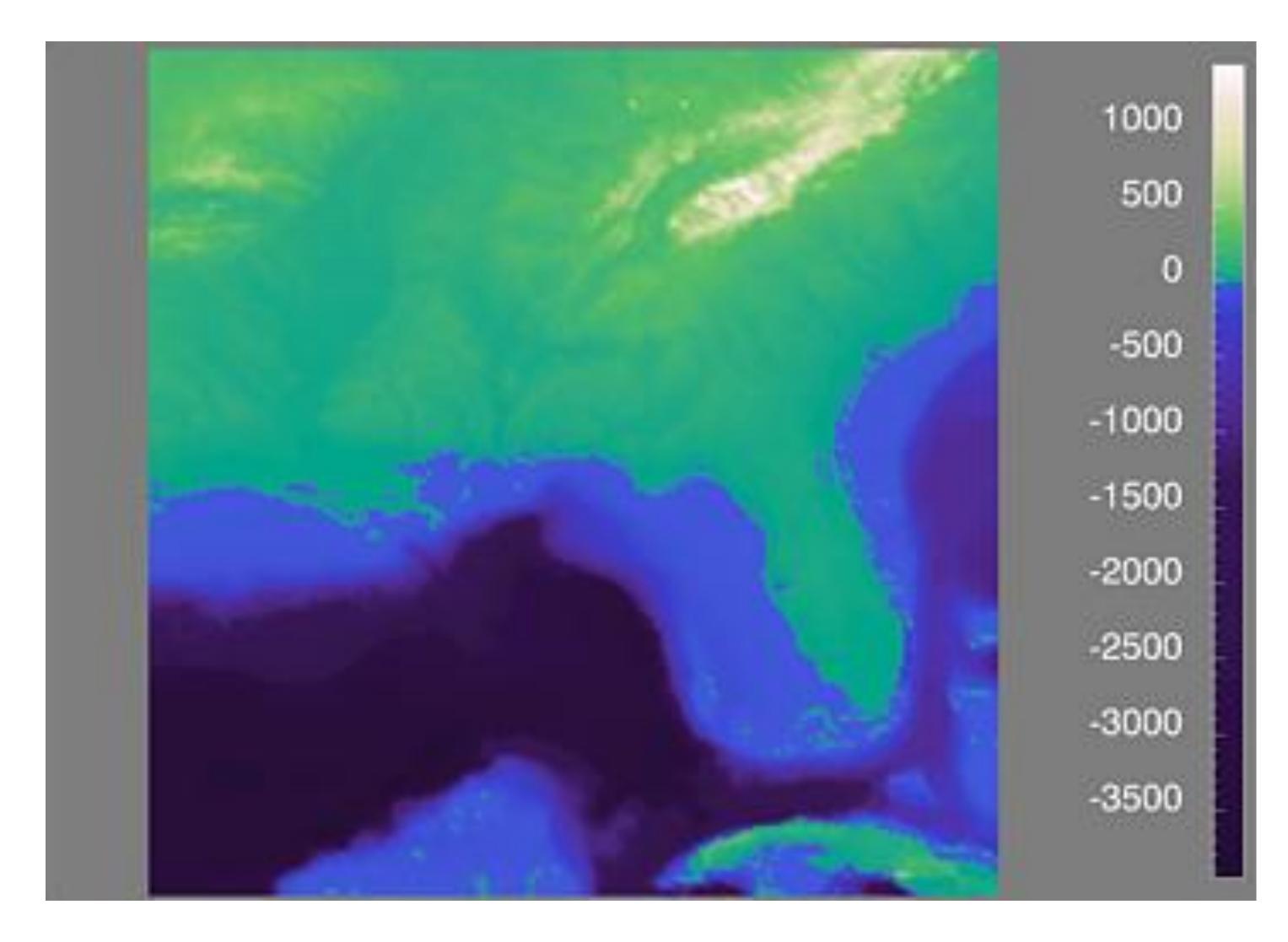




Rogowitz & Treinish, 1996 29



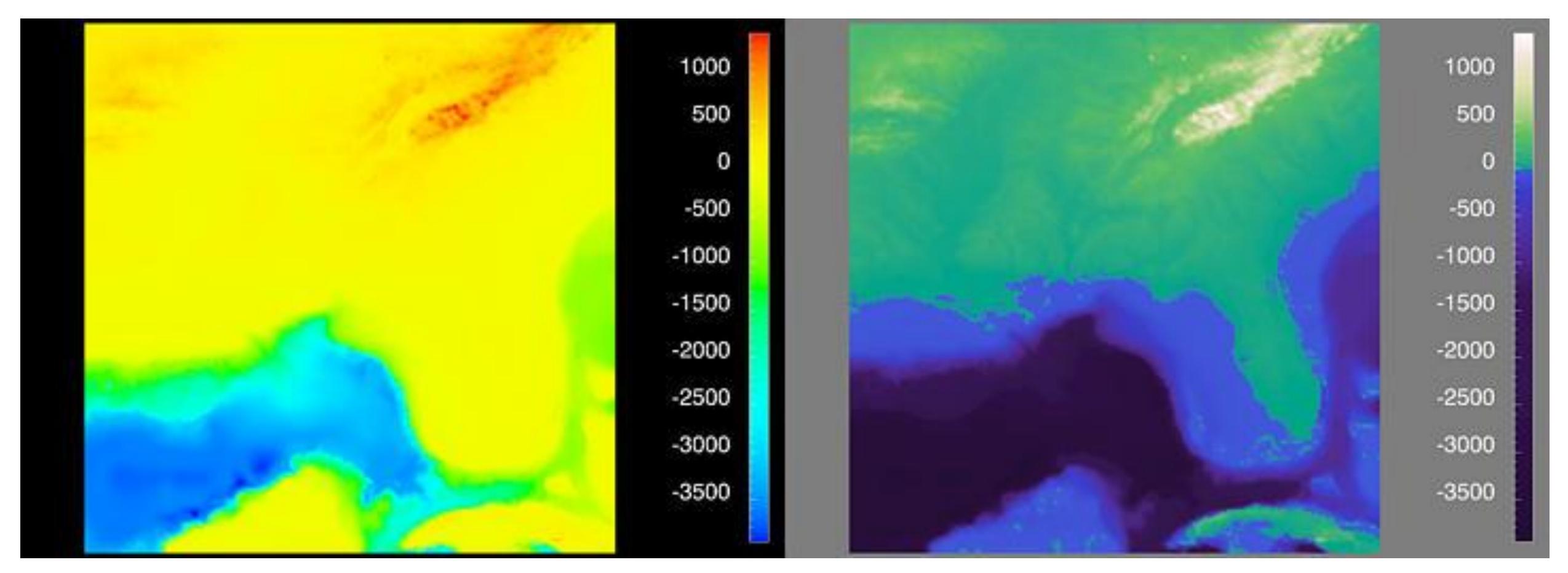




Rogowitz & Treinish, 1996 30







Sequential (possibly wrong)

Sequential rainbow (wrong!)

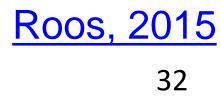
Diverging

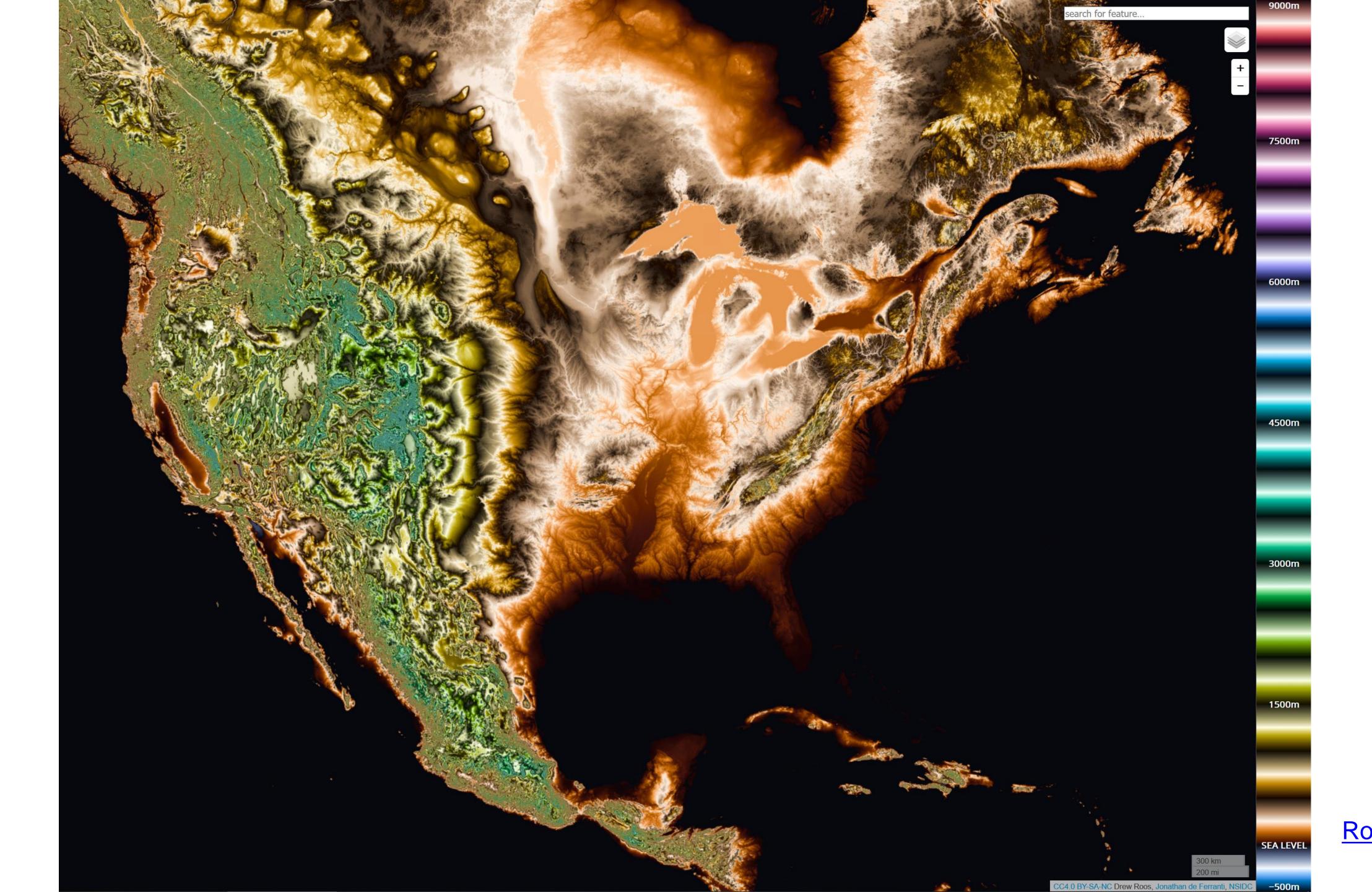
Rogowitz & Treinish, 1996 31

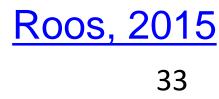












IN-CLASS EXERCISE



In-class exercise: Oilslick 10m

INSTRUCTIONS:

- Experiment with the different layers, different zoom levels, and different locations
- Think of answers to these questions: What areas are particularly interesting? Which layer / color scale works best, and for which tasks?
- Several of you will be asked to share your findings.

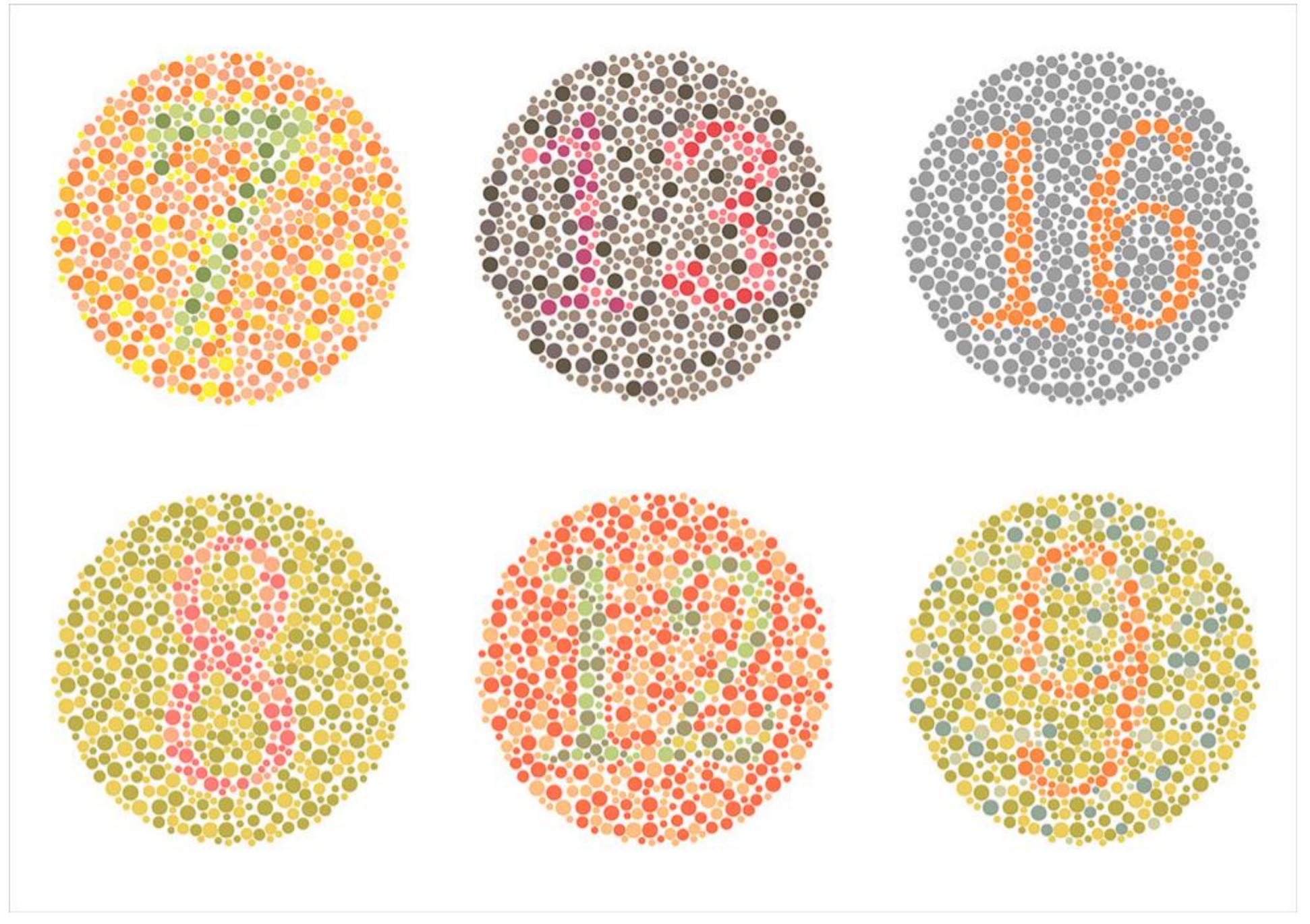


Working individually, go to <u>https://mrgris.com/projects/oilslick/</u>









Those with deuteranope color blindness (red/green) will have difficulty seeing the numbers.



Color Deficiencies (Color Blindness)

Person with faulty cones (or faulty pathways):

Protanope = faulty red cones



Deuteranope = *faulty green cones*





Tritanope = *faulty blue cones*



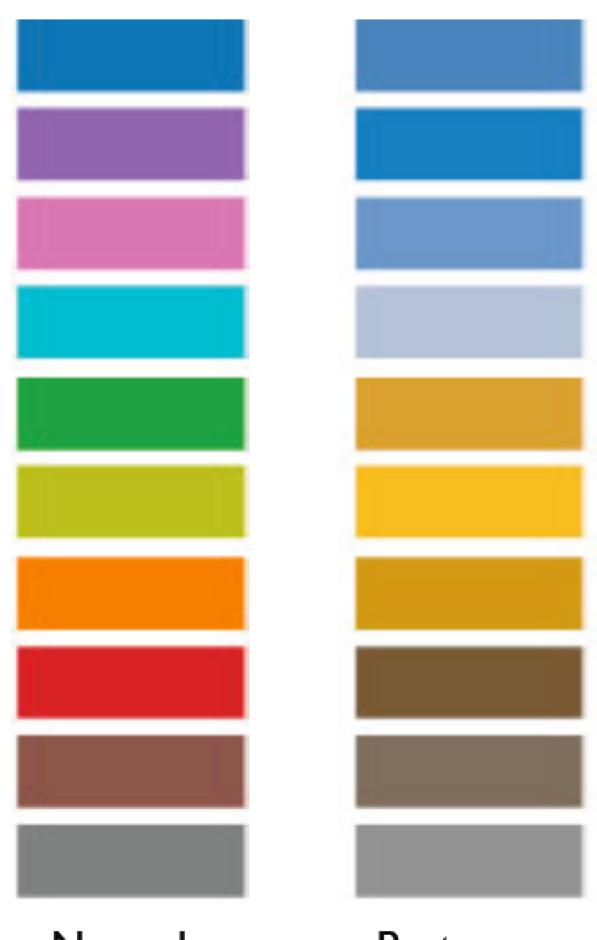
normal

Based on Slides by Hanspeter Pfister, Maureen Stone ³⁷



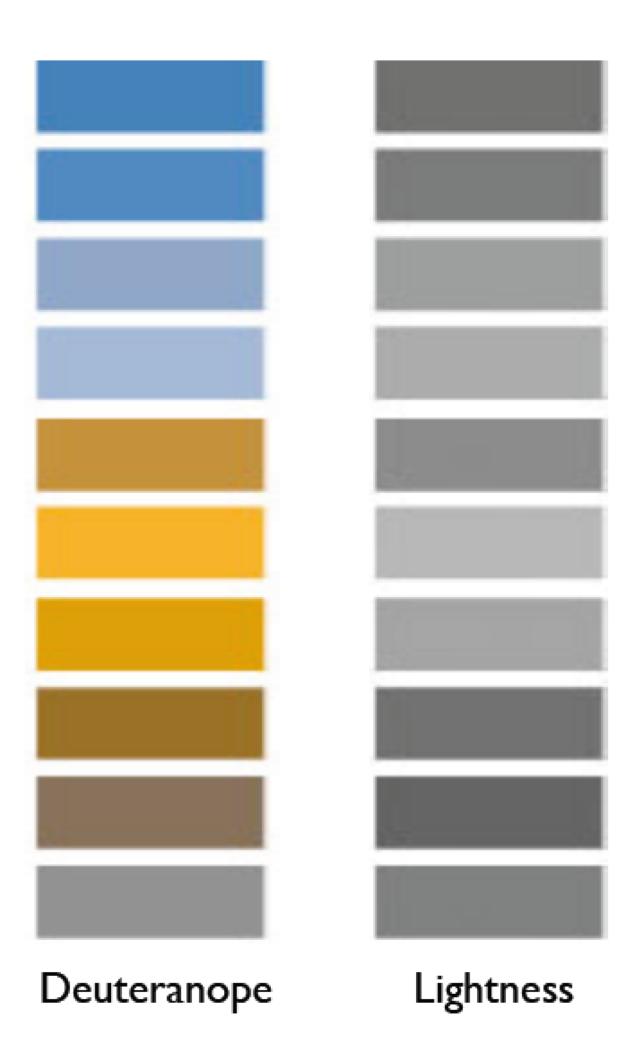


Color Deficiencies (Color Blindness)



Normal

Protanope



Based on Slides by Hanspeter Pfister, Maureen Stone ³⁸





Check your images/colormaps for issues!

Vischeck

Home

Vischeck •Run Images Run Webpages

Daltonize

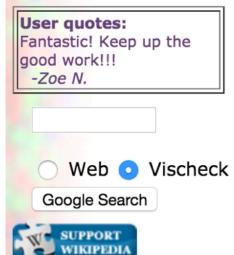
Examples

Downloads

Info & Links

FAQ

About Us



Try Vischeck on Your Image Files

Select the type of color vision to simulate:



Deuteranope (a form of red/green color deficit)



Protanope (another form of red/green color deficit)

Tritanope (a blue/yellow deficit- very rare)

Image file: Choose File No file chosen

Run Vischeck!

Notes:

- Vischeck accepts most common image formats. However, we recommend that you use PNG or JPEG format for uploading large images as these tend to transfer faster.
- For PowerPoint slides, you can save all your slides as PNG images with "Save As..." and run Vischeck on each slide.
- If you have many images to process, consider downloading Vischeck to run on your own computer.)
- Uploading a large file may take a while please be patient!

Please read our terms of use before using Vischeck.

http://www.vischeck.com/vischeck/vischeckImage.php https://www.color-blindness.com/coblis-color-blindness-simulator/



Home
VD Essentials
Color Blindness Tests
Color Tools Contact

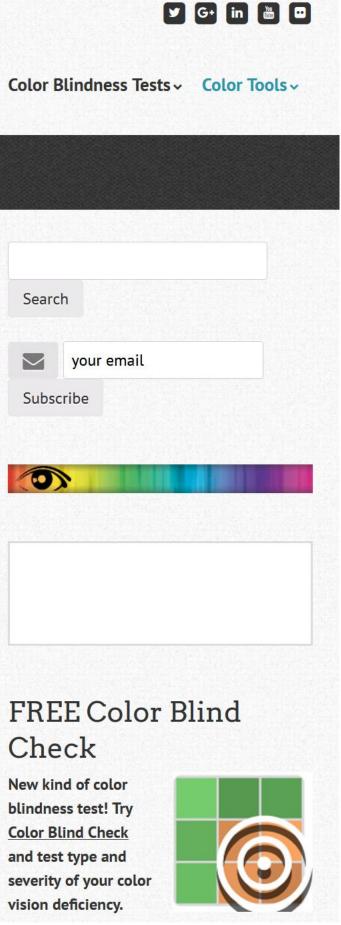
Coblis — **Color Blindness Simulator**

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 it and get a feeling of how it is to have a color vision handicap.

As all the calculations are made on your local machine, no images are uploaded to the server. Therefore you can use images as big as you like, there are no restrictions. Be aware, there are some issues for the "Lens feature" on Edge and Internet Explorer. All others should support everything just fine.

So go ahead, choose an image through the upload functionality or just drag and drop your image in the center of our Color BLIndness Simulator. It is also possible to zoom and move your images around using your mouse - try it out, I hope you like it.

baste your file in the area belo	ow or: Browse No file selecte	ed.
Anomalous Trichromacy:	Dichromatic view:	Monochron
 ○ Red-Weak/Protanomaly ○ Green-Weak/Deuteranomaly ○ Blue-Weak/Tritanomaly 	 ○ Red-Blind/Protanopia ○ Green-Blind/Deuteranopia ○ Blue-Blind/Tritanopia 	○ Monoch○ Blue Cc
e with normal view: No Lens 	○ Normal Lens ○ Inverse Len	s
() ()	Anomalous Trichromacy: O Red-Weak/Protanomaly O Green-Weak/Deuteranomaly O Blue-Weak/Tritanomaly	Anomalous Trichromacy: Dichromatic view: O Red-Weak/Protanomaly O Red-Blind/Protanopia O Green-Weak/Deuteranomaly O Green-Blind/Deuteranopia







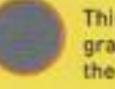
INTERACTIONS BETWEEN COLORS AND WITH LIGHTING



"Lightness Constancy"

The perception that the apparent brightness of light and dark surfaces remains more or less the same under different luminance conditions is called **darkness (lightness) constancy**.



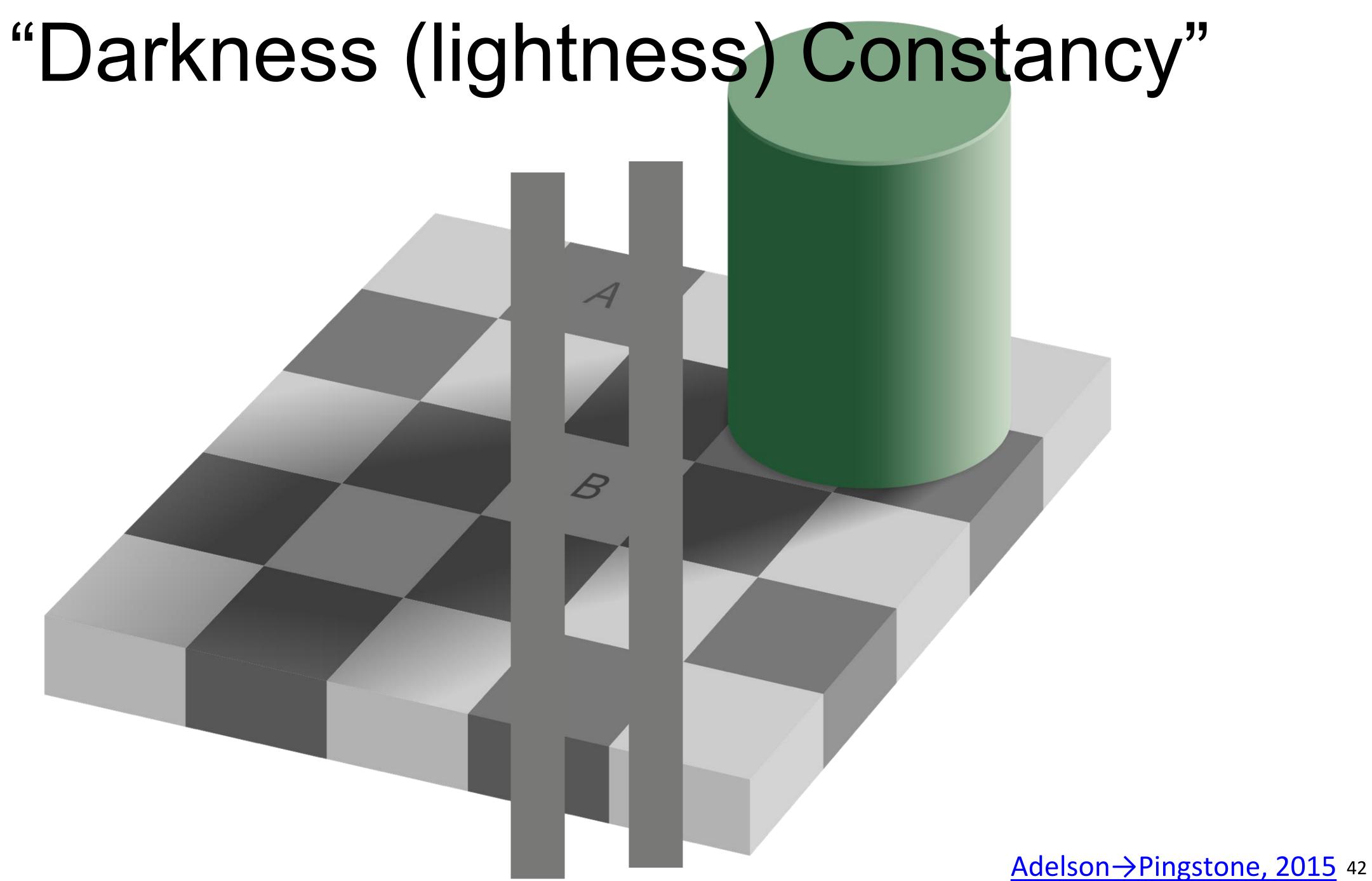


This is the same gray as the center of the O in OFF



This is the same gray as the top part of the S in GLOVES

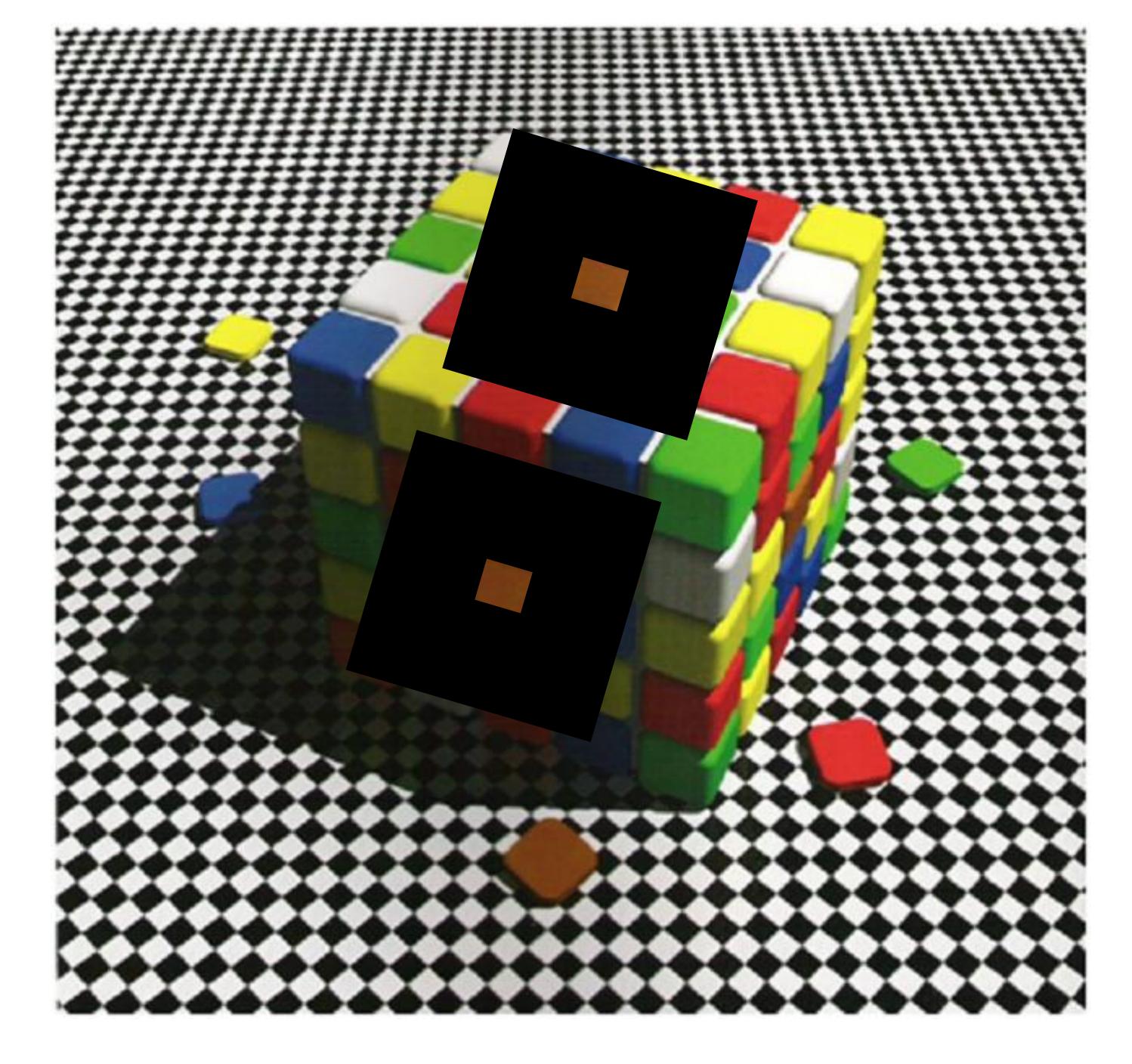








"Color Constancy"



Lotto, 2009 43









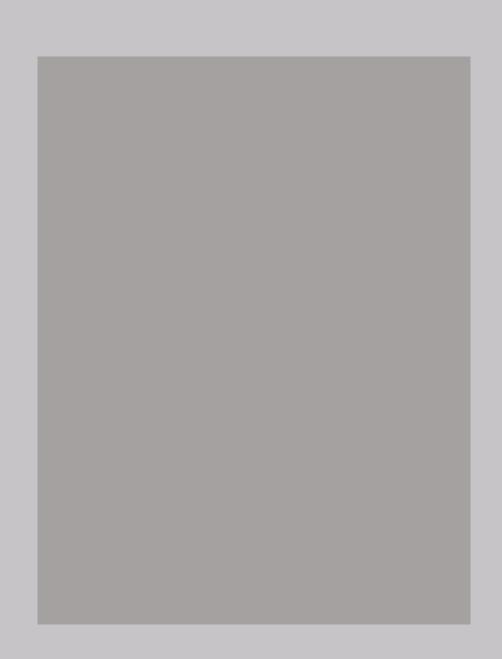






Avoid gradients as backgrounds or bars!

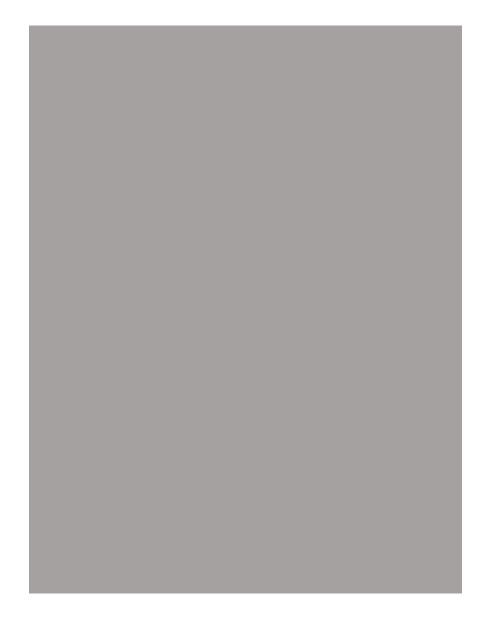




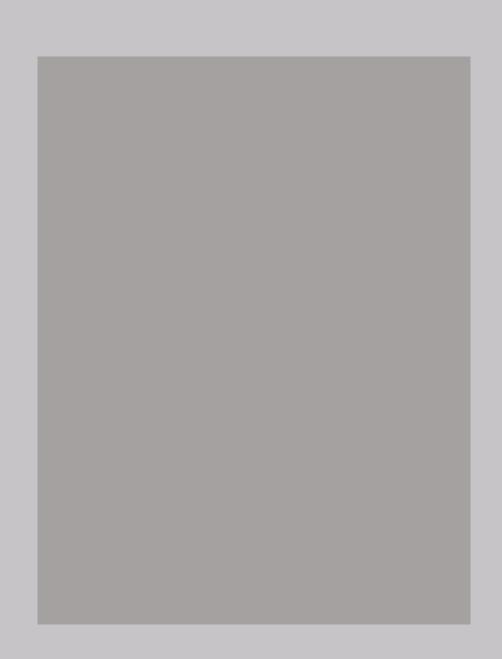










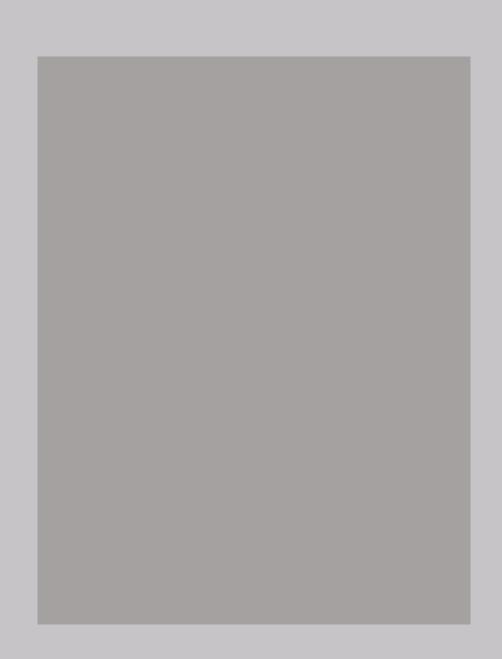






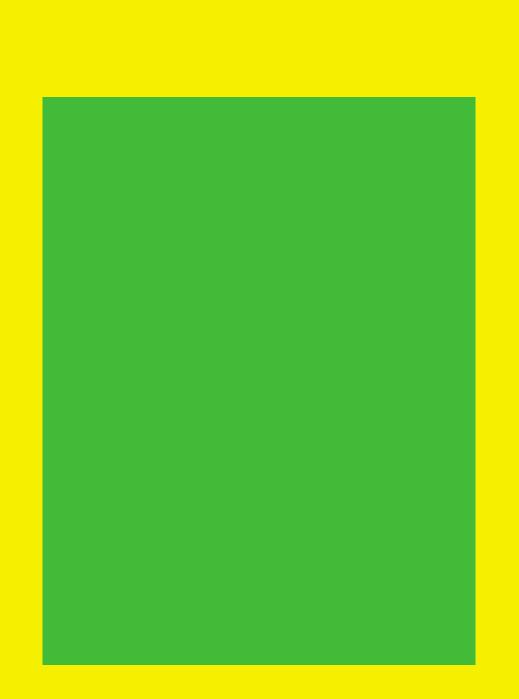






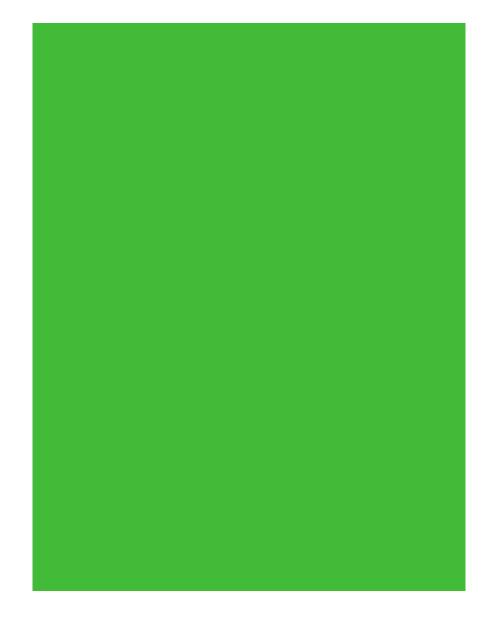


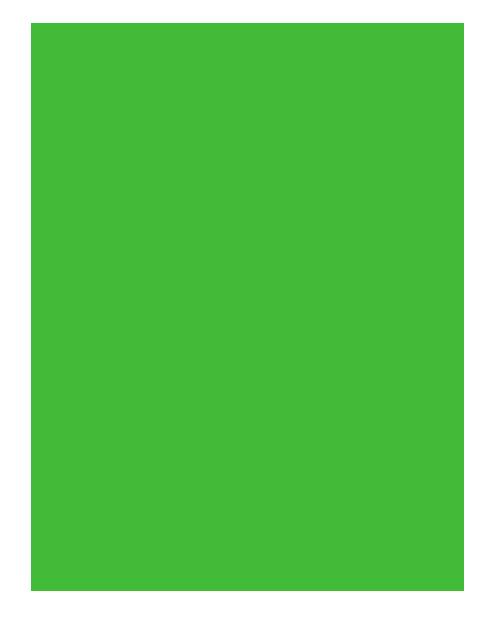




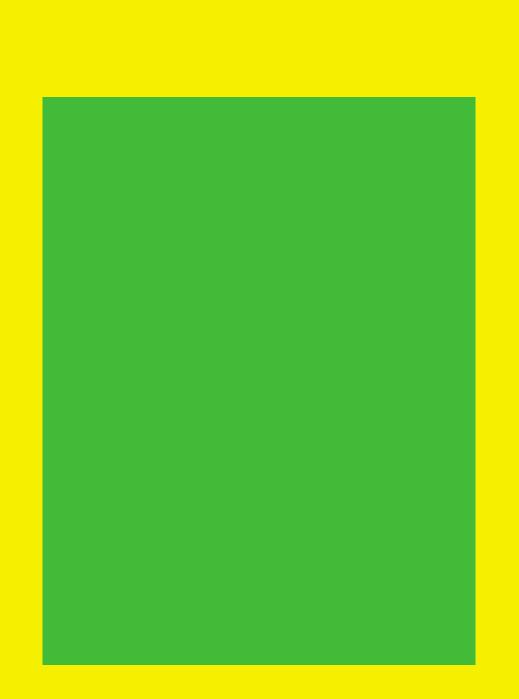










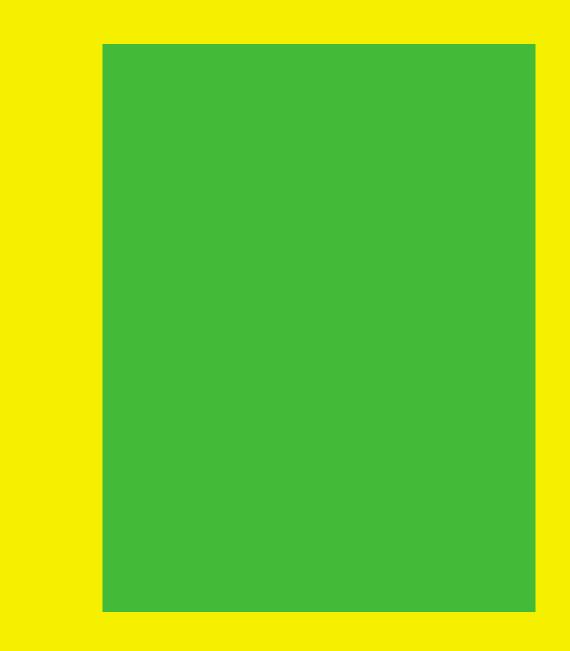






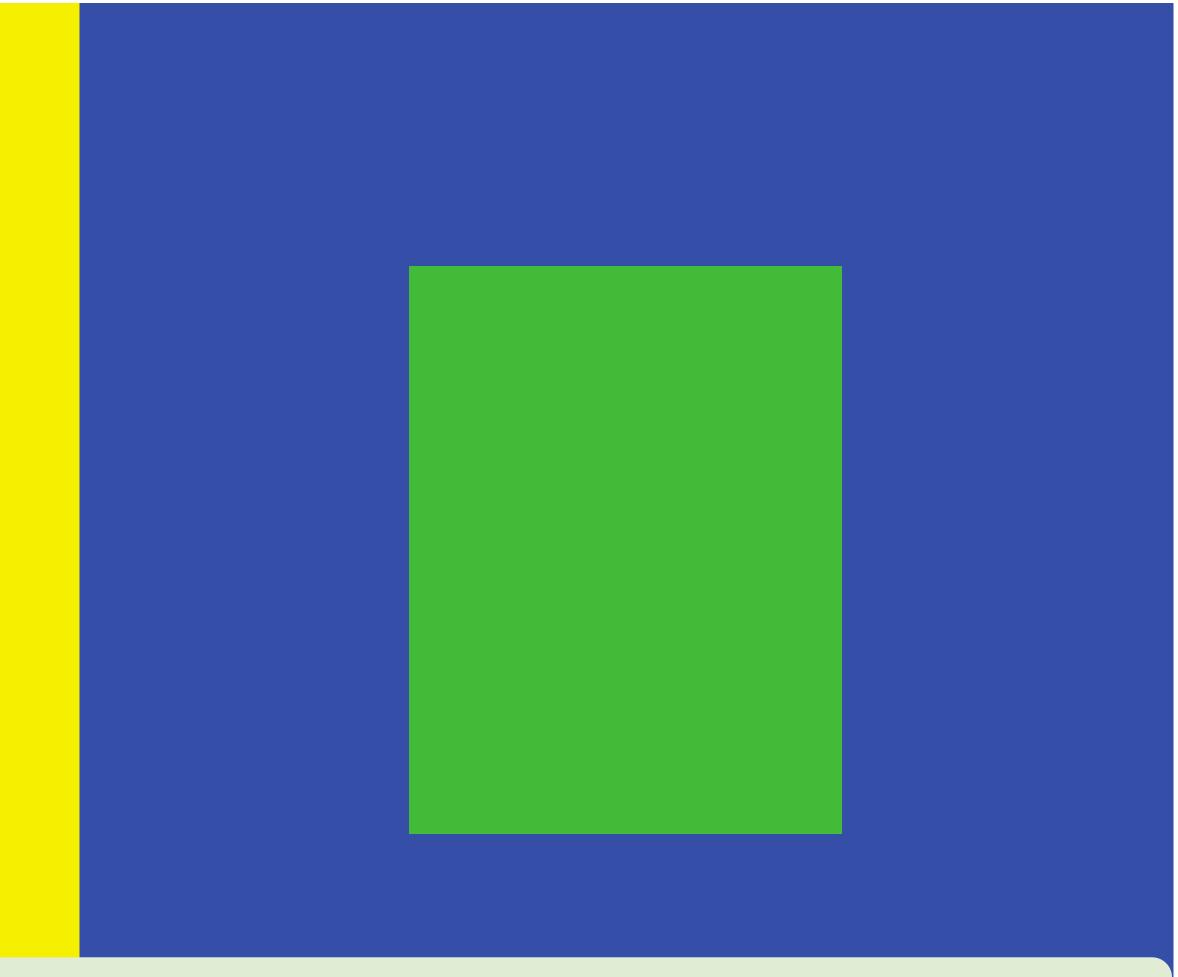




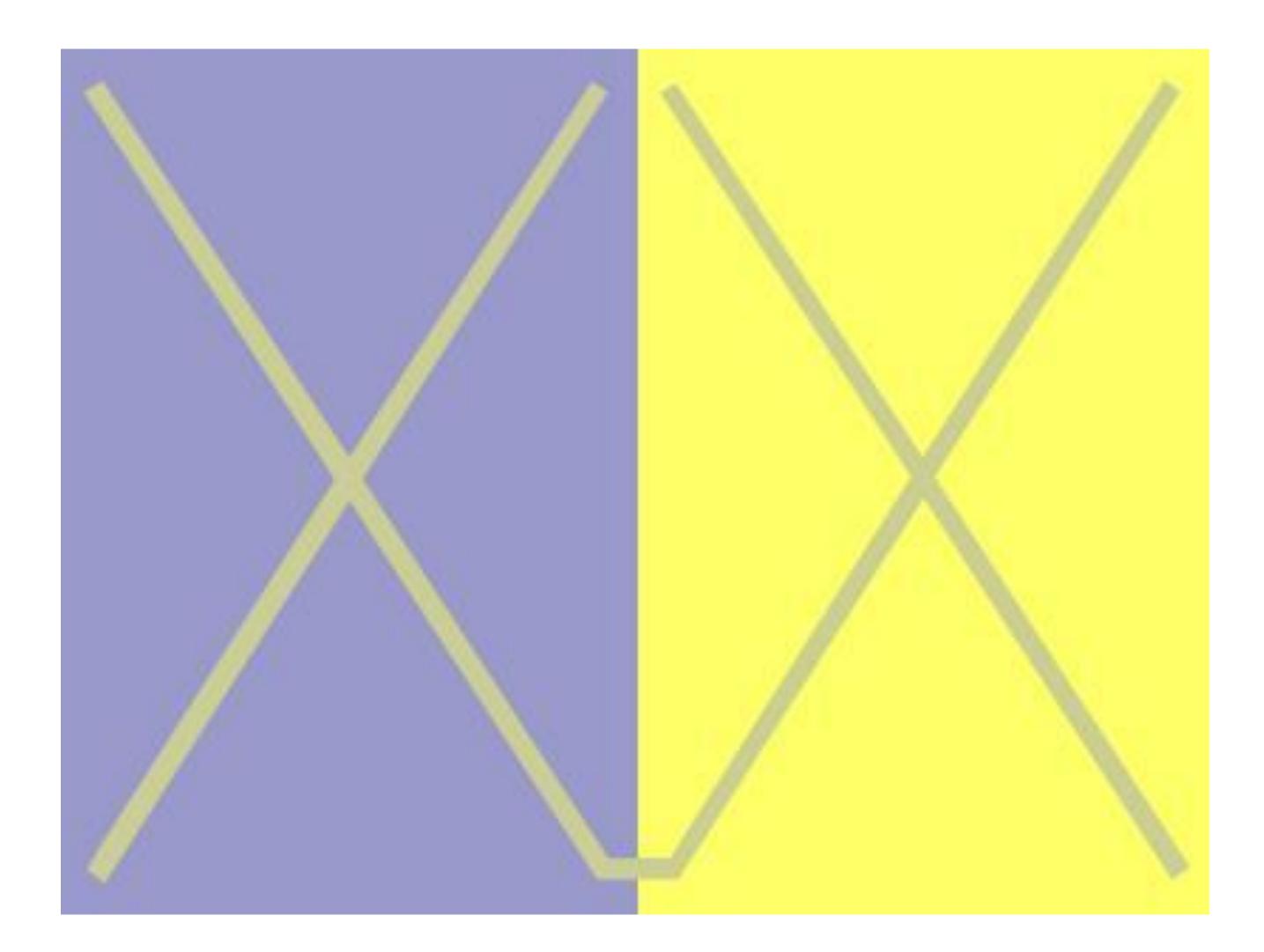


Be careful with bars and scatter plot points - the colors may appear differently with different background colors and neighboring colors!

Be aware that colors in legends may appear different than on the plot!







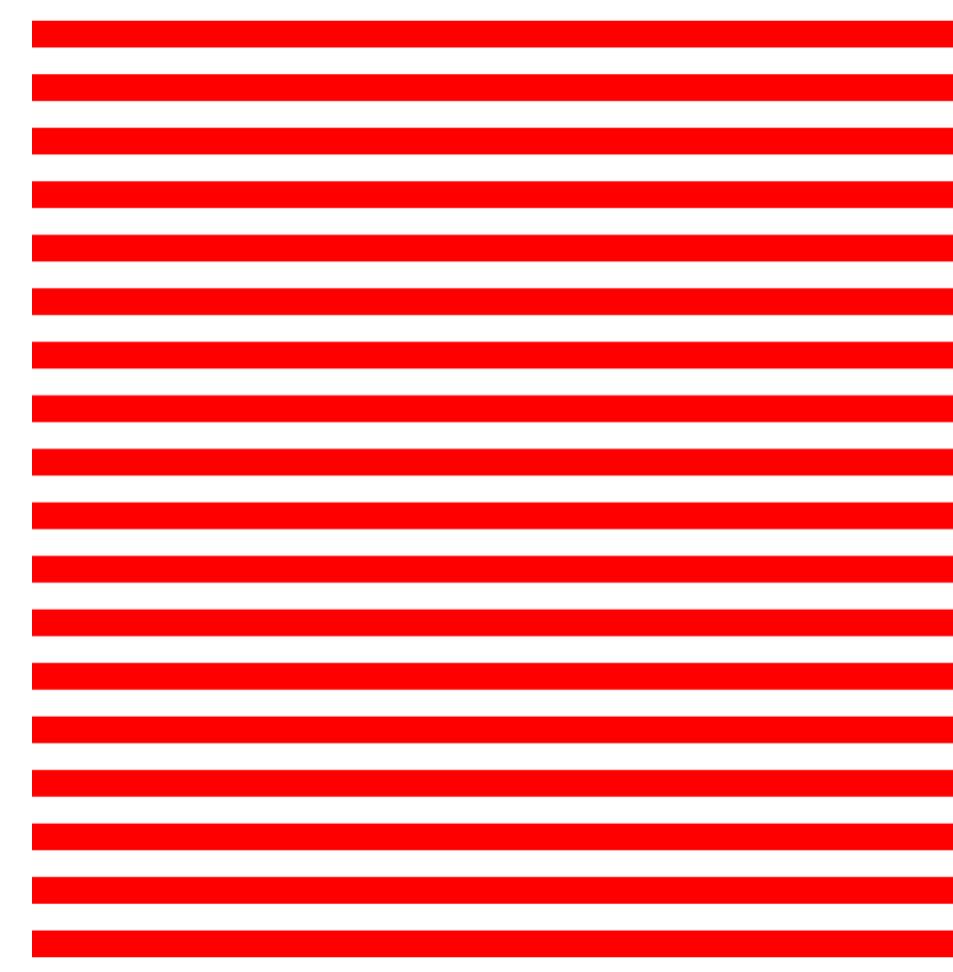


Griffin, 2015 58





"von Bezold Spreading Effect"





"von Bezold Spreading Effect"



Be careful with colors in scatter plots! Be aware of color changes when adding borders around bars and plots! Be aware that colors in legends may appear different than on the plot!



Which area is larger (green or red)?

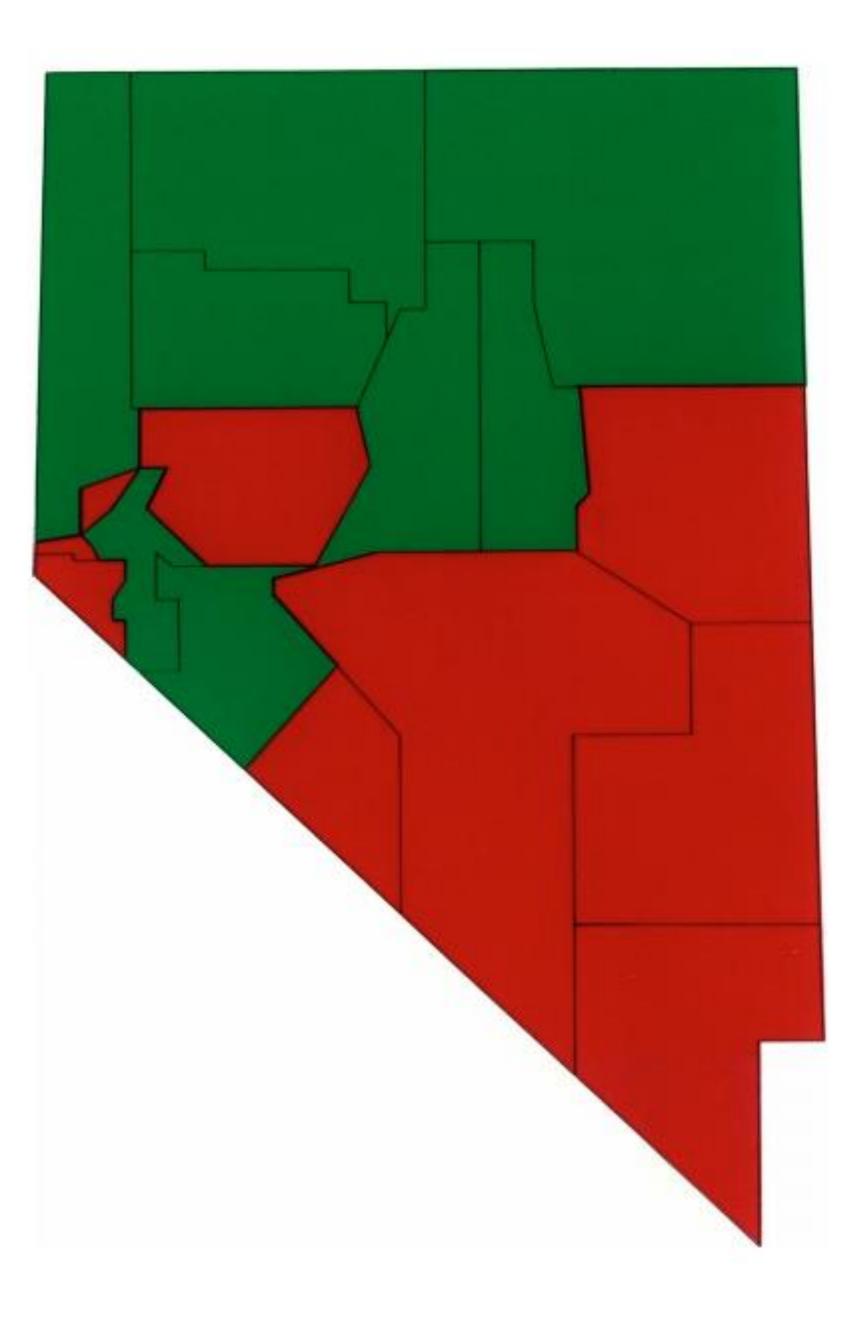


Figure 1. Stimulus From the High-Saturation Group

Cleveland & McGill, 1983 ⁶¹

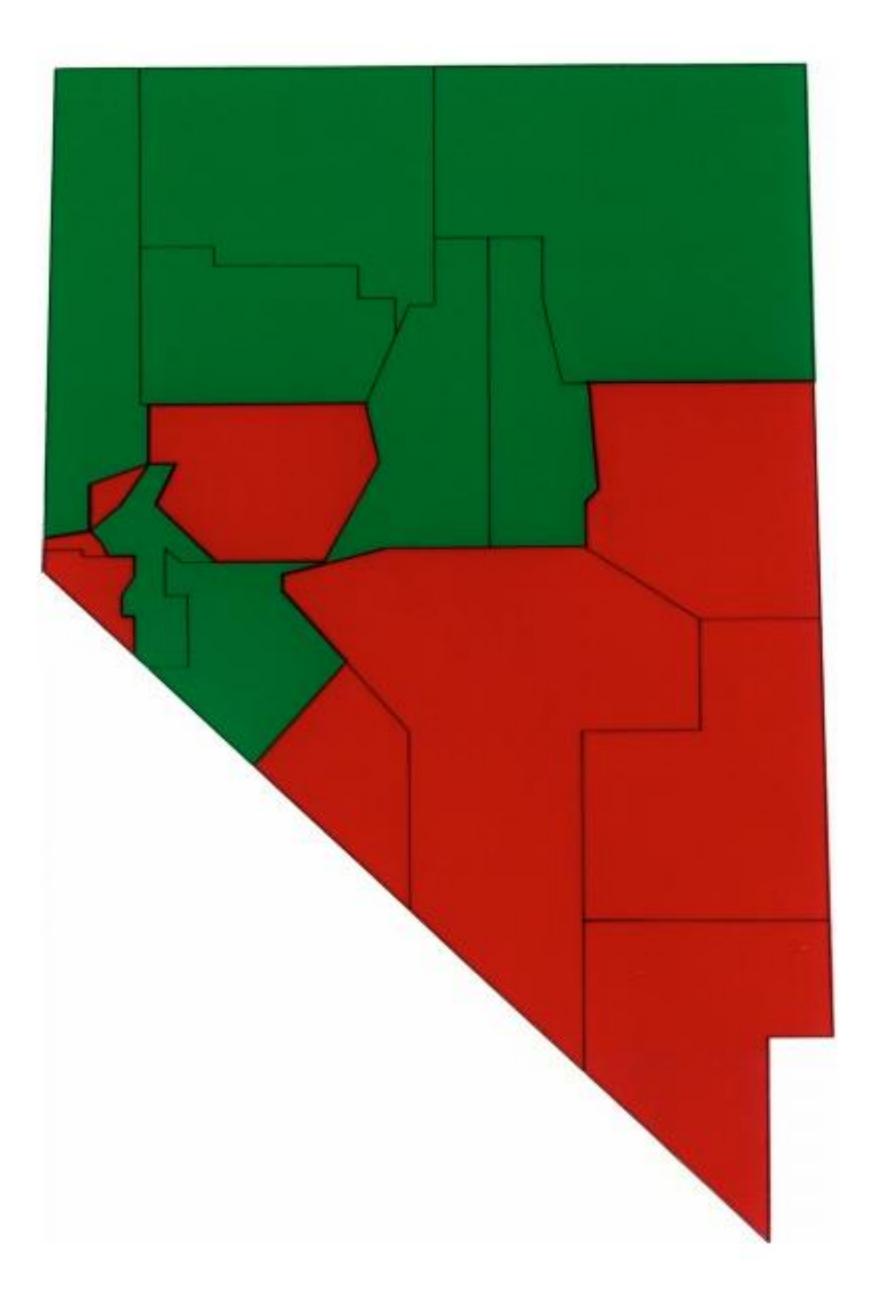




Which area is larger?

Areas are equal(!).

Study participants favored red in the highly saturated case (left) but were more correct with the desaturated case (right)



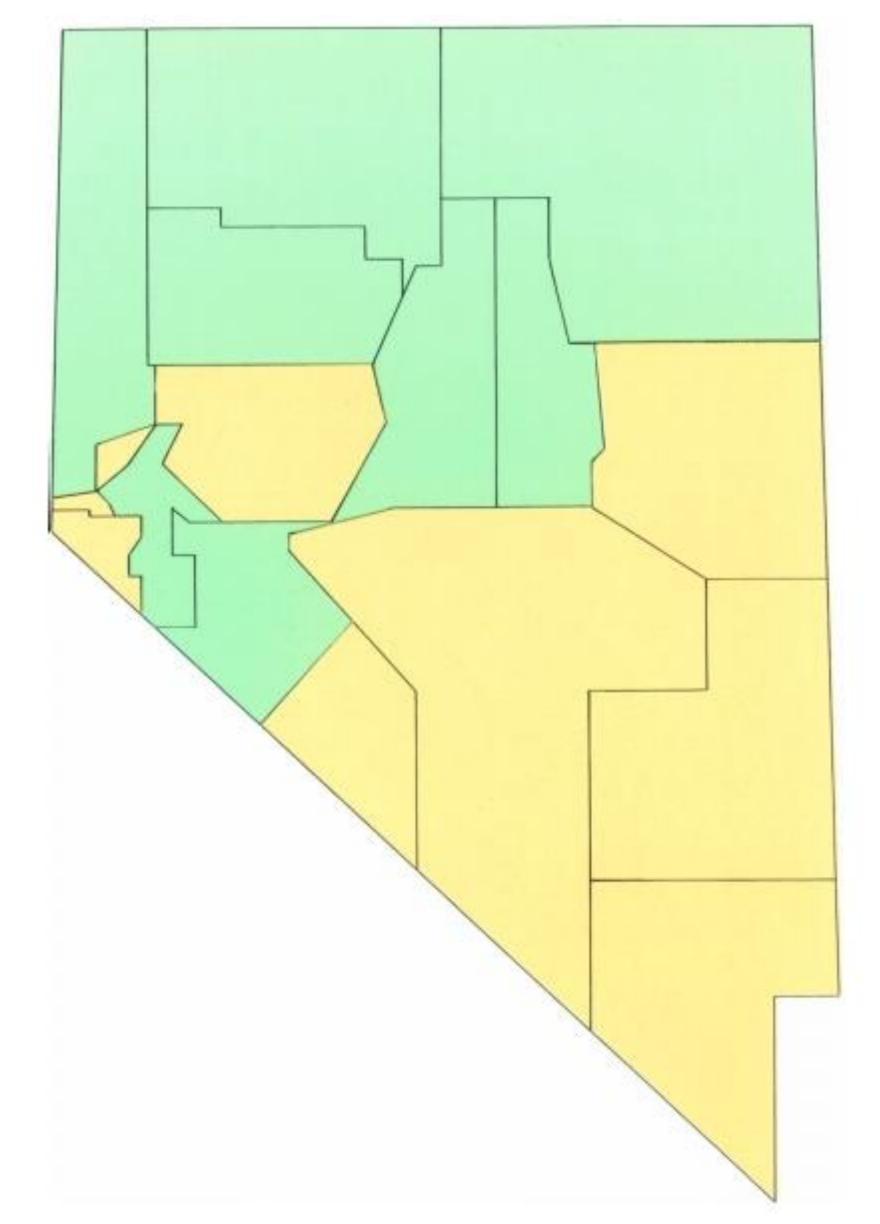


Figure 2. Stimulus From the Low-Saturation Group Cleveland & McGill, 1983⁶²





POP-OUT EFFECTS



<u>Healey, 2012</u> 63





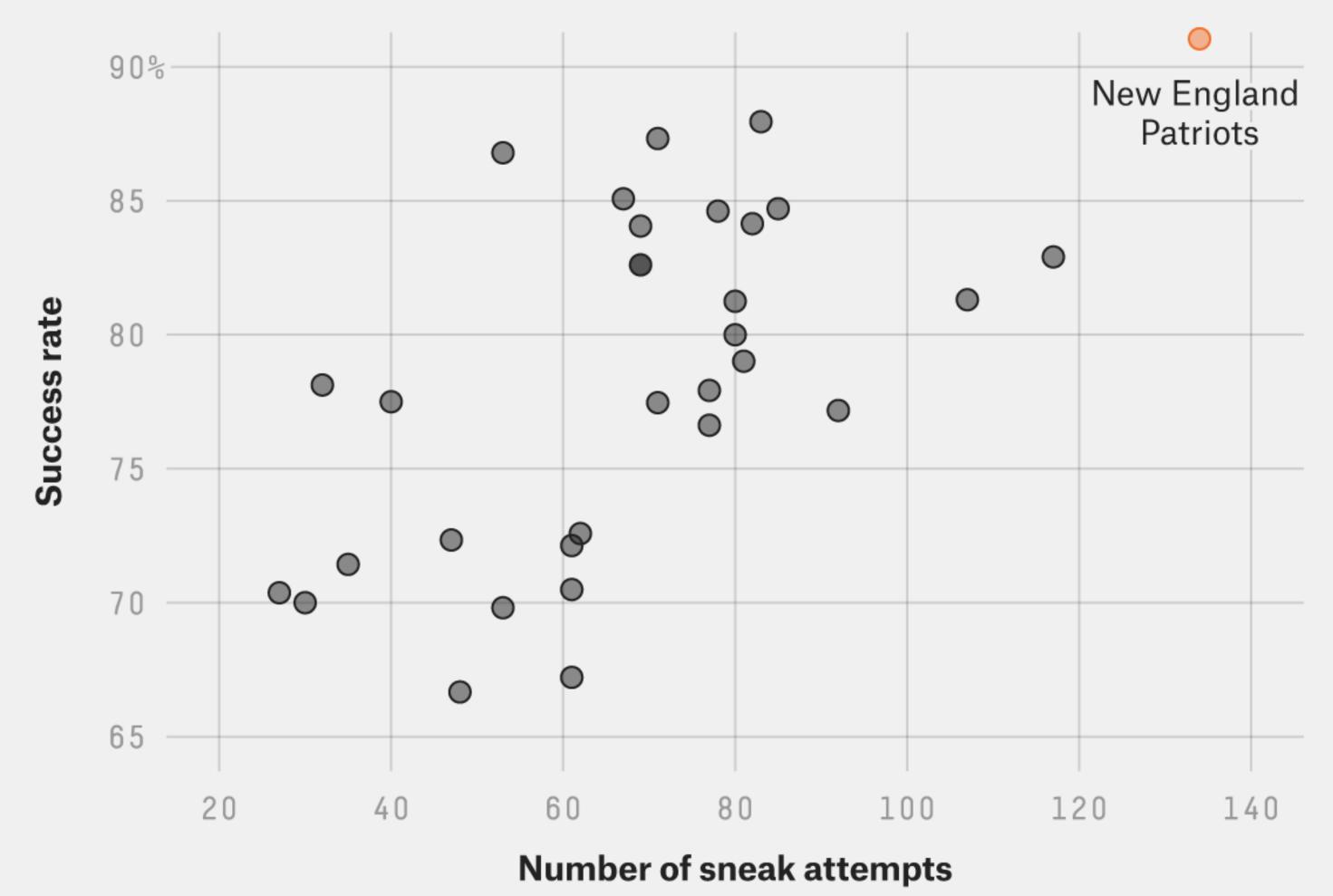
A quarterback sneak is a play in American football and Canadian football in which the quarterback, upon taking the center snap, dives ahead while the offensive line surges forward. It is usually only used in very short yardage situations.

https://en.wikipedia.org/wiki/Quarterback_sn <u>eak</u>

Which pop-out effects are used in this example visualization?

The Patriots' QB sneaks stand out

QB sneak success rate versus number of attempts on 1- and 2-yard plays on third and fourth down, 2001-15



FiveThirtyEight



SOURCE: ARMCHAIR ANALYSIS

https://fivethirtyeight.com/features/the-patriots-are-even-sneakier-than-you-think/ 64









Desaturated background, light blue

**NASA has an amazing collection of visualization and imaging experts. As in the example above, background colors are always selected to be desaturated thus making the foreground have a popout effect. The preferred background color is generally light blue which is desaturated and gives a 3D depth effect (i.e., blue sky in the distant background).

https://www.nasa.gov/content/goddard/hubble-goeshigh-definition-to-revisit-iconic-pillars-of-creation











Color Mixing Pitfalls

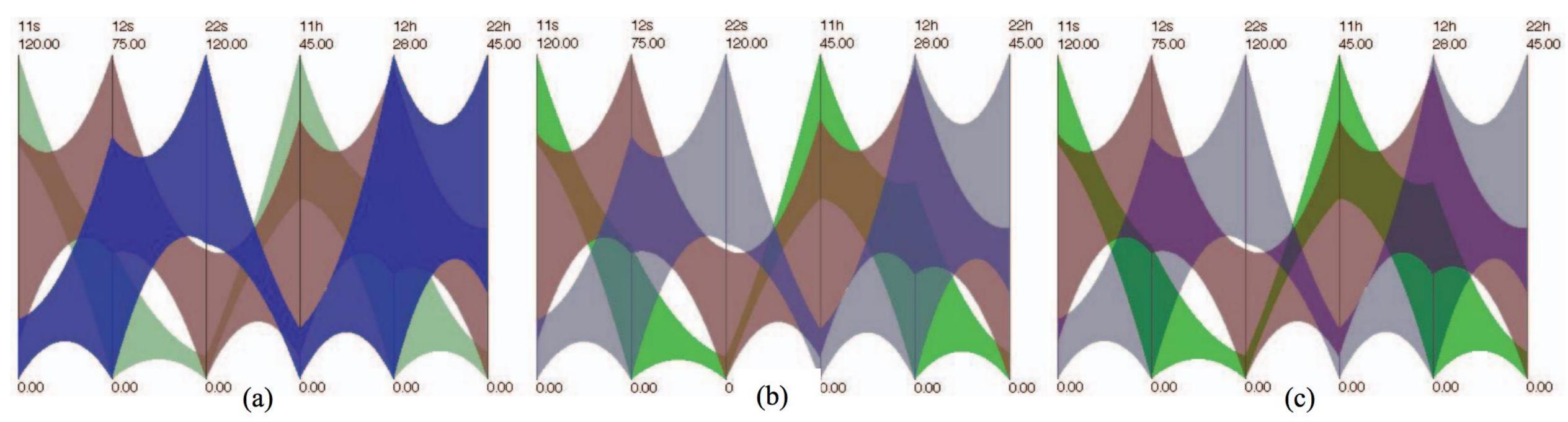
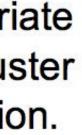


Fig. 12: Illustrative visualizations of a six-dimensional dataset using illustrative parallel coordinates. (a) Ideal visualization with appropriate weightings and color choices, and the use of the local model in overlapping areas. (b) Improper weightings are employed. The blue cluster no longer seems to be in front. (c) The use of improper weightings and the disabling of the local model results in a confusing visualization.

Note the swap in blue/red for foreground/background vs. NASA

"Aimed at reducing false colors in the overlap regions. ...[Reduce] saturation of the color in the rear object only in the overlap region while keeping its lightness."

<u>Wang et al., 2008</u>



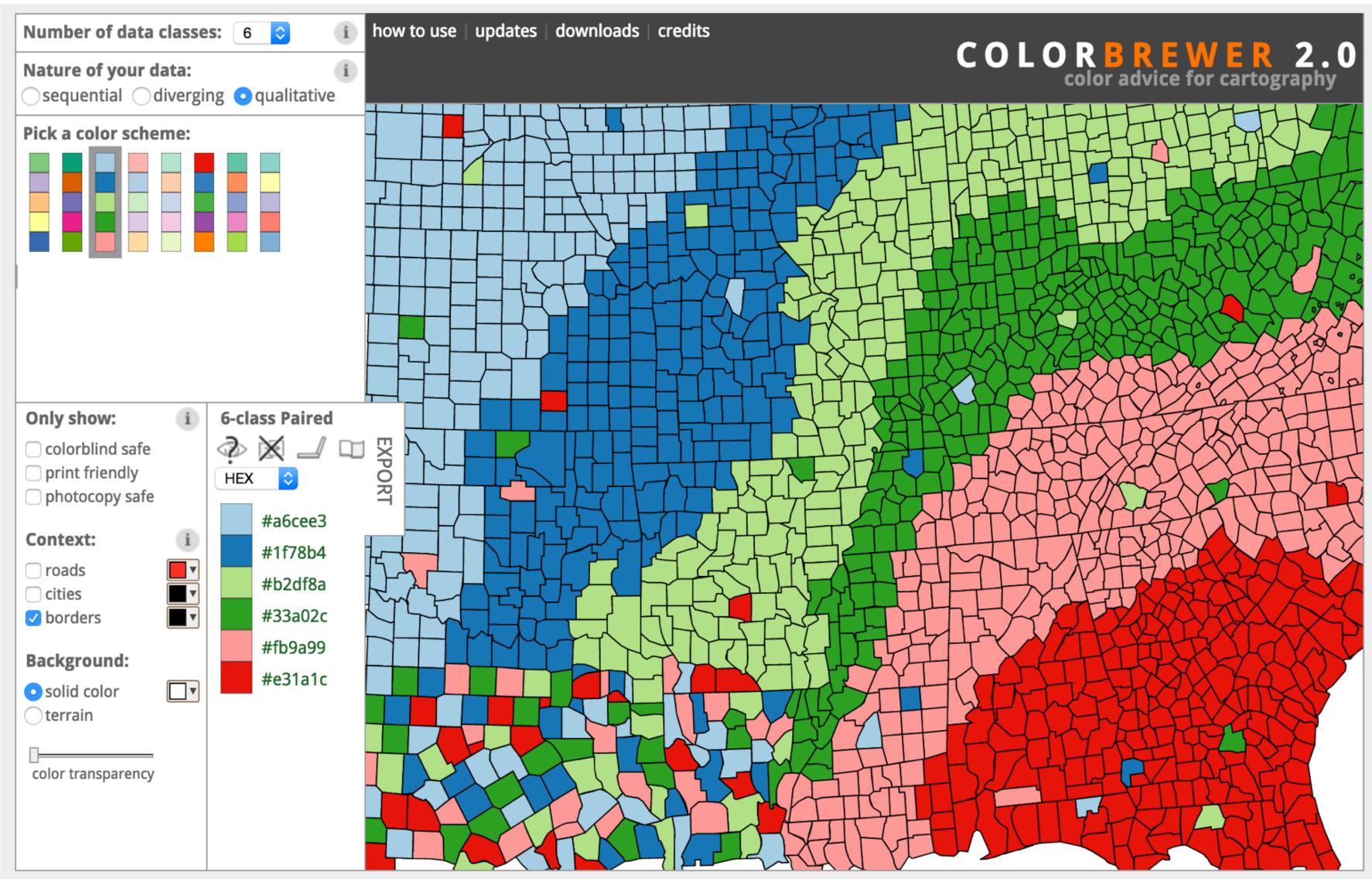




TOOLS FOR PICKING COLORMAPS



Color Brewer

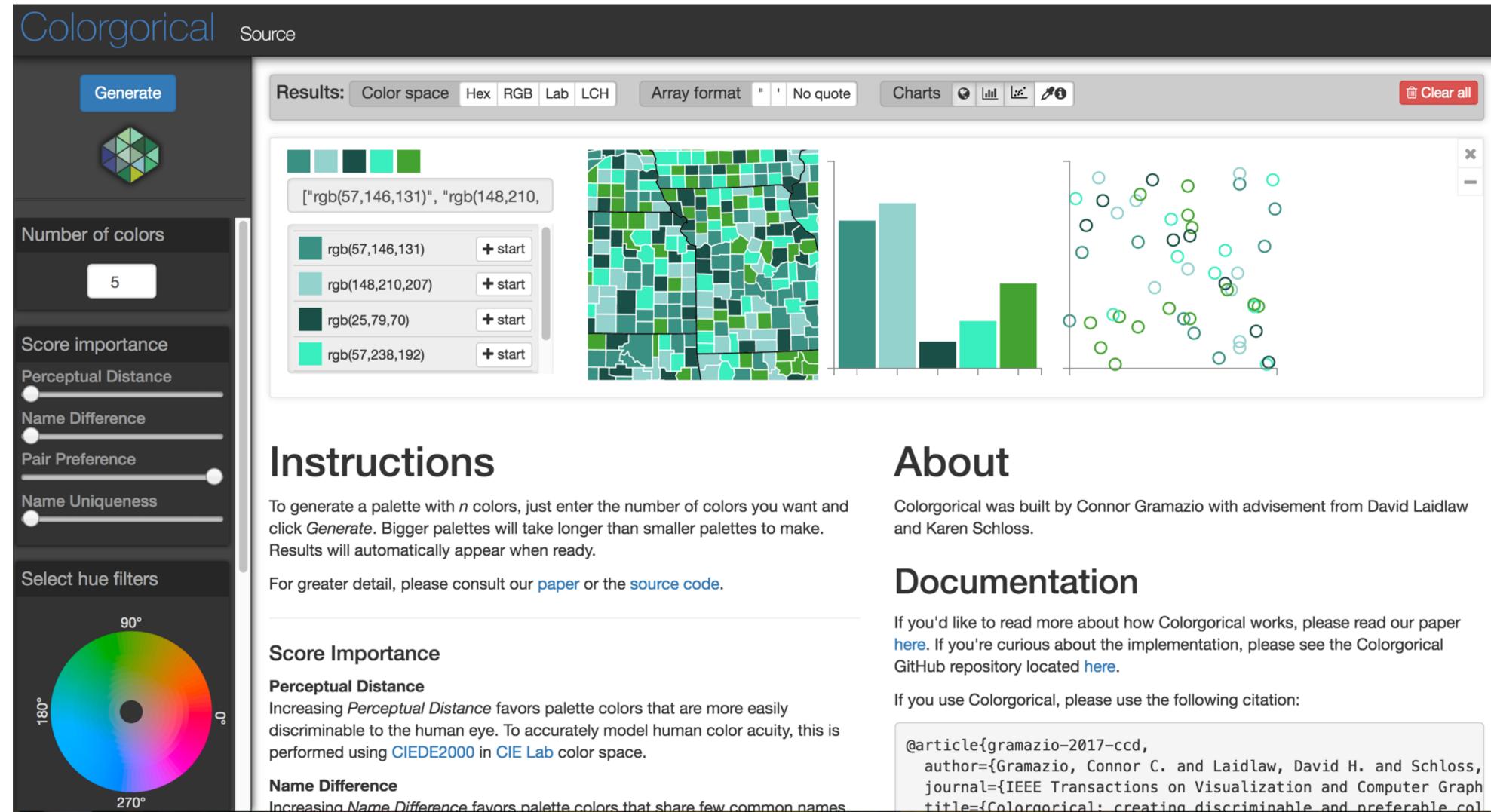




http://colorbrewer2.org/



Colorgorical



http://vrl.cs.brown.edu/color

```
title={Colorgorical: creating discriminable and preferable col
```



Other Useful Tools

- Get a list of colors from an image: https://html-color.codes/color-from-image
- Analyze your palette: <u>https://projects.susielu.com/viz-palette</u> Analyze the name similarity of colors in your palette: http://vis.stanford.edu/color-names/analyzer/
- Details on multi-hued color scales: https://www.vis4.net/blog/2013/09/mastering-multi-hued-colorscales/#combining-bezier-interpolation-and-lightness-correction Easy picking a multi-hued color scale: <u>http://tristen.ca/hcl-picker/</u> Easily correcting darkness (lightness) for a
- scale: <u>http://gka.github.io/palettes/</u>
- Do a ton programmatically: <u>https://gka.github.io/chroma.js/</u>
- virdis colors:

https://cran.r-project.org/web/packages/viridis/vignettes/intro-toviridis.html



Color Advice Summary Use a limited hue palette Control color "pop out" with low-saturation colors

- Avoid clutter from too many competing colors
- Use neutral backgrounds
 - Control impact of color
 - Minimize simultaneous contrast
- Use Color Brewer etc. for picking scales
- Don't forget aesthetics!

Based on Slides by Hanspeter Pfister, Maureen Stone 71







Pop-out Effects

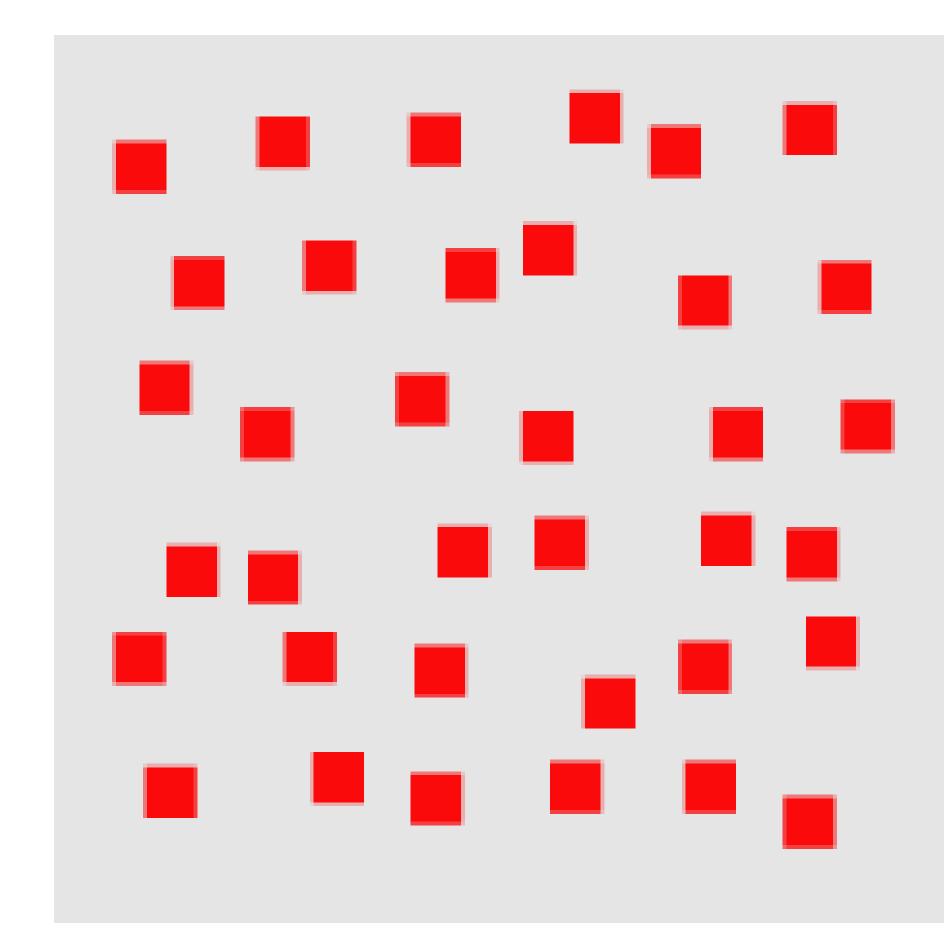


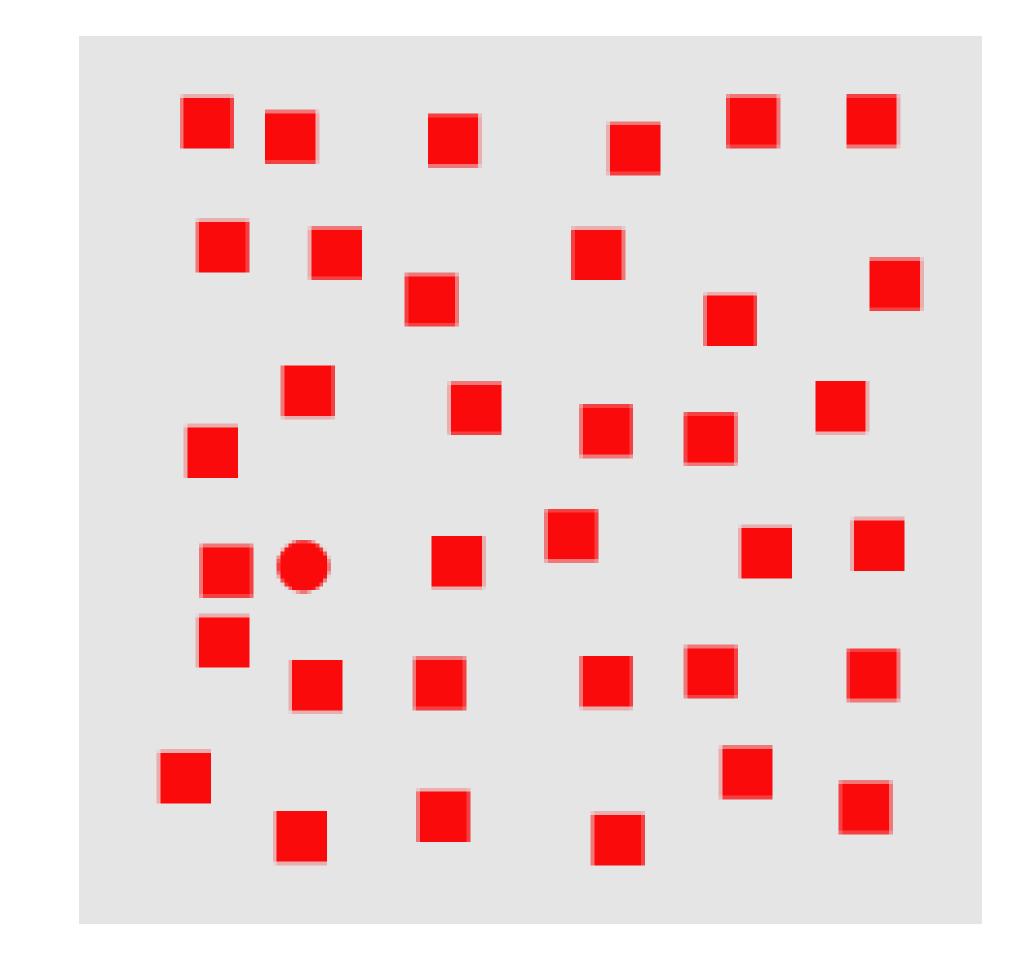


<u>Healey, 2012</u> 73









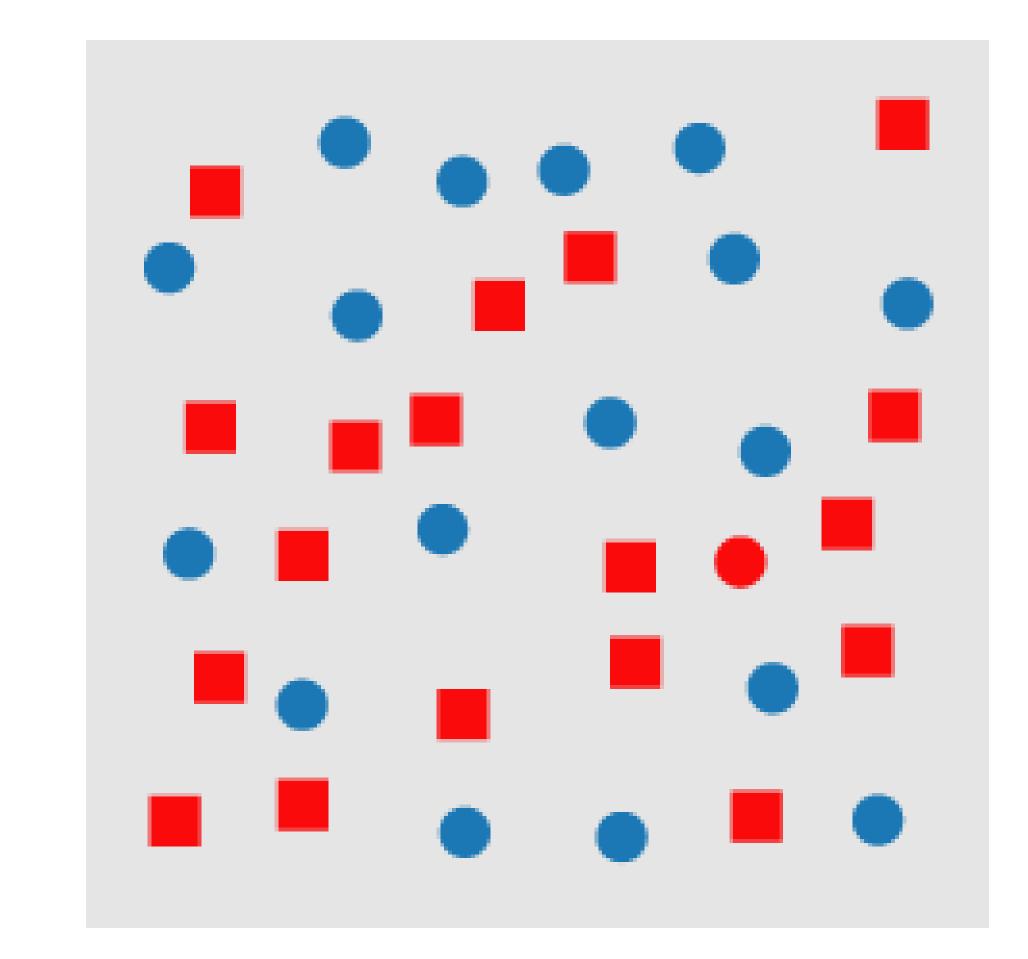
SHAPE

Healey, 2012 74





"CONJUNCTION" (HARDER TO FIND RED CIRCLE!)







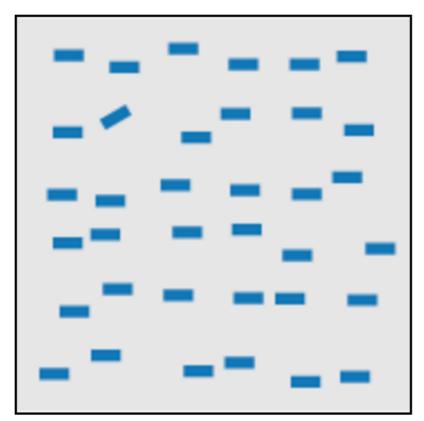


MOTION

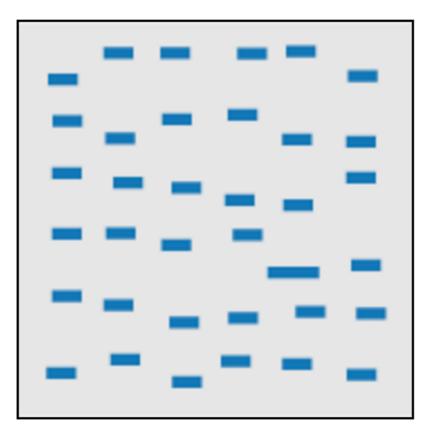
<u>Healey, 2012</u> 76



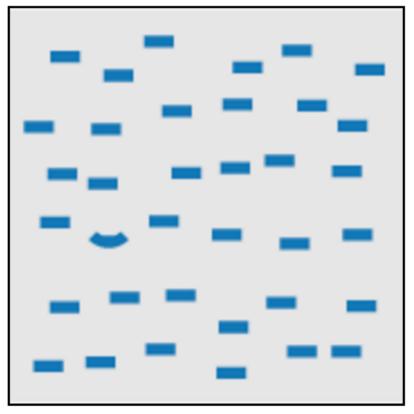




line (blob) orientation Julész & Bergen 83; Sagi & Julész 85a, Wolfe et al. 92; Weigle et al. 2000

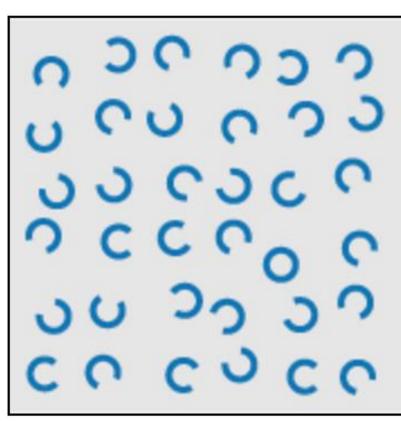


length, width Sagi & Julész 85b; Treisman & Gormican 88

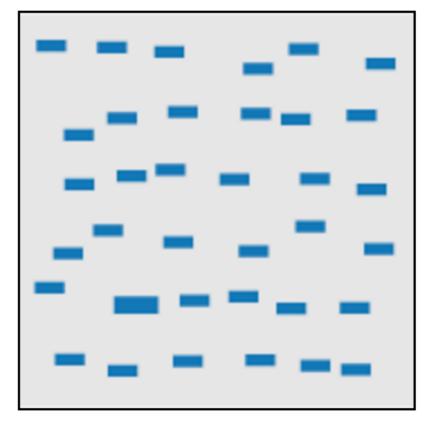


density, contrast Healey & Enns 98; Healey & Enns 99

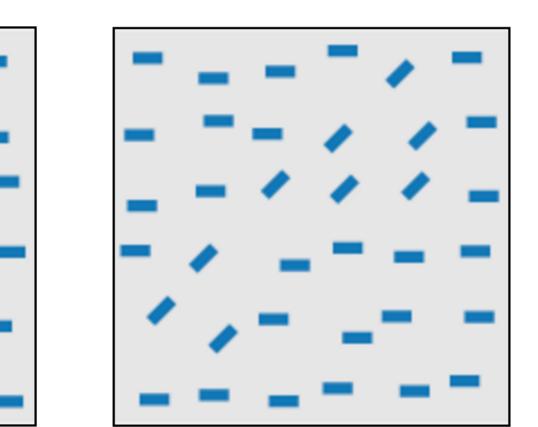
curvature **Treisman & Gormican 88**



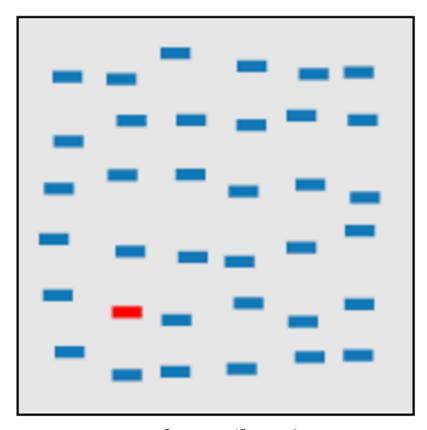
closure Julész & Bergen 83



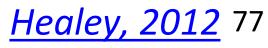
size Treisman & Gelade 80; Healey & Enns 98; Healey & Enns 99



number, estimation Sagi & Julész 85b; Healey et al. 93; Trick & Pylyshyn 94

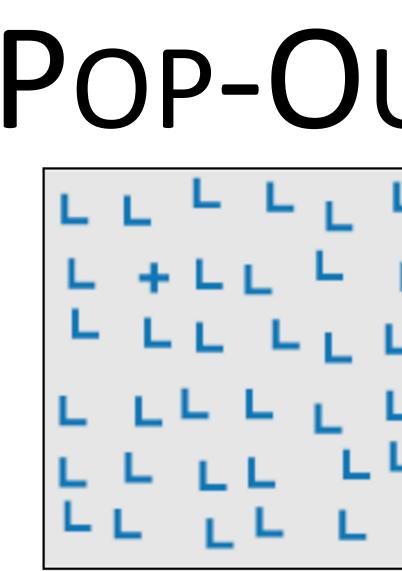


colour (hue) Nagy & Sanchez 90; Nagy et al. 90; D'Zmura 91; Kawai et al. 95; Bauer et al. 96; Healey 96; Bauer et al. 98; Healey & Enns 99

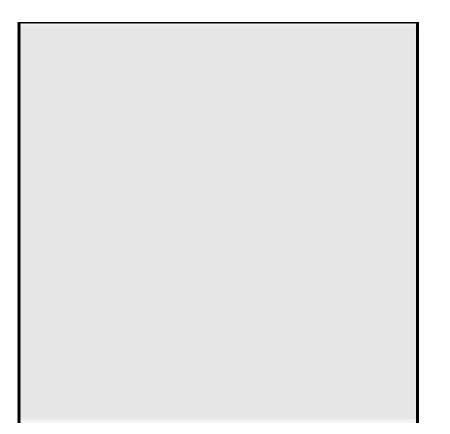








intersection Julész & Bergen 83

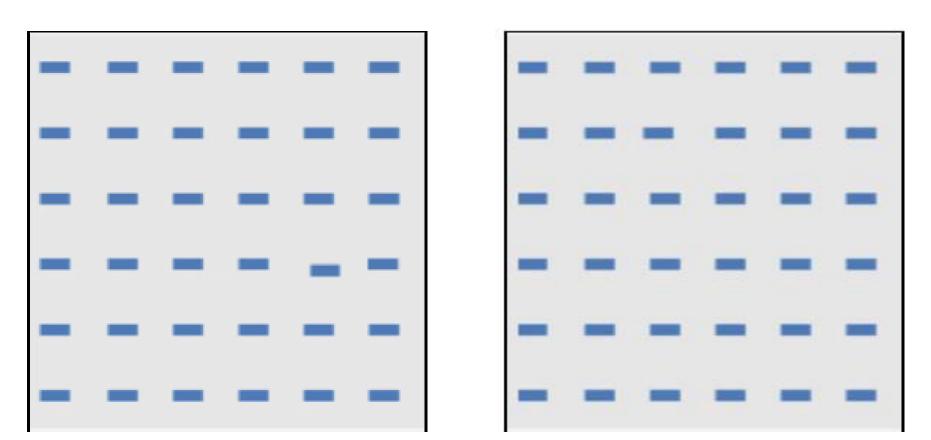


intensity, binocular lustre

Beck et al. 83; Treisman &

Gormican 88; Wolfe & Franzel

88

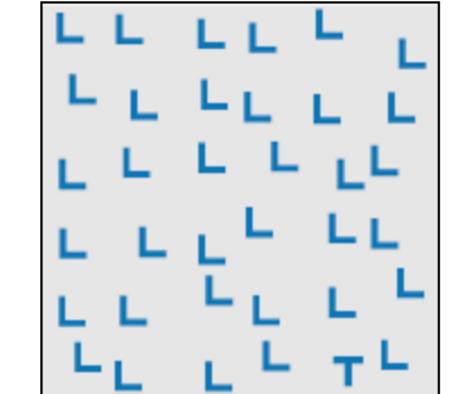


direction of motion Nakayama & Silverman 86; Driver & McLeod 92; Huber & Healey 2005

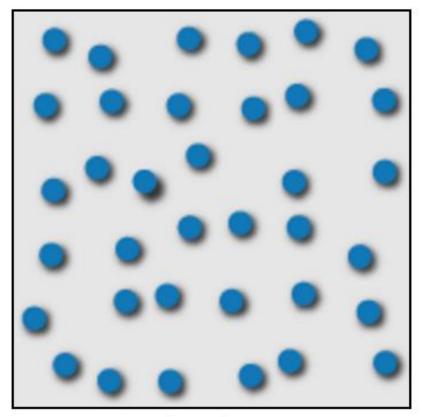
flicker

Gebb et a. 55; Mowbray & Gebhard 55; Brown 65; Julész 71; Huber & Healey 2005

POP-OUT EFFECTS

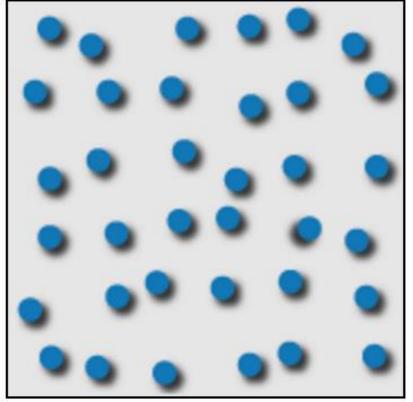


terminators Julész & Bergen 83



3D depth cues Enns 90b; Nakayama & Silverman 86

velocity of motion Tynan & Sekuler 82; Nakayama & Silverman 86; Driver & McLeod 92; Hohnsbein & Mateeff 98; Huber & Healey 2005



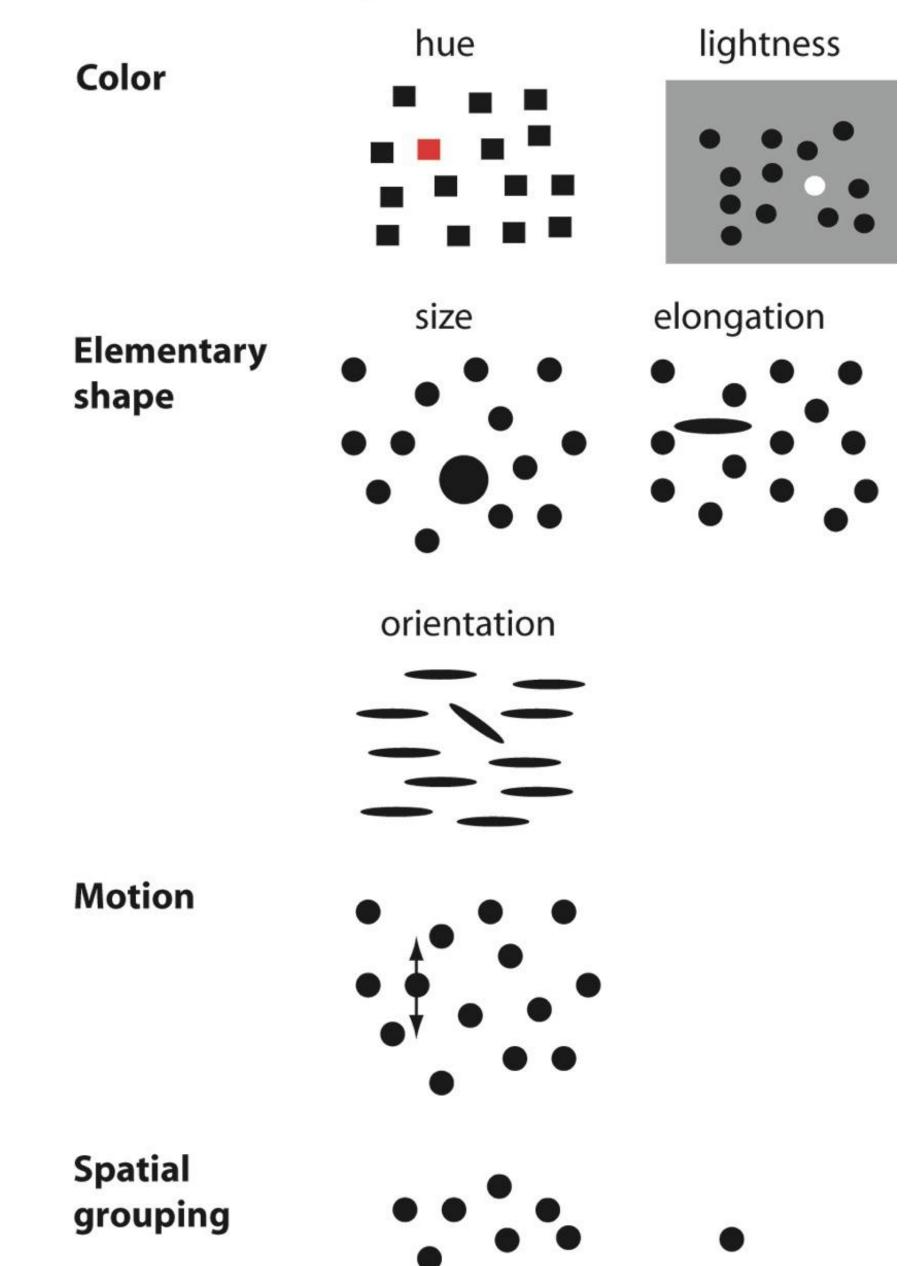
lighting direction Enns 90a

Healey, 2012 78









Use these "popout" effects to help design effective visualizations!

(E.g., draw viewer's attention to main points, effective redundant encodings, etc.)

Ware, VTFD 79

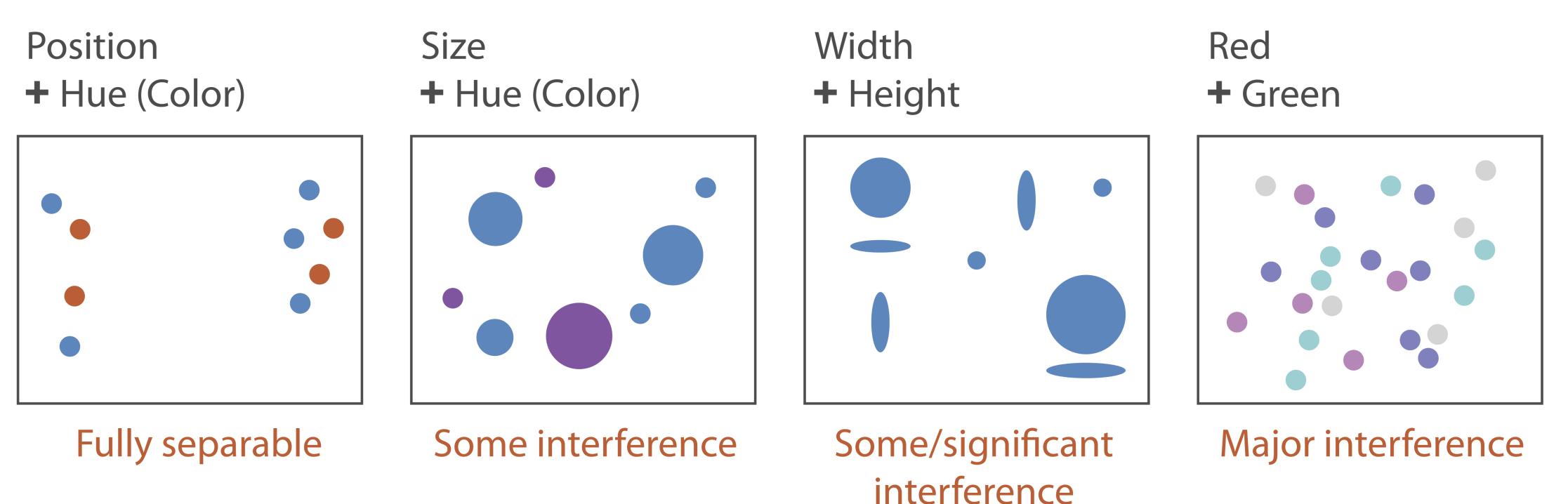






Discriminability and Separability

The question of discriminability is: if you encode data using a particular visual channel, are the differences between items perceptible to the human as intended?



Munzner, VAD 80



Discriminability and Separability



color color color location motion shape

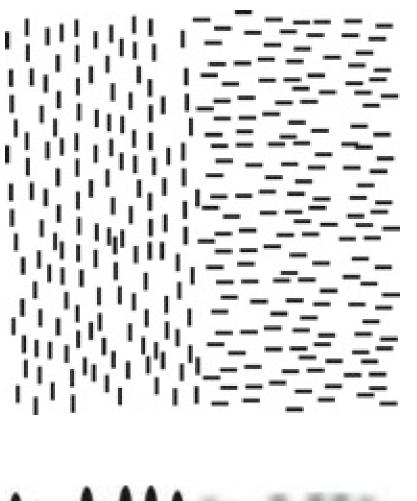
color size x-size red-green shape orientation y-size yellow-blue

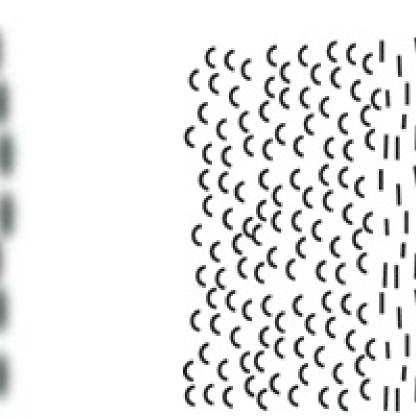
Ware, "Information Visualization"⁸¹

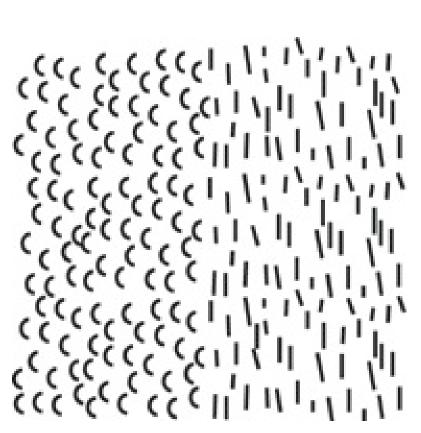


Textures

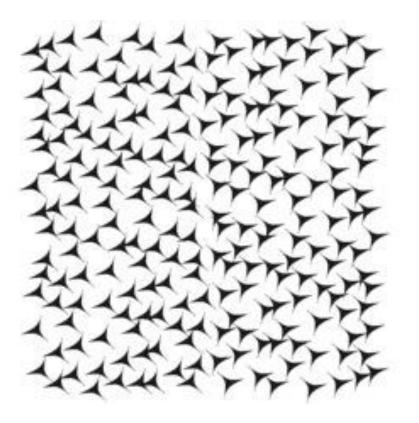
easy

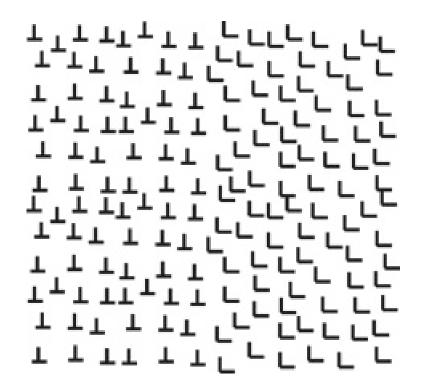


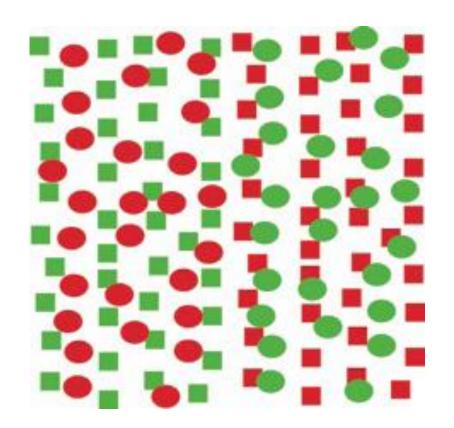




hard









t on a background containing similar feature elements will be very difficult to read even though the background color is different. やいたかいなからみ

Subtle, low contrast background texture with little feature similarity will interfere less.

Textures: Interference

The more the background differs in element granularity, in feature similarity, and in the overall contrast, the easier the text will be to read.







More (13!) Color Design Tips

R1: Vivid colors (bright, saturated colors) stand out. They guide attention to a particular feature, generating the pop-out effect.

R2: An excessive amount of vivid colors is perceived as unpleasant and overwhelming; use them between duller background tones.

R3: Foreground-background separation works best if the foreground color is bright and highly saturated, while the <u>background is de-saturated</u>.

R4: Colors can be better discriminated if they differ simultaneously in hue, saturation and darkness.

R5: The low-end darkness steps should be very small, while the high end requires larger steps (Weber's Law).

R6: <u>Discrimination is poorer for small objects</u>. Hue, saturation and darkness discrimination all decrease.

R7: Complementary (opponent) colors are located opposite on the color wheel and have the highest chromatic contrast. When mixing opponent colors they may cancel each other, giving neutral grey.

R8: Some hues appear inherently more saturated than others. Yellow has the least number of perceived saturation steps (10). For hues on both sides of yellow, the saturation steps increase linearly.

R9: An opposite effect of R8 is that the brightest lights fall in the yellow range, while blues, violets (purples) and reds are least bright.

R10: For labeling, apart from black, white, grey, there are 4 primary colors (red, green, blue, yellow) and 4 secondary colors (brown, orange, purple, pink). Also, the number of color labels should be $\leq 6-7$.

R11: <u>Warm colors (red, orange, yellow) excite</u> emotions, grab attention. Cold colors (green to violet) create openness and distance.

R12: Important for hue-based labeling is the fact that increasing the darkness (and saturation) does not change the perceived hue.

R13: Also important for labeling is that <u>objects of similar</u> hue are perceived as a group, while objects of different hues are perceived as belonging to different groupings.

Wang et al., 2008 84







ILLUSIONS AND TRICKS



Visual Attention & Change Blindness

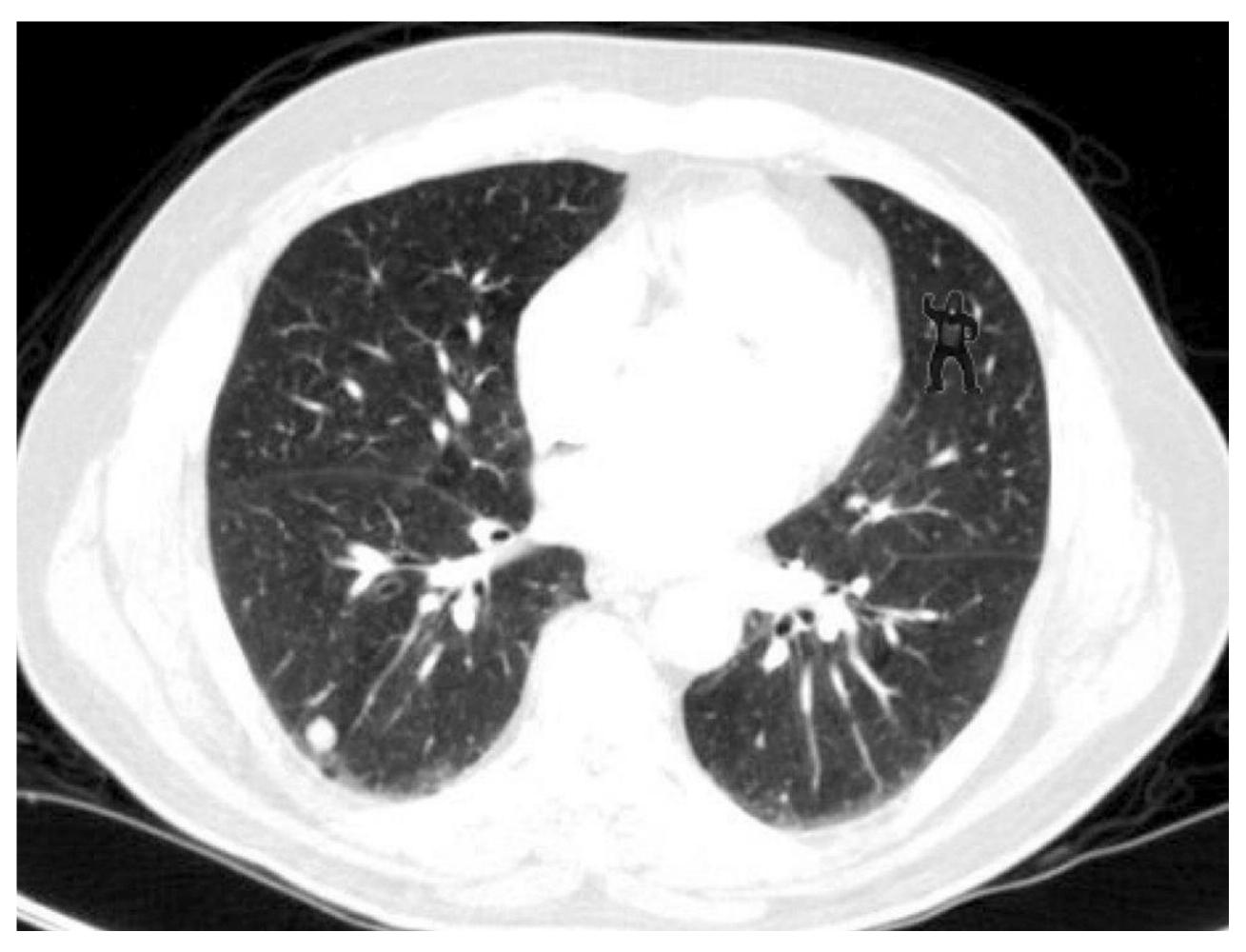


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6

Visual Attention & Change Blindness

Task: Identify the lumps/nodules in the patient's lungs to look for cancer or abnormal growth.



83% of the radiologists missed the gorilla! <u>http://search.bwh.harvard.edu/new/pubs/DrewVoWolfe13.pdf</u>





Lie Factor = (Size of effect in graphic) (Size of effect in data)

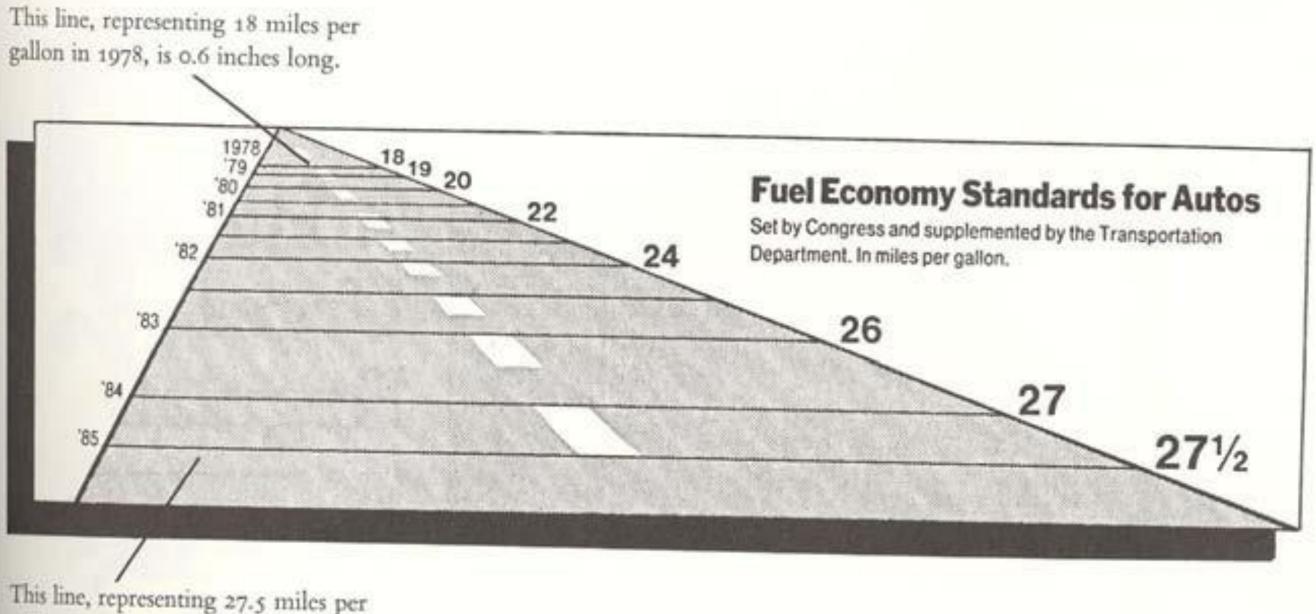
Lie Factor = >1, overstating

Lie Factor = 1, accurate :)

Lie Factor = <1, understating

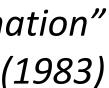
"The representation of numbers, as physically measured on the surface of the graphic itself, should be directly proportional to the numerical quantities measured."

Lie Factor



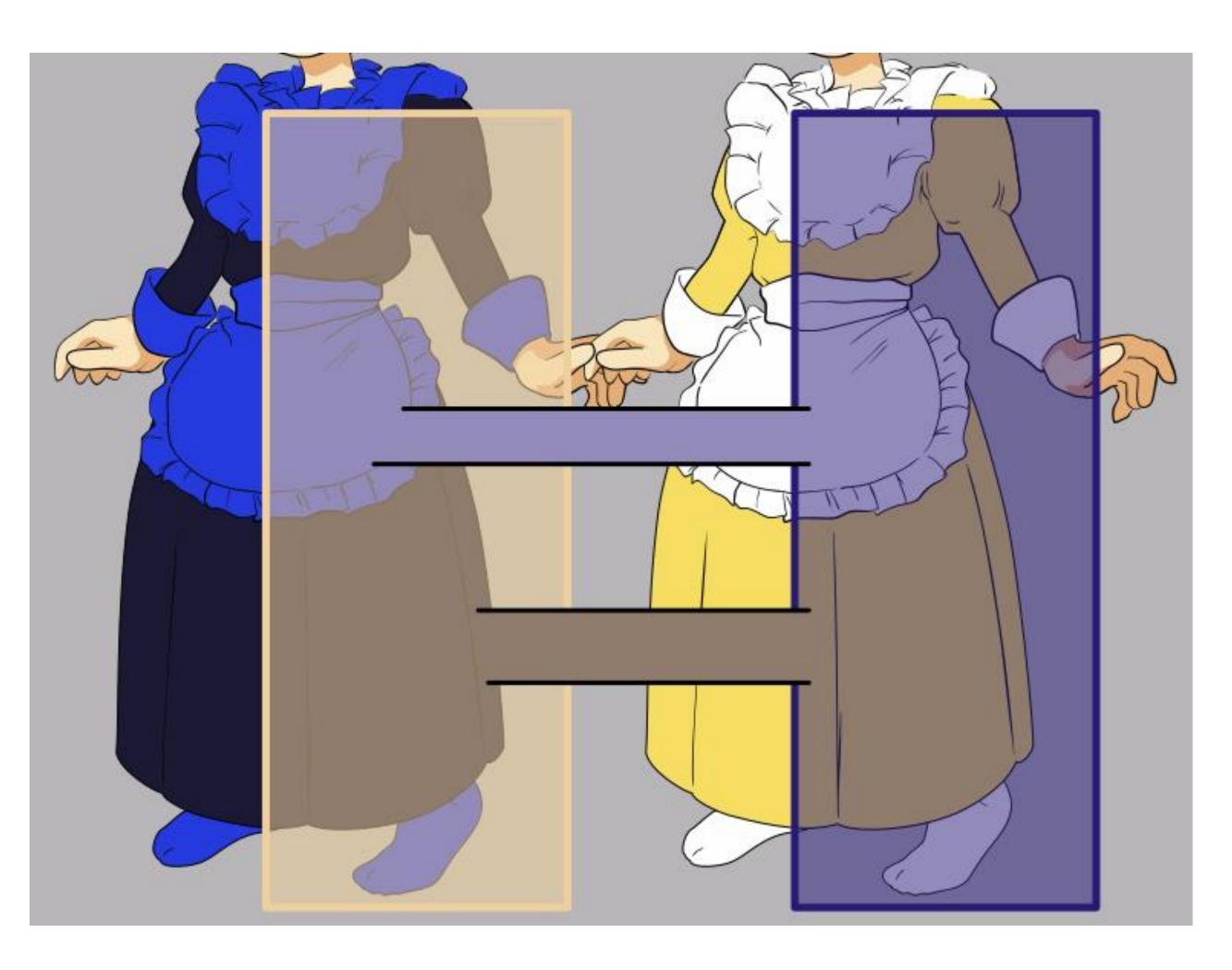
gallon in 1985, is 5.3 inches long.

Tufte, "Visual Display of Quantitative Information"





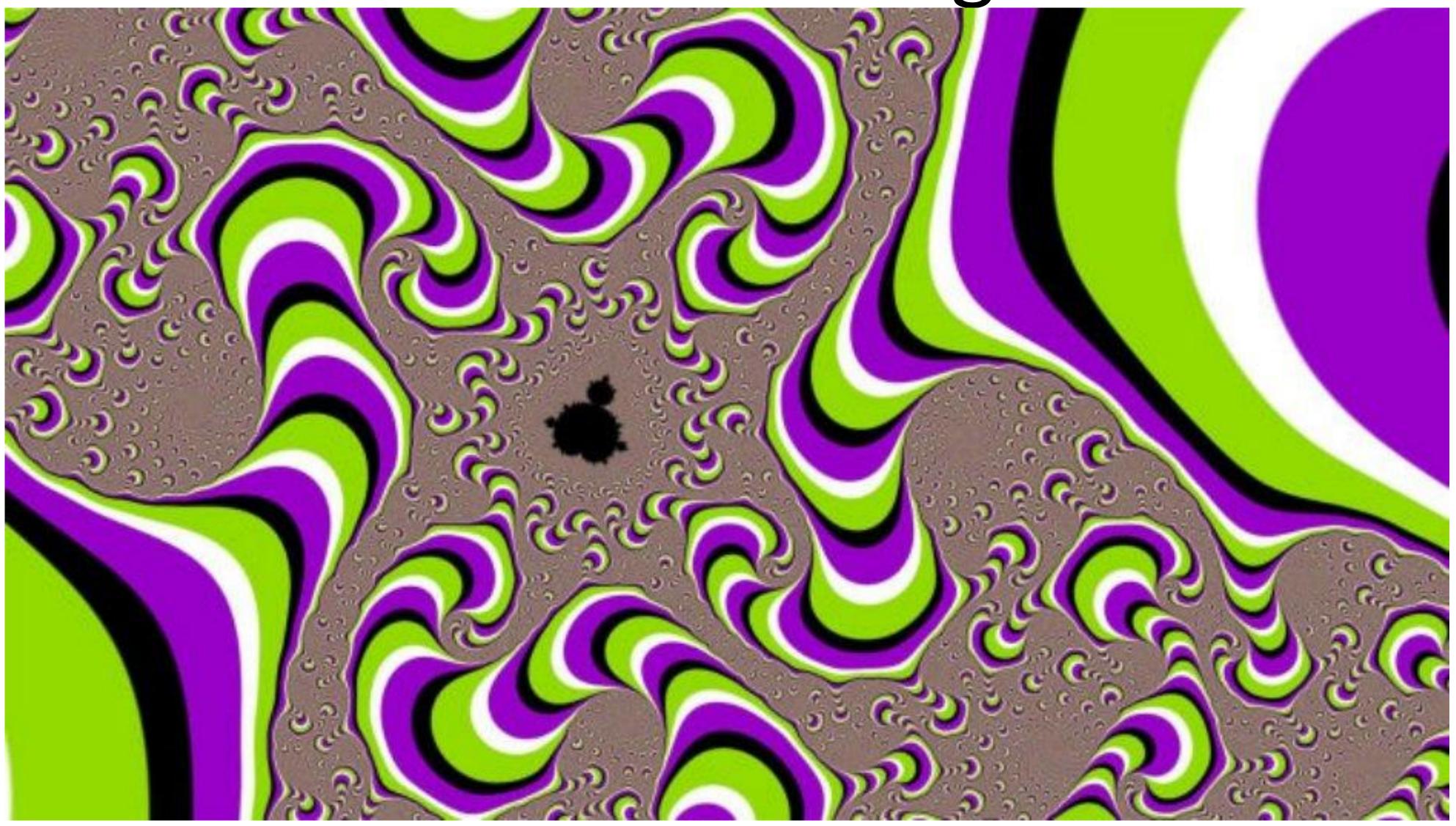
The Dress: blue/black or yellow/white?



https://en.wikipedia.org/wiki/The_dress



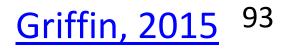
Still or moving?



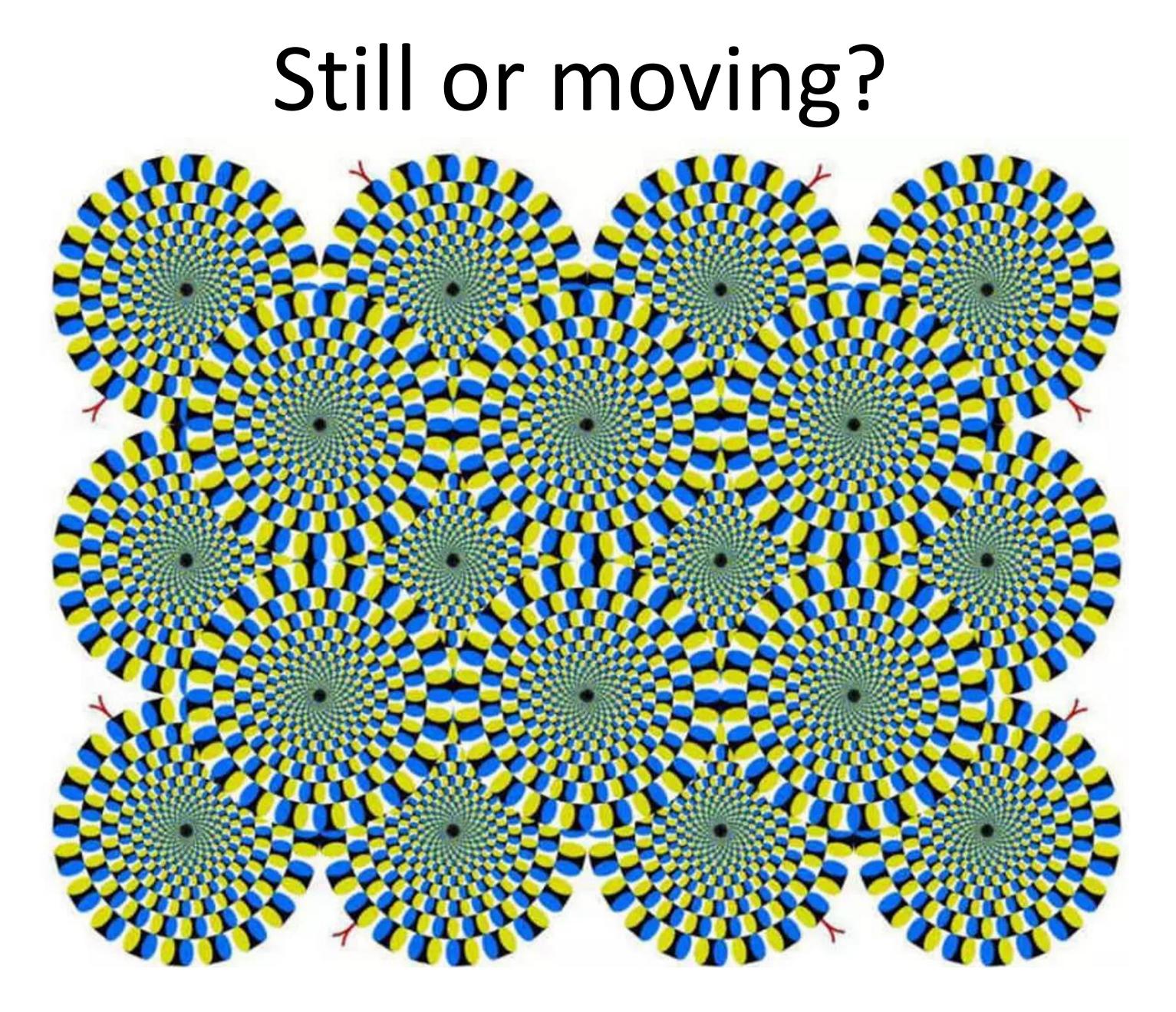








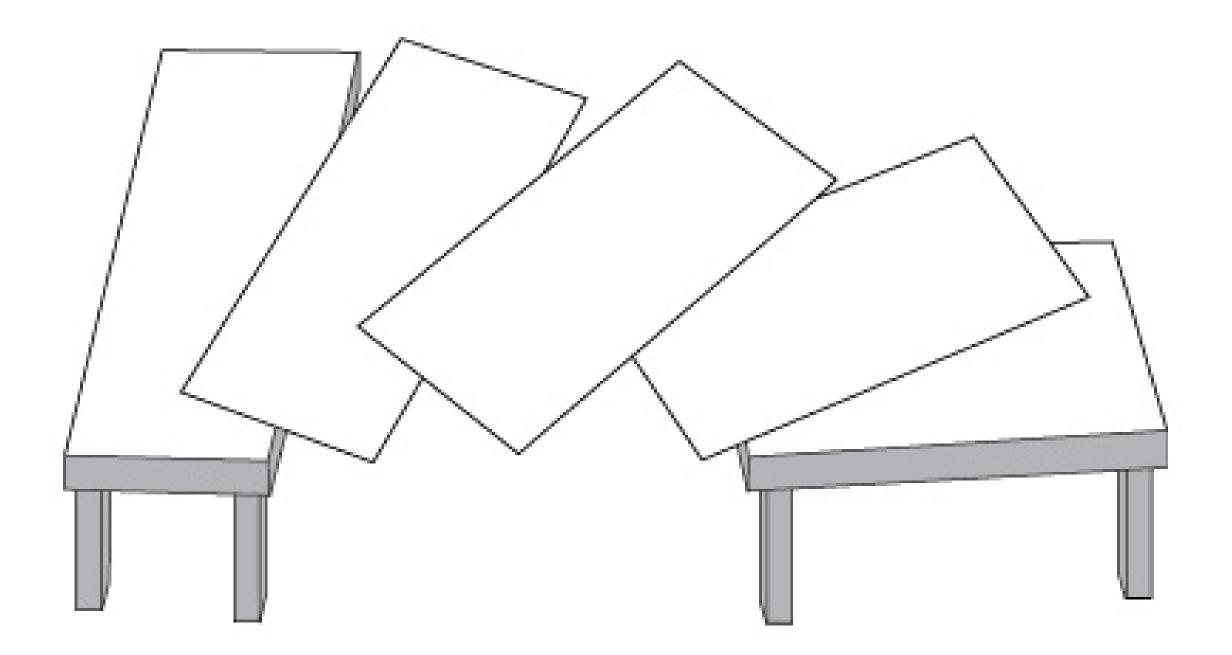








Shepherd's Table Illusion



Illusion based on how we perceive depth/perspective...

http://mentalfloss.com/article/28862/brainworksexplaining-optical-illusions-and-other-mental-tricks

